Kenya Electricity Generating Company Limited

Tender for Supply, Installation & Commissioning of SCADA Wide Area Network & Backup Control Centre Hardware for KenGen Hydroelectric Power Plants

APPENDIX I

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1.1 INTRODUCTION

1.1.1 KenGen has an existing SCADA system used to automate and allow remote control of seven forks, Turkwel, Sondu, Sang'oro and upper Tana HEP plants.

1.1.2 Seven Forks plants are Masinga, Kamburu, Gitaru, Kindaruma and Kiambere which are along Tana River. Distance from Nairobi to the seven forks plants is between 150km for Masinga and 190km for Kiambere. Tana and Wanjii are in Murang'á county.

1.1.3 All the HEP plants in the scope of this project are served by all-weather roads (tarmac) all the way from Nairobi.

1.1.4 To improve power plant operations, KenGen has decided to upgrade the existing TDM SCADA WAN for seven forks and provide additional WAN connections. The project also covers supply of hardware & system software for control centres but excluding the SCADA applications which are not in scope.

1.1.5 The project scope covers: Manufacture, Testing and training at the Factory; delivery to site (DDP incoterms); installation and commissioning of SCADA computing and networking hardware for KenGen HEP stations in Kenya.

1.1.6 The procuring entity requirements in these documents are subdivided into three parts

1.1.6.1 Scope of supply (chapter 1/clause 1) provides the scope of supply of goods and services. Preliminary bill of materials by the procuring entity given in appendix II is also a part of scope of supply.

1.1.6.2 General technical specifications (chapter 2/clause 2) provide general specifications for goods and services. It includes specifications for items that may not be directly in scope of supply but may be utilised to meet the scope of supply.

1.1.6.3 Particular technical specifications (chapter 3 — 6 /clause 3 — 6) provide detailed speciation's for goods and services in scope of supply. Guaranteed technical particulars requirements by employer given in Appendix II also form part of particular specifications.

1.2 PROJECT SCOPE

1.2.1 Preamble

1.2.1.1.1 The tenderer shall indicate make, type, model number and manufacturer of major equipment in the preliminary bill of materials.

1.2.1.1.2 All functions, devices, accessories, or fittings which may not have been specifically mentioned, but which are usual or necessary for the proper and safe completion, operation, and maintenance of the equipment in question, shall be deemed to be included in the scope of supply and shall be supplied.

1.2.1.1.3 Any alternative/ additional system or device considered necessary for providing complete effective and reliable system shall also be included in the scope of supply by the bidder.

1.2.1.1.4 In the event of any conflict between the particular specifications and the Scope of supply, the particular specifications shall prevail. In the event of any conflict between scaled dimensions and figures on the Drawings, the figures shall prevail.

1.2.1.1.5 Should the Bidder find discrepancies or omissions in these Specifications or, should they be in doubt as to their meaning, they should immediately contact the Project Manager for interpretation, clarification, or correction thereof before submitting their Bid.

1.2.1.1.6 All the systems and devices listed under scope of supply are to use the station auxiliary DC power supply of 110VDC or 240VAC/415VAC. Where power supply units or power transformers are required to power the devices, they shall be part of scope of supply irrespective of whether such device has been included in the scope of supply by the procuring entity or not.

1.2.2 Overall Project Scope

1.2.2.1.1 The scope of supply shall cover the following.

(a) Supply, installation and commissioning of SCADA Network and communication equipment delivered and installed in all the major KenGen hydro plants and areas including Masinga, Kamburu, Hydro Plaza, Kianjiru, Matendeni, Gitaru, Kindaruma, Kiambere, Tana and Wanjii.

(b) Supply, installation, and commissioning of SCADA control centres hardware equipment delivered and installed at Kamburu, Gitaru and Hydro Plaza. Re-configuration and redeployment as detailed in particular specifications.

(c) Supply, installation and commissioning of underground fibre optic cable

from Gitaru power station to Matendeni and from Matendeni to Hydro Plaza and Kamburu, approximately 15Km

(d) Provision of specified Tools

(e) Provision of Spares and accessories

(f) Provision of training

(g) Provision of technical support and warranty

1.2.2.1.2 In fulfilment of the above scope, the contractor shall

(a) Carry out design of all systems and equipment in scope of supply.

(b) Procurement and supply of equipment in scope of supply

(c) Provide, install, configure software with perpetual licences for all the hardware in scope of supply.

(d) Provide, install, and configure software with subscription licenses where specified. Provide three-year licences for all Subscription based software in scope of supply and provision of three-year basic software support for all applicable software in scope of supply as detailed in specifications.

(e) Carry out Configuration and initialisation of all equipment in scope of supply as per procuring entity requirements and specifications prior to FAT.

(f) Carry out Factory Acceptance testing of all equipment (with software installed and configured) in scope of supply witnessed by the procuring entity at the manufacturer's factory or contractor's premises.

(g) Provide factory training at point of manufacture as detailed in the specifications.

(h) Provision of site training after arrival equipment at site. Site training to be carried out at procuring entity's facilities.

(i) Set up, configure, and deploy the SCADA WAN and back up control centres hardware with all features and performance as specified.

(j) Carry out reliability run /commissioning for ninety days after deployment of the last system.

(k) Provide technical support after commissioning of the project.

(l) Provision of warranty and after sale services as detailed in the specifications.

(m) Provision of all technical documentation as detailed in clause 1.7 of specifications.

(n) Provision of any other goods or services not mentioned or included in this tender but which the contractor deems critical for the completion of the contract. These shall be itemized by the bidder in the offer and price schedule where necessary.

1.2.2.1.3 Contractor shall carry out the following project activities which include but not limited to:

(a) Design
(b) Manufacture,
(c) Factory acceptance testing and training at the Manufacturer's Factory
(d) Transportation, insuring and delivery of equipment and materials to all Sites.
(e) Offloading of equipment and site storage
(f) Site training
(g) Installation and deployment
(h) Commissioning/reliability run.
(i) Technical documentation provision
(j) Technical support and
(k) Warranty

1.2.2.1.4 Contractor shall supply all cabinets specified in the scope of supply assembled and all equipment mounted and tested prior to shipment to site.

1.2.2.1.5 All equipment MUST be inspected, and tests witnessed by procuring entity's personnel prior to shipping of any equipment to site. Procuring entity shall not permit offloading of any equipment at site which have not been inspected prior to transportation.

1.2.2.1.6 Contractor shall mount all the specified cabinets and equipment at all the sites as per the detailed scope of supply and technical specifications. All works and materials required for this shall be provided by the contractor.

1.2.2.1.7 Contractor shall carry out all structured cabling at sites as detailed in scope of supply and specifications. All structured cabling required for the operation of the new systems shall be carried out by the contractor.

1.2.2.1.8 All software's and licenses required for operation of the supplied systems to achieve performance and functionalities detailed in technical specifications shall be supplied installed and configured by contractor.

1.2.3 Detailed Scope of supply

Contractor shall supply, Install, and commission a minimum of the equipment/systems listed in the preliminary bill of materials given in APPENDIX II. The list is not exhaustive, all components necessary to achieve the functionality and performance requirements given in the technical specifications shall be supplied irrespective of whether such equipment are listed in the preliminary bill of materials or not.

1.2.4 Detailed Scope of Services

1.2.4.1 Design

1.2.4.1.1 Contractor shall design all panels and prepare drawings for review and approval as detailed in clause 1.7.

1.2.4.1.2 Contractor shall prepare bill of materials for review and approval detailed in clause 1.7.

1.2.4.1.3 Contractor shall prepare all other technical documentation including test and inspection plans as detailed in specifications.

1.2.4.1.4 Contractor shall design the complete Network architecture as detailed in technical specifications.

1.2.4.1.5 Contractor shall undertake survey and route design of the underground fibre works as detailed in specifications.

1.2.4.1.6 Contractor shall undertake radio frequency planning for ethernet radios and DECT wireless network.

1.2.4.1.7 Contractor shall undertake all other design work required to meet requirements given in the specifications and as detailed in clause 1.8.

1.2.4.2 General Procurement and supply of systems

1.2.4.2.1 Contractor shall procure and manufacture all required materials, equipment, and software as per the approved bill of materials and drawings. As detailed in clause 1.9

1.2.4.2.2 Contractor shall inspect and carry out tests witnessed by the procuring entity as detailled in clause 1.9.3 prior to delivery to site.

1.2.4.2.3 Contractor shall deliver all equipment to site.

1.2.4.2.4 Contractor shall insure all systems up to the issuance of operation acceptance certificate.

1.2.4.3 Panel and panel assemblies

1.2.4.3.1 Contractor shall manufacture all cabinets and panels in scope of supply.

1.2.4.3.2 Contractor shall mount all panel mounted devices and carryout wiring as per approved drawings.

1.2.4.3.3 Contractor shall remove existing equipment from existing panels in scope, mount new equipment, carry out necessary electrical wiring and structured cabling as per approved designs.

1.2.4.3.4 Contractor shall configure and install software into the equipment to meet all specified functions in the tender.

1.2.4.3.5 Contractor shall carry out tests on all panel assemblies witnessed by procuring entity as per approved drawings.

1.2.4.3.6 Contractor shall deliver all panels in scope of supply fully assembled to site after successful tests and inspection.

1.2.4.3.7 Contractor shall remove existing panels and move to a safe storage area.

1.2.4.3.8 Contractor shall carry out panel installation and interfacing to other plant systems as per approved drawings.

1.2.4.3.9 Contractor shall carry out testing and commissioning of all supplied systems as per technical specifications, approved drawings, and test plans.

1.2.4.4 Ethernet Radios Site works.

1.2.4.4.1 Contractor shall remove existing radios, antennas, waveguides, and cables on the towers and panels prior to installation of the new radio systems.

1.2.4.4.2 Contractor shall install the new radios and antennas on the radio towers as per approved drawings.

1.2.4.4.3 Contractor shall carry out all structured cabling to the radio ODU as per approved drawings and as detailed in scope of supply.

1.2.4.4.4 Contractor shall undertake Antenna alignment and link testing as per OEM requirements.

1.2.4.4.5 Contractor shall commission the radios ensuring they meet all the communication authority regulatory requirements.

1.2.4.5 Telephone system Site works.

1.2.4.5.1 Contractor shall carry out all structured cabling to provide connectivity to all the telephone nodes and switches.

1.2.4.5.2 Contractor shall install fibre optic cables to powerhouse and substation as per approved designs and as detailed in scope of supply.

1.2.4.5.3 Contractor shall install conduits in the control building areas, powerhouse, substation areas etc for installation of ethernet cables for the telephone nodes and DECT base stations as per approved designs.

1.2.4.5.4 Contractor shall install and deploy DECT base stations and test the network to ensure coverage as per approved designs.

1.2.4.5.5 Contractor shall install twisted pair wiring for the analogue telephone sets from the PBX to the various points in the plant as per approved documents. Contractor

shall terminate and test the analogue telephone sets.

1.2.4.5.6 Contractor shall install, deploy and test corded IP telephone sets as per approved designs.

1.2.4.6 Underground Fibre works.

1.2.4.6.1 Contractor shall undertake underground fibre works detailed in clause 5.1.2

1.2.4.7 General Civil works

1.2.4.7.1 Contractor shall undertake all other civil works required for installation of the equipment in scope of supply.

1.2.4.8 Deployment and commissioning

1.2.4.8.1 After installation, contractor shall configure, and deploy all systems as detailed in technical specifications and clause 1.10.

1.2.4.8.2 Contractor shall undertake tests as detailed in specifications and as per approved test plans to ensure all systems meet performance requirements detailed in technical specifications.

1.2.4.8.3 Contractor shall undertake commissioning of the installed systems and all existing systems reconfigured or modified as per technical specifications.

1.2.4.8.4 Contractor shall be responsible for system operations and maintenance of the system during the period of commissioning as defined in the contract conditions and clause 1.10.

1.2.4.9 Other Services

1.2.4.9.1 Provision of technical documentation as detailled in clause 1.7

1.2.4.9.2 Provision of training as detailled in clause 1.11

1.2.4.9.3 Technical support as detailled in clause 1.12

1.2.4.9.4 Software Support as detailled in the particular technical specifications and detailled scope of supply

1.2.4.9.5 Provision of warranty as detailled in clause 1.13

1.3 DEFINITIONS

Whenever the following terms or words are used in the specifications or any other documents forming part of this tender document, they shall have the following meaning unless otherwise stated:

1. AC: means Alternating Current
2. ACB: means Air Circuit Breaker
3. ADC: means Analogue to Digital Conversion
4. AVR-Automatic voltage regulator
5. BOM-shall mean Bill of materials or list of equipment
6. BUCC/BCC-Backup control centre
7. CB: -means circuit breaker unless otherwise stated
8. CE - Customer edge
9. CDC-Central dispatch centre
10. CT: means current transformer
11. DAS: -Data acquisition server-in context of this tender it shall mean SCADA computer hardware connected to plant control systems interfacing the plant systems to the SCADA system.
12. D-AVR- Digital Automatic voltage regulator
13. DC: means Direct Current
14. DECT: Digital enhanced cordless telecommunications
15. EDG: means Emergency diesel generator
16. ETU: Shall mean electronic trip units commonly used in low voltage circuit breakers
17. Factory: shall imply either contractor facilities where panel assembly is to be carried out (staging site) or OEM manufacturing facilities
18. FAT: Factory acceptance tests
19. FIDIC - Fédération Internationale des Ingénieurs Conseils (International Federation of Consulting Engineers)
20. GCB-shall mean generator circuit breaker
21. GSU: Generator step up transformer
22. HEP: Hydroelectric power
23. HMI- Human machine interface- In this document refers to hardware and/or software required for human user to interface to the systems supplied for control and monitoring purpose
24. HV-High Voltage: operating voltage higher than 52.5 Kv
25. HVAC-Heating, ventilation, and air conditioning
26. ICS – Industrial control systems

27. IED: -Intelligent electronic device refers to programmable microprocessor based electronic devices e.g., numerical protection relays, smart relays etc. used in industrial environment for instrumentation, metering, control or protection purposes.
28. IP xx - Ingress protection: means "Degree of Protection Provided by Enclosure". and shall be according to IEC 60529
29. IT – Information technology
30. LAN-Local Area Network
31. LCC: Local control centre
32. RCC: Remote or regional control centre
33. LV-Low Voltage: operating voltage below 1000V. (For transformers, the term Low Voltage Winding is used for the side with lowest rated voltage regardless value)
34. MCCB: means Moulded case circuit breaker
35. MPCB-Motor protection circuit breaker
36. MCB: means Miniature circuit breaker
37. MM- multimode
38. MPLS: Multi-protocol label switching
39. MV-Medium Voltage: operating voltage higher than 1000 V and up to 52.5 kV.
40. NAS-Network attached storage
41. NC-Normally closed
42. NDC-National dispatch centre
43. NO-Normally open
44. NSTA- National Standards and Testing Authority
45. OEM-Original Equipment manufacturer
46. OFC-Optical fibre cable
47. OLTC-On Load Tap Changer
48. OPC- Open Platform Communications (OLE for process control)-shall imply the widely accepted communication platform for real-time plant data exchange between control devices from different manufacturers
49. OPC UA -OPC Unified architecture
50. OPC DA – OPC Data access
51. OT – Operations technology- hardware and software systems that monitor and control physical equipment and processes. i.e., ICS systems
52. PC- Personal computer: Refers to IBM PC compatible computers i.e. intel X86/X64 based personal computers running windows operating system
53. PE-provider edge
54. PIMS-Plant information management system
55. PLC-shall mean Programmable Logic Controller unless otherwise defined in the document

56. POSE: Physical operating system environment
57. PSN: Packet Switched Network
58. RCC: Regional control centre
59. SAS: Substation Automation System
60. SAT: Site acceptance tests
61. SCADA: -shall mean Supervisory control and data acquisition system. Procuring entity/KenGen SCADA shall mean the existing SCADA at the power plants operated by the procuring entity
62. SDG-SCADA data gateway-multi protocol converter for SCADA communication protocols
63. Seven forks- shall mean Masinga, Kamburu, Gitaru, Kindaruma, Kiambere sites
64. SLD: - shall mean single line diagram
65. SM- single mode
66. SOE: - Sequence of events
67. SPST-Single pole single throw
68. SPDT-Single pole double throw
69. SSL-secure socket layer (deprecated)
70. **Station/plant**-These words shall predominantly refer to a power station i.e., Turkwel, Masinga, Kamburu, Gitaru, Kindaruma, Kiambere etc. in the tender unless implied otherwise by the sentence
71. **System**-Could mean a physical (hardware) system or a software system
72. **TDM**-Time division multiplexing
73. TLS-Transport layer security
74. **Unit**-Shall in many occasions in this document refer to complete generation unit composed of Turbine, generator, GSU transformer, control system and balance electrical and mechanical system. unless implied otherwise by the sentence
75. VFL: Visual Fault Locator
76. **VM**: Virtual machine
77. VOSE: Virtual operating system environment
78. VT: means voltage transformer
79. WAN: Wide area Network

1.4 GENERAL MANDATORY REQUIREMENTS

1.4.1.1 These specifications describe the requirements for goods and services to be procured by the procuring entity. Tenderers are requested to submit with their offers the detailed specifications, drawings, catalogues, etc for the products they intend to supply.

1.4.1.2 Tenderers must indicate on the technical schedules whether the equipment offered comply with each specified requirement.

1.4.1.3 All the dimensions and capacities of the equipment to be supplied shall not be less than those required in these specifications. Deviations from the basic requirements, if any shall be explained in detail in writing with the offer, with supporting data such as calculation sheets, etc. The procuring entity reserves the right to reject the products, if such deviations shall be found critical to the use and operation of the products.

1.4.1.4 The tenderers are requested to present information along with their offer's information on proper representative and/or workshop for back-up service/repair and maintenance including their names and addresses.

1.4.1.5 All documents to be submitted shall be in ENGLISH language ONLY. The SI-system (meter, Newton, second) shall be used throughout the documentation covered by this Specification.

1.4.1.6 Systems specified in this tender and all associated systems shall be designed to ensure continuity of operation under all working conditions and to facilitate inspection, maintenance, and repairs. All reasonable precautions shall be taken in the design of equipment to ensure safety of personnel concerned with the operation and maintenance of the equipment.

1.4.1.7 All components shall be adequately rated or sized for their most onerous duty at the specified environmental conditions. Due account shall be taken of any heat generated by the equipment therein and the components shall be appropriately selected, rated or de-rated as necessary to suit the most onerous operating temperature within the equipment.

1.4.1.8 All Works shall comply with the technical guaranteed data stated in the specifications. The Contractor shall be responsible for any discrepancies, errors and omissions in the particulars and guarantees.

1.4.1.9 All apparatus, accessories or fittings which may not have been specifically mentioned, but which are usual or necessary in the respective equipment for the completeness of the finished work in an operable status, shall be deemed to be included in the Contract and shall be provided by the Contractor without any extra charge. All equipment shall be

complete in all details, irrespective of whether such details are mentioned in the Specifications.

1.4.1.10 Any reference in the quantity and price schedules, the delivery period schedule or in the various clauses and schedules of the text of either the Specification or the Bid, to any equipment shall imply equipment that is complete with all accessories, apparatus and fittings as outlined

1.4.1.11 All materials and skilled labour, whether of temporary or permanent nature, required by the Contractor for the design, manufacture, delivery to site of the equipment shall be supplied and paid for by the Contractor.

1.4.1.12 If in conflict, the ranking of documents in the technical specifications by procuring entity, in decreasing priority, is as follows:

(a) Particular technical specifications
(b) Scope of supply and Preliminary bill of materials by procuring entity
(c) General technical specifications
(d) Specification drawings
(e) Standards

1.4.1.13 If the Tenderer is of the opinion that there is conflict or disagreement between the particulars of the documents, standards etc. it must be clearly stated in the tenderer Bid offer document, failure to which, the materials and equipment offered shall be deemed to comply in every respect with the current Specification both in manufacture and in performance, and compliance thereof shall be insisted upon without additional cost to the procuring entity.

1.4.1.14 Specifications given in general technical requirements shall apply to all Equipment specified in the particular specifications. The equipment, devices etc. whose specifications have been provided in general technical specifications shall be used in the subsections of the project specified by each particular specification. If there is a conflict between general technical specifications and particular technical specifications the latter shall prevail. **Not** all equipment specified in the general technical specifications are in scope of supply.

1.4.1.15 The bidder shall visit the site and get acquainted with the actual requirements of site prior to quoting rates. No claims for inadequate description of the scope shall be entertained later.

1.4.1.16 Deviations to this specification SHALL NOT be acceptable unless specifically indicated in the offer in the relevant schedule "deviation from technical specifications form". All deviations shall be clearly spelt out by the Bidder Any implied deviation, or any deviation mentioned elsewhere in the offer shall not be considered.

1.4.1.17 It is not the intent of this specification to completely specify all details of design and

construction herein. Nevertheless, the equipment and installation shall conform to high standards of engineering design and workmanship in all respects and shall be capable of performing continuous operation in a manner acceptable to the procuring entity. Reliability, availability and maintainability are of the utmost importance to the procuring entity in the design of the equipment described herein.

1.5 TENDER BID DOCUMENTATION BY TENDERER

1.5.1 General requirements

1.5.1.1 Tender bid documentation will guide the procuring entity during the tender evaluation. Documents shall clearly demonstrate the bidders offer compliance to technical specifications.

1.5.1.2 The following Documents shall be provided by the bidder:

1.5.1.2.1 Bidders' technical proposal, composed of:

(a) Project Implementation plan

(b) Dully filled Guaranteed technical particulars

(c) Dully filled Preliminary bill of materials

(d) Deviations form technical specifications if applicable.

(e) List of supporting technical documents - providing details of referenced manuals, technical data sheets, manufacturer catalogues etc

1.5.1.2.2 OEM technical manuals

1.5.1.2.3 Technical data sheets, manufacture catalogues etc

1.5.1.2.4 Type test reports as detailed in particular specifications.

1.5.1.2.5 Product certifications as detailed in particular specifications

1.5.1.3 All manuals, data sheets and catalogues provided **MUST** be listed in the List of supporting technical documents forming part of bidders' technical proposal as detailed in the tendering forms for them to be considered to have been submitted.

1.5.1.4 Where a submitted catalogue, manual or datasheet contains more than one model of the device the bidders shall circle or highlight the model they are offering.

1.5.1.5 In the event of any difference between the Drawings and the Specifications stated, the latter shall prevail. In the event of any difference between scaled dimensions and figures on the drawings, the figures shall prevail.

1.5.2 Bidders' Technical Proposal

1.5.2.1 A proposal containing information elaborate enough to enable the employer to comprehend and assess the vital details, features, capabilities and functioning of the equipment offered and their arrangements shall be included in the bid offer.

1.5.2.2 Bidders' technical proposal shall offer a clear response to the employers' specifications.

1.5.2.2.1 It shall clearly demonstrate the complete scope of work as defined by the specification and MUST include, but not be limited, to the followings: -

(a) **Implementation program** in Gant chart format. The Gant chart shall illustrate a comprehensive [summary] work programme, showing all the activities and duration required, from tender award stage to delivery of the equipment in chronological order. ALL project activities and duration MUST be clearly illustrated, the activities include:

(i) Design and design review/approval by procuring entity
(ii) Provision of technical documentation
(iii) Manufacture
(iv) Factory training
(v) Factory Inspection and acceptance testing, FAT
(vi) Packing, transportation, Offloading and placement.
(vii) Site training
(viii) Installation and deployment
(ix) Commissioning
(x) Technical support

(b) **Preliminary Bill of materials (BOM)** dully filled and Bidder's scope of supply if not fully covered by the provided preliminary bill of materials.

(c) **Guaranteed technical particulars** duly filled

(d) **Deviation from technical specifications schedule** duly filled if applicable

(e) **List of supporting technical documents** providing details of referenced manuals, technical data sheets, manufacturer catalogues etc as per the tendering form provided.

1.5.3 OEM Technical manuals

1.5.3.1 Comprehensive OEM Technical manual shall be provided for

(a) Industrial grade Routers
(b) Industrial grade ethernet Switches
(c) Hybrid IP PBX
(d) Ethernet point to point radios.

1.5.3.2 Each Manual shall as a minimum, cover the following topics:

1.5.3.2.1 Detailed description of equipment, including at minimum: the structural description and dimensions, functional descriptions with block diagrams, characteristic curves and logic diagrams, General assembly drawings, control and wiring diagrams, operating conditions, operation description, etc.

1.5.3.2.2 Equipment rating: power, insulation, voltage, current, temperature, flow, fault withstand, breaking capacity, various operating characteristic curves, relevant clearances, tolerances, operating temperature etc.

1.5.3.2.3 Range of features to be provided.

1.5.3.2.4 Range of optional features not provided.

1.5.3.2.5 Range of settings provided for all features, both offered and optional.

1.5.3.2.6 Operation and maintenance

1.5.3.2.7 Statement of performance under reference conditions.

1.5.3.2.8 Effects of interruptions to dc auxiliary power supply.

1.5.3.2.9 Standards the equipment complies to

1.5.3.3 All Manuals to be provided in soft copies

1.5.3.4 All manuals provided MUST be listed in List of supporting technical documents form for them to be considered to have been submitted.

1.5.4 Technical data sheets

1.5.4.1 Technical data sheets and or catalogues briefly describing technical specifications; rated values; operating conditions; physical dimensions, standards of manufacture and testing, photo illustration of the equipment etc. shall be provided.

1.5.4.2 Datasheets/catalogues shall contain information to support all technical specifications of equipment offered by the bidder

1.5.4.3 The equipment/item offered shall be clearly marked in the datasheet/catalogue

1.5.4.4 Data sheets and catalogue to be provided in soft copies only

1.5.4.5 Datasheets and catalogues shall be provided for but not limited to each of the following:

1. Industrial grade Routers
2. Hybrid IP PBX
3. Industrial grade Ethernet Switch
4. Ethernet point to point radio
5. CWDM Multiplexer
6. Fibre optic repeater
7. IP DECT Multi cell Manager station
8. IP DECT base station
9. Ruggedized DECT Handset
10. Ruggedized Corded IP telephone set
11. IP Desk phone
12. Industrial grade network cabinets
13. IT server cabinets

14. Rack mount enterprise grade VM host servers
15. Rack mount enterprise grade ethernet switch
16. Thin Client computers
17. LED/LCD monitors
18. Inverter power supply unit (if applicable)
19. Switched power supply unit
20. Smart handheld Optical Time Domain Reflectometer OTDR,
21. Fibre optic field Fusion splicing equipment
22. Desktop two port dual display KVM switches (if applicable)
23. Panel/DIN mount four port KVM switches
24. Rack mount LCD, keyboard & KVM switch console
25. SFP modules
26. Fibre optic cable
27. Any other device stated in the bidder's offer

1.6 PROJECT WORK PROGRAM

1.6.1 Work program shall be detailed to cover all project activities to be carried out.

1.6.1.1 After the tender award, the approved tenderer shall prepare a draft implementation plan covering the design, manufacture, testing delivery, training and commissioning support, in sufficient detail. The implementation plan shall be prepared in the form of a Critical Path Method Network and a Gantt chart.

1.6.1.2 After tender award and prior to contract signing the procuring entity and Approved tenderer shall meet, discuss and review the draft work program, the contractor shall subsequently prepare a final work program for procuring entity approval.

1.6.2 After contract signing, a kick-off meeting shall be held at the procuring entity premises to discuss the following:

1.6.2.1 Observe in detail the existing equipment

1.6.2.2 Design process

1.6.2.3 Documents approval

1.6.2.4 Network conceptual design review

1.6.2.5 Project implementation program

1.6.2.6 Factory acceptance testing and training

1.6.2.7 Commissioning

1.6.2.8 Any other pertinent project issue

1.6.3 Time for completion Shall be three hundred and sixty-five (365) days and shall be the duration from the commencement date to the date of completion/deployment of the last site/system

1.6.4 The Guarantee Test of the Facilities shall involve reliability run of the system for a period of ninety (90) days from the date of completion

1.6.5 The Defects Liability Period Shall be three hundred and sixty-five (365) days from the date of issuance of operation acceptance certificate to be issued after guaranteed test of the facilities.

1.6.6 Technical support period shall be Shall be three hundred and sixty-five (365) days from the date of issuance of operation acceptance certificate to be issued after guaranteed test of the facilities.

1.6.7 Contract period Contract shall be valid for thirty (30) months from the date of commencement. This includes 12 months defects liability period.

1.7 DOCUMENTATION

1.7.1 General Mandatory Requirements

1.7.1.1 The Contractor shall prepare and submit to the Project Engineer for approval dimensioned general and detailed design drawings and other pertinent information of all the Plant and equipment specified in the tender documents.

1.7.1.2 Approval of drawings shall not relieve the Contractor of his obligations to supply the Plant in accordance with the Specifications. The Contractor is responsible for any errors that may appear in the approved documents. He shall as soon as an error has been detected, deliver the corrected documents to the Project Engineer for re-approval.

1.7.1.3 All text on documents provided by the Contractor shall be in the United Kingdom ENGLISH LANGUAGE ONLY. Technical Documentation written in any other language SHALL BE REJECTED and presumed not to have been submitted.

1.7.1.4 All drawings and documents shall be dimensioned in millimetres

1.7.1.5 The Contractor shall, during the total project time, maintain a List of Documentation to be updated by him whenever needed. The List of Documentation shall include the date of original issue of each document submitted as well as the dates of every revision. The List of Documentation shall also include a time schedule for the submittal of the documentation.

1.7.1.6 Symbols used for electrical equipment and components shall be in accordance with IEC 60617. The Contractor shall establish a coherent system for physical and functional reference designation in accordance with IEC81346 and RDS PP. A similar systematic scheme shall be defined for cable numeration. These schemes shall be used throughout on the drawings and documentation and the designation shall be labelled on the components and cables. Auxiliary relays shall be assigned alphanumeric device numbers in the drawings where the numeric part shall be as per IEEE C37.2-2008 (e.g., K51 for overcurrent auxiliary relay)

1.7.1.7 In addition to what is stated elsewhere in the tender, the following shall apply to all technical documentation handed over to the procuring entity after the project:

1.7.1.7.1 The sizes of all documents and drawings shall conform to the ISO standard, i.e.: A1 (594mm x 841mm), A2 (420mm x 594mm), A3 (297mm x 420mm) & A4 (210mm x 297mm)

1.7.1.7.2 Scales to be used on the drawings shall be 1:10, 1:20, 1:40, 1:50 and multiples of this series.

1.7.1.7.3 All drawings shall be dimensioned in millimetres

1.7.1.7.4 Technical documentation e.g., manuals, test reports, list of materials, cable lists

i.e. all technical documents including ALL drawings shall be provided in A4. Schematic diagrams shall be provided in both A4 and A3. Structural & mechanical drawings shall be provided in A4, A3 and A2/A1 (depending on drawing size).

1.7.1.7.5 All drawings made special for this project shall be compiled on a computer aided drawing system and as part of the as built documentation be handed over on a CD with a format readable in latest version of AutoCAD and in any another editable format to be agreed upon and pdf in addition to the paper copies.

1.7.1.7.6 All drawings and technical documentation shall be bound in hard covers as per sample to be provided. NO document shall be folded to fit the book binding, the Binding covers shall be sized according to the containing documents i.e., there shall be A4, A3, and A2/A1 binding covers. Documents of different sizes SHALL NOT be bound together on the same cover. The number of pages per bound volume shall not exceed two hundred (200)

1.7.1.8 Any illegible copies of documentation submitted shall be rejected by the employer.

1.7.1.9 The SI-system (meter, Newton, gram second) shall be used throughout the works and documentation.

1.7.1.10 The Employer's technical specification drawings attached to the Bid Documents are of informative character. These drawings are intended to illustrate the basic requirements to be satisfied. It is the responsibility of the contractor to prepare a detailed layout/schematic for the new system. Any liability arising from use of these specification drawings to implement the system shall be borne by the contractor

1.7.2 Technical Documentation

1.7.2.1 Technical documentation shall consist of but not limited to: -

1.7.2.1.1 Technical manuals

1.7.2.1.2 Bill of materials,

1.7.2.1.3 All technical drawings i.e., schematic, wiring, panel layout drawings, mechanical & structural assembly drawings.

1.7.2.1.4 Wiring schedules i.e., cable schedules and terminal diagrams

1.7.2.1.5 Functional design specifications and calculations

1.7.2.1.6 Software design documents

1.7.2.1.7 Device setting/parameter configurations

1.7.2.1.8 Configuration plans

1.7.2.1.9 Project progress reports

1.7.2.1.10 FAT plans/program

1.7.2.1.11 SAT plans/program

1.7.2.1.12 Training programs and materials

1.7.2.1.13 FAT reports

1.7.2.1.14 SAT reports

1.7.2.1.15 Type test reports for all supplied equipment

1.7.2.2 Technical manuals shall contain: -

1.7.2.2.1 System description consisting of: Introduction/overview of components, functional description, overall Equipment operating philosophy and operating conditions.

1.7.2.2.2 System/equipment rating: power, insulation, voltage, current, temperature, flow, fault withstand, various operating characteristic curves, relevant clearances, tolerances, operating temperature etc.

1.7.2.2.3 Equipment overall design and specific detailed features of design including Design calculations, descriptive drawings, schematic diagrams, layout diagrams, block diagrams, list of internal materials, connection and terminal list, equipment and components dimensional drawing and control diagram.

1.7.2.2.4 Installation and assembly instructions

1.7.2.2.5 Complete operating instructions: included shall be precautions and critical points to be observed, including suggested form to be used in taking periodic readings to maintain an operations record. There shall be a tabulation of possible operating difficulties with the probable causes listed and remedial action to be undertaken for each one. Emergency procedures

1.7.2.2.6 Manufacturer catalogues and technical data sheets for all components and devices.

1.7.2.2.7 Software Manuals for ALL software provided including manuals for Programs and application created for this project e.g. Logic diagrams, HMI application etc. Software manuals to detail: how to use the software, install and uninstall, license key, support, upgrading & updating, system requirements, troubleshooting etc.

1.7.2.2.8 Detailed instructions for programming settings and configuration of all software configurable devices. Instructions for downloading, uploading and backing up settings & configurations,

1.7.2.2.9 Complete instructions for ordering replacement parts in a manner that would prevent errors or misunderstanding. Recommended forms for tabulating replacement part information and instructions for returning materials to the factory shall be included.

1.7.2.2.10 Maintenance instructions manuals split into:

(a) Manuals for preventive maintenance indicating periodic inspections, tests, cleaning, lubrication and other routine maintenance. A clear concise

document with CHECKLISTS detailing tests and inspections to be done after duration of time e.g. monthly, annual etc.

(b) Trouble shooting manual listing all possible failure and their remedy

1.7.2.2.11 Repair manuals describing fault location, dismantling, re-assembly etc.

1.7.2.2.12 Four sets of manuals shall be provided.

1.7.2.3 All technical Drawings shall be part of technical documentation.

1.7.2.4 Bill of materials as minimum shall contain device, equipment or material: designation or name, model no., quantity, manufacturer, and description. i.e. basic ratings, no. of inputs & outputs of each type, provided functions/features, optional functions/features not provided, no. of contacts etc.

1.7.2.5 Factory test report (FAT) and Site acceptance test report (SAT) shall be the duly filled approved test plan with at least the following: plotted design characteristic curves, test result characteristic curves, Equipment set points for various parameters during testing e.g. pick up values, alarm and trips etc., tabulated results of all tests carried out etc.

1.7.2.6 The documentation shall leave the operators and maintenance personnel in position to operate the plant in a safe and optimal way and to perform repairs, upgrades and rehabilitation usual to be done by such personnel.

1.7.2.7 The Project Engineer shall approve all technical documents before final submission.

1.7.3 Drawings Requirements

1.7.3.1 engineering drawings shall include the following types of drawings: schematics, single line diagrams, layout, structural, mechanical, wiring, logic diagrams, terminal diagrams and all other technical drawings to be used during the project

1.7.3.2 Before starting manufacture of the equipment, dimensioned drawings showing all the equipment and components details, detailed schematic, structural and layout diagrams and detailed data of all the equipment and materials to be used shall be submitted to the Procuring entity for approval.

1.7.3.3 Drawings shall have a KenGen identification number structured as below.

1.7.3.3.1 KGN-###-$$-TUR-XXXX – Turbine and associated systems e.g., governor, turbine instruments etc.

1.7.3.3.2 KGN-###-$$-GEN-XXXX – Generator and associated systems i.e., excitation, generator instruments etc.

1.7.3.3.3 KGN-###-$$-CAX-XXXX – Common auxiliaries e.g. low voltage switch boards, common DC distribution, battery chargers etc

1.7.3.3.4 KGN-###-$$-SBS-XXXX – Substation equipment e.g., generator MV switchgear, step up transformers, HV switchgear etc

1.7.3.3.5 KGN-###-$$-PROT-XXXX – Protection equipment e.g., Protection IED etc

1.7.3.3.6 KGN-###-$$-UCB-XXXX – Unit control boards e.g., unit control PLC, Unit MCC, manual control panel, synchronizing equipment etc.

1.7.3.3.7 KGN-###-$$-MET-XXXX – Revenue metering equipment

1.7.3.3.8 KGN-###-$$-SCD-XXXX – SCADA equipment e.g., servers, network & telecom, HMI systems etc.

Where:

(a) ### shall be a site code e.g., KAM for Kamburu to be provided during design

(b) $$- Shall be unit or Common system designation e.g. U1 for unit 1 and C0 for common systems and D0 for common plant documentation

(c) XXXX shall be, a numeric number. This shall be further discussed and agreed on during the preliminary design.

1.7.3.4 In addition to the information provided on drawings, each drawing shall carry a revision number, date of revision and brief details of revision or designer notes wherever any revision is carried out, correspondingly revision number must be updated. All revisions carried out (not initiated by the procuring entity) shall be highlighted on the drawing and a Separate sheet furnished stating the reasons for such revision. A note stating drawing is generally revised is not acceptable.

1.7.3.5 These drawings shall be submitted within the times mentioned here under from the Date of tender award. Time shall be allowed to permit changes to be made if required by the Procuring entity. The drawings shall be modified as necessary if requested by the Procuring entity and resubmitted for final approval.

1.7.3.6 After approval of drawings by the procuring entity, the Contractor shall supply the approved drawings, as indicated below.

1.7.3.6.1 Drawings for approval 1 Copy

1.7.3.6.2 Approved drawings 1 Copy

1.7.4 Document Approvals

1.7.4.1 During project execution, technical documents shall be approved by the procuring entity as per provision of this clause (1.7.4). This shall apply to all technical documents, however; the documents below shall follow all the process described this clause (1.7.4).:

1.7.4.1.1 All drawings i.e., structural, layout, schematic, logic diagrams, wiring schedules, device lists etc.

1.7.4.1.2 Bill of materials

1.7.4.1.3 Functional design specifications & design calculations

1.7.4.1.4 Architectural designs

1.7.4.1.5 Device setting/parameter configurations

1.7.4.1.6 Testing plans/program

1.7.4.2 The Contractor shall provide the following documents within the first month after the

contract commencement for approval.

1.7.4.2.1 Work program containing Method statements and implementation program

1.7.4.2.2 Bill of materials

1.7.4.2.3 Training program and syllabus

1.7.4.3 Detailed schematic, structural and layout drawings shall then be submitted after approval of the above preliminary documents.

1.7.4.4 When the Contractor prepares their work program, as required herein, they shall make allowance for document approval time and indicate it on the program. Claims or extensions of time will not be approved if they are related to the late submission of drawings to the Procuring entity or if they involve delays caused by drawings not being approved by the Procuring entity.

1.7.4.5 During the design stage, the contractor shall send documents/drawings to the procuring entity for approval and comments. A copy of each document will be returned to the Contractor marked “Approved”, or “Approved as noted”, or “Not Approved”.

1.7.4.6 Documents submitted by the contractor for approval will be checked / reviewed by the employer and comments, if any, on the same will be conveyed to the contractor. It is the responsibility of the contractor to incorporate correctly all the comments conveyed by the Employer on the Contractor’s documents & drawings. If the Contractor is unable to incorporate certain comments in their design, they shall clearly state in their forwarding letter such non-compliance along with valid reasons and justification.

1.7.4.7 Comment of “not approved” would imply the drawing/document must be re done as per comments given; meaning the procuring entity is not in agreement with the content, idea and implications of the drawing/document on the overall design and operation of the system. Comment of “approved as noted” shall imply the procuring entity agrees with the idea or implications of the drawing/document but requires some changes to be implemented before approval.

1.7.4.8 Documents with comments of “Approved as noted”, or “Not Approved” shall be reviewed by the contractor as per given comments and resubmitted to the employer for approval. The employer will review the resubmitted document as described in the previous clause. The process shall be repeated until all the submitted documents are approved.

1.7.4.9 Documents requiring revision shall be promptly dealt with and resubmitted as aforementioned. Thereafter, changes shall NOT be made in the Contractor’s drawing without written permission of the project Engineer. The above procedure shall be repeated for all authorized changes. It is to be understood, however, that approval of the drawings shall not relieve the Contractor of any responsibility in connection with the work.

1.7.4.10 All documents submitted for approval or sent to the Procuring entity for any other reason

may be sent by courier or e-mail

1.7.4.11 Any work performed or material ordered by the contractor prior to receipt of drawings stamped 'Approved' by the employer shall be at the risk of the contractor. After print of any drawing has been returned 'Approved', the contractor may release the parts covered by the drawing, for production / construction.

1.7.4.12 All drawings and data supplied by the Contractor subsequent to the date of contract, which cover changes in the work, extra work, or which supplement existing drawings and data shall, upon approval by the Procuring entity Engineer, form part of the contract documents.

1.7.4.13 If, at any time before the completion of the work, changes are made necessitating revision of approved drawings/document, the contractor shall make such revisions and proceed in the same routine as for the original approval.

1.7.4.14 To expedite the delivery and return of the required drawings, scanned drawings shall be used and sent to the following KenGen E-mail addresses–

bpogeto@kengen.co.ke

c.c:-

dwangariria@kengen.co.ke

Or any other email supplied by the procuring entity.

1.7.4.15 Equipment manufacture and assembly shall be in accordance with the approved drawings and data and shall not commence until such approval has been obtained. Subsequent changes contemplated by the Contractor shall be indicated on revised drawings and data resubmitted for approval. The Contractor shall make any changes in the design which are considered necessary to make the work conform to the provisions and intent of the specification without additional cost to KenGen.

1.7.4.16 Approval of the Contractor's drawings and data shall in no way construe or imply relief of the Contractor from responsibility for any error or omission therein or from any obligation under the Contract.

1.7.4.17 After final approval of documents, the contractor shall send to the procuring entity all the documents listed in clause 1.7.4.1 stamped/or indicated as "factory as built". These shall be used for factory acceptance tests and FAT report.

1.7.5 Final Documentation

1.7.5.1 After all items of the equipment have been manufactured and delivered; complete sets of prints and softcopies of the technical documentation for all new systems shall be furnished as indicated below.

1.7.5.1.1 Soft copies of ALL as built drawings in AutoCAD electrical format

1.7.5.1.2 Four Complete sets of bound prints for ALL technical documentation detailed clause 1.7.2 in A4 size

1.7.5.1.3 Four Complete sets of bound prints for ALL as built SCHEMATIC drawings in A3 ONLY

1.7.5.1.4 Four Complete sets of bound prints for all as built structural and mechanical drawings in A3 and A2/A1.

1.7.5.1.5 Soft copies of ALL Logic diagrams and software applications in original software format and the software with a licence, used to create the logic diagrams/programs

1.8 DESIGN

1.8.1 General Design Obligations

1.8.1.1 The Contractor shall be deemed to have scrutinized, prior to the commencement Date, the Employer's Requirements (including design criteria and calculations, if any). The Contractor shall be responsible for the design of the Works and for the accuracy of such Employer's Requirements (including design criteria and calculations), except as stated below.

1.8.1.2 The Employer shall not be responsible for any error, inaccuracy or omission of any kind in the Employer's Requirements as originally included in the Contract and shall not be deemed to have given any representation of accuracy or completeness of any data or information, except as stated below. Any data or information received by the Contractor, from the Employer or otherwise, shall not relieve the Contractor from his responsibility for the design and execution of the Works.

1.8.1.3 However, the Employer shall be responsible for the correctness of the following portions of the Employer's Requirements and of the following data and information provided by (or on behalf of) the Employer:

1.8.1.3.1 Portions, data and information which are stated in the Contract as being immutable or the responsibility of the Employer,

1.8.1.3.2 Definitions of intended purposes of the Works or any parts thereof,

1.8.1.3.3 Criteria for the testing and performance of the completed Works, and

1.8.1.3.4 Portions, data and information which cannot be verified by the Contractor, except as otherwise stated in the Contract.

1.8.2 Scope of design services

1.8.2.1 The Contractor shall be responsible for all design required to provide the systems as defined in the technical specifications.

1.8.2.2 Contractor shall undertake design to ensure the systems developed or supplied meet performance requirements given in the specification.

1.8.2.3 Contractor design shall ensure the supplied systems meet functional and architectural requirements given in the tender.

1.8.2.4 Design shall encompass but not limited to the following, as detailed in technical specifications.

1.8.2.4.1 electrical designs,

1.8.2.4.2 civil works designs,

1.8.2.4.3 network architecture designs

1.8.2.4.4 All other design services as detailed in the specifications and scope of supply.

1.8.3 Review and approval

1.8.3.1 Contractors' designs shall be sent to procuring entity for review and approval. All designs shall be approved prior to purchase of equipment or implementation.

1.8.3.2 Review process shall be undertaken as detailed in clause 1.7.4

1.8.3.3 Procuring entity comments shall be incorporated into the design and resubmitted for approval.

1.9 MANUFACTURING AND SHIPMENT

1.9.1 Quality Assurance Plan:

1.9.1.1 The bidder shall invariably furnish along with his offer the quality assurance plan adopted by their sub-supplies in the process of manufacturing all major equipment/component.

1.9.1.2 Precaution taken for ensuring usage of quality raw materials and sub-components shall be stated in the quality assurance plan.

1.9.1.3 The bidder should specifically express their consent to accept additions, revisions to their quality assurance plan to meet the employer's requirements if needed. The final quality assurance plan to be adopted, with mutual consent, shall be decided after discussion with successful bidder.

1.9.2 Places of Manufacture and Sub-Contractors

1.9.2.1 All equipment offered should be the product of recognised and experienced manufacturers who have been manufacturing specified equipment for the last twenty years. Equipment shall be of basic design and size similar to such that has been in successful continuous operation for at least three years preferably under similar climatic conditions. Proven plant reliability and high availability are of prime importance and the attention of the tenderer is drawn to these particular requirements.

1.9.2.2 The manufacturer's identity and places of manufacture, testing and inspection before shipment for the various portions of the Contract Works shall be specified in the Technical Schedules and shall not be departed from without the agreement of the Project Engineer

1.9.2.3 As soon as practicable after entering into the Contract, the Contractor shall, having obtained the Project Manager's consent in accordance with the Conditions of Contract, enter into the Sub- contracts he considers necessary for the satisfactory completion of the Contract Works.

1.9.2.4 All Sub-contractors and Sub-suppliers of components and materials shall be subject to the approval of the Project Engineer. Information shall be given on each Suborder sufficient to identify the material or equipment to which the sub-order relates, stating that the material is subject to inspection by the Project Manager before dispatch.

1.9.2.5 If the Employer at any stage in the design and production period finds out that the sub-contractor does not fulfil the requirements in the specifications and it is obvious that the required quality cannot be achieved by corrective measure, he can request the subcontract to be suspended and the works to be produced elsewhere without extra cost

for the Employer.

1.9.3 Inspection and Testing

1.9.3.1 Tendering requirements

1.9.3.1.1 The manufacturer shall be responsible for performing or for having performed all the required tests specified under the specifications. Tenderer shall confirm the manufacturer's capabilities in this regard when submitting tenders. Any limitations shall be clearly specified.

1.9.3.1.2 Full details of type tests performed on equipment identical to that being offered shall be submitted with the offer, accompanied by a proposed schedule of tests to be performed for each item of equipment.

1.9.3.1.3 Type test reports & certificates submitted for tender evaluation shall be as detailed in particular specifications.

1.9.3.1.4 In general, type test results shall show that the equipment being proposed for this Contract shall perform in accordance with its design specification in the environments to which it will be subject in its application on this Contract. The environmental factors include climatic (temperature humidity, wind, rain etc.), electromagnetic (radiated and conducted), mechanical (transport vibration, handling knocks, earthquake stresses) and chemical (salt laden atmosphere).

1.9.3.1.5 Where appropriate, the type tests should also demonstrate that the equipment does not exceed accepted standards in terms of its impact on its environment (noise, mains harmonics etc.).

1.9.3.2 Manufacturing quality control, inspection and testing procedures.

1.9.3.2.1 All materials used in the Contract Works are subject to inspection by the Project Engineer and it is the Contractor's responsibility to advise the Project Engineer when equipment and materials are available for inspection, at least one month in advance. Factory tests on equipment shall be made according to the applicable IEC Standards, or as specifically specified or according to standards approved by the Project Engineer. Routine tests shall be made on each unit of all equipment.

1.9.3.2.2 Type tests shall be made on one unit of each type of different equipment components. Instead of carrying out the type tests the Contractor may submit suitable certificates of tests made on equipment components of the same type; however, the employer reserves the right of accepting these certificates or to reject them partially or totally. Routine tests shall however be conducted on all

assembled equipment; type tests reports will only be allowed as substitute for some components of the completed equipment.

1.9.3.2.3 Measuring and test equipment to be used shall be approved by the Project Manager and if required shall be calibrated at the expense of the Contractor at an approved laboratory

1.9.3.3 Factory Inspection, testing and training program

1.9.3.3.1 The Contractor shall prepare test procedures and result sheets for all tests. He shall also prepare a cross reference listing to show that all of the requirements of the Functional Design Specification have been included in the tests. The Contractor shall prepare and execute a testing program which will establish that specified requirements have been met and that the items furnished and installed will perform as specified and required.

1.9.3.3.2 The Contractor shall submit to the Procuring entity for approval, during or immediately following the submission of drawings, testing plan/ programs describing each test to be performed during factory acceptance tests (FAT), site commissioning and performance tests. The program shall establish the sequence of the tests, the equipment preparation and operation procedures to be followed and the DETAILED PROCEDURE for conducting each test.

1.9.3.3.3 Inspection and test plans (program) may be of any form to suit the Contractor's system, but shall as a minimum:

(a) Contain all tests specified in the particular specifications and all test requirement of the standard stated in the specifications.
(b) Detail inspections in form of check lists to be carried out before testing.
(c) Indicate where subcontract services will be employed
(d) Identify the characteristics to be inspected, examined, and tested at each point
(e) Give detailed procedures, acceptance criteria to be used and the applicable verifying document. Indicate basis of the acceptance criteria i.e. standard or specification applicable.
(f) Indicate mandatory hold points established by the Project Engineer that require verification of selected characteristics of an item of process before this work can proceed.
(g) Define or refer to sampling plans if proposed and where they will be used. Where applicable, specify where lots or batches will be used.
(h) Duration required for each test and all tests for each system

1.9.3.3.4 The program shall also contain performance guarantees, design values, technical particulars, or other criteria for the evaluation of each test. These programs shall be submitted for approval and distributed in the same manner as the drawings.

1.9.3.3.5 Contractor shall submit a Factory training programme as per requirements given in scope of supply and particular technical specifications. All training topics specified in the specifications shall be covered. The program and syllabus shall be approved by procuring entity engineer in similar manner to drawings prior to the FAT. The minimum duration shall be as specified however the contractor give the necessary time required to cover the training course successfully and include in the bid.

1.9.3.4 Attendance of Procuring entity's Personnel at Factory Tests and Training

1.9.3.4.1 Factory acceptance tests shall be carried out at the OEM manufacturing facilities and at the point of assembly of the panels. Factory shall imply either contractor facilities where panel assembly is to be carried out and OEM manufacturing facilities

1.9.3.4.2 The Contractor shall arrange for at least **five (5)** Procuring entity's engineers or staff members to witness tests of major items of equipment at the Contractor manufacturing plant/s. and contractor premises.

1.9.3.4.3 Tests and inspection for major components e.g., Ethernet radios, industrial routers and industrial switches. shall be carried out at the OEM factory where these devices are manufactured for a minimum of **seven (7)** days prior to delivery to contractor's premises. Equipment to be inspected at the manufacturer's factory prior to delivery to the contractor shall be agreed upon during design review.

1.9.3.4.4 The Contractor shall submit factory training and factory acceptance tests schedule for approval. After approval by the Procuring entity, the Contractor shall invite the Procuring entity's engineers for training and factory acceptance tests. A period of at least one month shall be provided from date of invitation to the date of departure to the contractor's OEM country of manufacture to allow enough time for travelling preparations for foreign OEM's.

1.9.3.4.5 Training at manufacturer's plant or a reputable training centre preferably one run by manufacturer in the country of manufacture shall be provided, in order to enable procuring entity engineers, understand the equipment design, operate and maintain the equipment successfully. Factory acceptance testing shall proceed after the training.

1.9.3.4.6 The above two tasks shall be arranged to follow each other; training to precede the factory acceptance tests.

1.9.3.4.7 Contractor shall be responsible for all travel within country of manufacture and all other associated costs of stay by procuring entity engineers other than accommodation and out of pocket expenses which will be catered by the procuring entity. Necessary expenses including internal air ticket cost between Contractor's OEM manufacturing facilities, inland travel charges in the Contractor's country shall be included in the Tender. Where manufacturing facilities are located in different countries the contractor shall bear the cost of international travel and visa application between contractor's main factory home country and the other countries

1.9.3.4.8 The procuring entity will be responsible for the round-trip airfares between Kenya and the Contractor's OEM main factory country, accommodation and out of pocket expenses.

1.9.3.4.9 Contractor shall facilitate visa application for the procuring entity engineers by providing necessary support documents required by the contractors' /manufacturer's country government

1.9.3.5 FAT

1.9.3.5.1 Factory acceptance tests shall be carried out at the OEM manufacturing facilities and at the point of assembly of the panels. Factory shall imply either contractor facilities where panel assembly is to be carried out or OEM manufacturing facilities

1.9.3.5.2 Prior to commencement of the tests, the equipment shall be inspected to ensure:

(a) Correct standards of workmanship and quality
(b) Correct identification labels, cabling, tagging, housing and mounting etc.
(c) Adequate accessibility
(d) Compliance with the Specification and reviewed drawings (including compliance with fire safety and materials requirements)
(e) Verification of model numbers, quantities of items etc.

1.9.3.5.3 All factory tests and training requirements detailed in the approved factory acceptance test plan/program and factory training program shall be carried out.

1.9.3.5.4 Valid calibration certificates from a third-party accredited laboratory for test equipment to be used during FAT shall be presented to the procuring entity engineers prior to the beginning of the FAT. Only test equipment with valid calibration certificates from a third-party laboratory credited by NSTA shall be used.

1.9.3.5.5 Conduct of the Tests

(a) The Contractor shall conduct the tests in accordance with the approved test procedures and shall enter the results in the approved result sheets.

(b) For each test, the Employer will determine whether the test has passed or failed. In general, the test will be considered to have failed if either:

(i) The result of the test is not in accordance with the expected result described in the test procedure, or

(ii) The result of the test is in accordance with the expected result described in the test procedure, but some other unexpected or unexplained event occurred which the Employer considers to be a fault

(c) Full use shall be made during the tests of operator manuals and other documentation provided by the Contractor to determine the accuracy of the tests.

1.9.3.5.6 Failures

(a) The Contractor shall correct all faults found during testing and shall arrange for the test to be repeated. The test shall only be repeated when the fault has been remedied and the equipment demonstrated to function correctly.

(b) Where remedial measures involve significant modifications that might, in the Employer's opinion, affect the validity of earlier tests then the Contractor shall repeat the earlier tests and obtain satisfactory results before repeating the test in which the fault was first identified.

(c) The Employer shall have the right to order the repeat or abandonment of any test in the event that results demonstrate that the equipment is significantly non-compliant with the Contract requirements, without in any way prejudicing his rights under the contract.

(d) The Employer shall have the right to suspend any test in the event that errors or failures have become unacceptable. The Employer shall also have the right to suspend any test in the event of a fault being detected by the Contractor but not reported to the Employer within 24 hours. In this event, the suspension shall remain in effect until reporting has been brought up to date to the satisfaction of the Employer

1.9.3.5.7 Repeat Tests

(a) The Contractor shall correct and re-test every fault detected during the tests.

(b) Time spent by the Employer witnessing re-tests or waiting at the Contractor's premises or the test site while corrections are made prior to re-test, shall be charged to the Contractor at the standard hourly rate for the personnel concerned.

(c) All other costs incurred by the Employer as a result of such re-tests, including accommodation, subsistence and travel charges, will be charged to the

Contractor at cost. If the Employer is required to return to the Contractor's premises or the test site to witness such re-tests then time spent by the personnel concerned in travelling to the site of and witnessing such re-tests, and all charges incurred by them in so doing, including travel and accommodation shall be charged to the Contractor.

1.9.3.5.8 After the tests, detailed test report and procuring entity inspection report shall be signed by the procuring entity engineers and contractor. These documents shall then become part of the contract.

1.9.3.5.9 FAT meeting minutes duly signed by the contractor and the procuring entity representative shall form part of official project documentation and shall be required by the procuring entity to approve payment processing by the bank. As part of the terms of letter of credit.

1.9.3.5.10 Procuring entity will give consent for shipping ONLY after ALL the issues discussed in the minutes and noted in the procuring entity inspection report have been rectified and evidence given to the procuring entity.

1.9.4 Packing, Transportation and Storage

1.9.4.1.1 The Supplier shall provide such packing of the Goods as is required to prevent their damage or deterioration during transit and temporary storage up to their final destination as indicated in the Contract. The packing shall be sufficient to withstand, without limitation, rough handling and exposure to extreme temperatures, salt and precipitation. Packing case size and weights shall take into consideration, the Goods' final destination and the absence of heavy handling facilities at all points in transit. Indoor electrical equipment must be enclosed in welded polythene envelopes inside packing cases and the envelopes shall be evacuated or have a desiccant inside.

1.9.4.1.2 The following information must be clearly stencilled or printed on each packing case, crate, cask, drum, bundle or loose piece, care being taken that the number and other particulars on each package agree with those entered in the packing list accompanying the Invoice:

(a) Employer's Identity
(b) Supplier's Identity
(c) Destination
(d) Project name
(e) Contract No.
(f) Package No.

(g) Item Code

(h) Weight, dimensions

1.9.4.1.3 The marking above shall be durable and upon the body of the package. Marking upon a batten fastened on the case, etc. shall not be used. In the case of bags, bundles and loose pieces, the shapes of which do not permit the marks to be put on the actual package, each bag, bundle or loose piece shall have two metal labels each with two holes securely fastened by independent wires. Each label shall be die-stamped with the above particulars.

1.9.4.1.4 The Contractor shall be responsible for all transportation from manufacturing site to the project sites

1.9.4.1.5 Goods shall only be shipped from factory to site after approval by the procuring entity.

1.9.4.1.6 Procuring entity shall give clearance for delivery of the equipment only after: all the finalised and approved Drawings, Instruction and maintenance manuals and software have been handed over to the procuring entity; any problems noted during FAT have been rectified and upon receipt of Authentic certified copies of the factory Test Reports

1.9.4.1.7 Contractor will be responsible for equipment offloading and storage at the site prior to installation and commissioning

1.10 INSTALLATION AND COMMISSIONING

1.10.1 Storage at Site

1.10.1.1 The Contractor shall be responsible for proper storage of equipment when delivered until taking over. Care shall be taken to assure adequate storage to avoid damage to equipment due to rain or strong sunshine.

1.10.1.2 Procuring entity will provide space for contractor to set up a storage facility and site office

1.10.2 Erection, and installation supervision

1.10.2.1 The Contractor shall carry out all erection, testing at site and commissioning of the new equipment specified in the Specifications. The Contractor shall perform all electrical, mechanical, civil works and furnish materials that might be necessary during the installation and mounting of the new equipment.

1.10.2.2 All work, methods of work and workmanship, whether fully specified herein or not, shall be of the highest order in all respects; the generally accepted requirements and commonly recognized good practice for first class work of the nature are to be adhered to.

1.10.2.3 The Contractor will make all materials, tools and equipment necessary for installation, testing and commissioning of the works available.

1.10.2.4 Contractor site manager with qualifications stated in qualification criteria schedule shall manage the works IN PERSON. He/she is expected to be available throughout the project execution or to be represented by an equally qualified person. Works will only proceed when the stated person is present on site. The contractor's design & commissioning engineers/experts and installation supervisors shall meet qualifications given in the personnel qualifications. Evidence of this shall be provided prior to commencement of installation.

1.10.2.5 It shall be Contractor's responsibility to provide all staff, such as engineers, supervisory staff, skilled and unskilled labour necessary to carry out and complete the Contract Works on schedule as specified. Information regarding site staff shall be provided to the project manager

1.10.2.6 KenGen shall second skilled labour to carry out the works under supervision of the contractor except for specialized works e.g., welding, non-destructive tests, onsite machining, pipework etc. This secondment shall be free of charge to the Contractor for the number of persons and duration specified. The exact number will be agreed

upon at contract signing and before commencement of installation. In counterpart, the Contractor shall offer proper on the job training to these personnel.

1.10.2.7 Work shall only be carried out in the time of day approved by the project engineer. No work shall be carried out in the plant in absence of employer personnel

1.10.2.8 The contractor shall disassemble and remove existing equipment and then store them at a yard provided by the employer. The contractor shall take due care for the equipment and parts to be reused.

1.10.2.9 Disassembly and removal of old equipment such as panels, cables etc. shall be carried out under supervision of the procuring entity. No equipment shall be removed without the procuring entity representative present and with his/her approval. All existing equipment shall be the property of the procuring entity.

1.10.2.10 The contractor shall indicate the period required at site to install and commission the equipment. The contractor shall submit a program for approval

1.10.2.11 Network or control servers' outages required for installation of the new systems shall be booked in advance. Outages shall be planned so that they do not affect power plant operation. Full network outage or control centre server full outage i.e., including all redundancies shall be not last more than four hours. The old equipment shall continue to be in use during installation to ensure these requirements are met. Contractor shall plan for continued operation of the old equipment.

1.10.2.12 Substation installation works may involve working on live substations and panels. For these and other instances the following factors are of paramount importance: (i) Minimisation of outage time and (ii) adaptation to operational constraints. All work must be planned with this in mind. The Contractor must obey all instructions and safety rules given by the Government and the Employer and must strictly follow all instructions from the Employer's supervisory personnel.

1.10.2.13 At the completion of the Contract, the Employer reserves the right, at his discretion, to take over tools, special tools, test equipment (not included in the bid document) and other construction equipment used by the Contractor in connection with the Contract, at depreciated prices to be mutually agreed upon at that time.

1.10.3 Site Acceptance Testing and Commissioning

1.10.3.1 After equipment has been erected and connected to other plant systems on site, the Contractor shall carry out to the satisfaction of Employer such tests as may be required to prove compliance with the Specification, independent of any factory tests. The tests shall be as per the designed standard and as stated in the particular specifications.

1.10.3.2 Prior to site acceptance testing and commissioning the contractor shall carryout a pre-SAT training, the training shall be carried out at site and shall prepare the

procuring entity engineers for commissioning. Training shall cover the tests to be carried, how they will be carried out, procedures to be followed, precautions and expected results and. During the training the procuring entity engineers will also advise the contractor engineers on the plant systems that shall be tested together with the new systems. The training shall ensure the procuring entity engineers understand the procuring entity's tools especially the software tools to enable full participation of procuring entity engineers during the testing. The contractor will take advantage of this training to ensure that the commissioning engineers disseminate all useful information pertaining to the testing s to the procuring entity engineers to minimise the number queries from the procuring entity engineers thereby reducing commissioning time. The content and scope of this training shall be as per other clauses of this specification.

1.10.3.3 In support of the Site testing activities, the Contractor shall prepare an overall test plan that covers all testing to be carried out on Site. The test plan shall indicate test precedence and dependencies and should be coordinated with the Contractor's general program of work. It shall conform to the relevant requirements for documentation set out in section 1.7 of specifications

1.10.3.4 The test plan will be subject to the approval of the Employer and should be closely coordinated with the Employer in terms of the availability of plant for testing and the timely provision of the associated permits to work.

1.10.3.5 Inspection and test plans (program) may be of any form to suit the Contractor's system, but shall as a minimum:

1.10.3.5.1 Contain all tests specified in the particular specifications and all test requirement of the standard stated in the specifications.

1.10.3.5.2 Detail inspections in form of check lists to be carried out before testing.

1.10.3.5.3 Identify the characteristics to be inspected, examined, and tested at each point

1.10.3.5.4 Give detailed test procedures

1.10.3.5.5 Give acceptance criteria to be used and the applicable verifying document. Indicate basis of the acceptance criteria i.e., standard or specification applicable.

1.10.3.5.6 Indicate mandatory hold points established by the Project Engineer that require verification of selected characteristics of an item of process before this work can proceed.

1.10.3.5.7 Duration required for each test and all tests for each system

1.10.3.5.8 show the sequence to follow step by step in all connections, including wet tests and other pertinent factors

1.10.3.6 Site acceptance testing plans shall be sent to the procuring entity for approval in a similar fashion as drawings as per section 1.7.4 of specifications

1.10.3.7 The Employer shall have the right, to waive some tests and require additional tests to be carried out if findings on Site indicate additional or alternative tests are required to properly demonstrate that the works comply with the requirements of the Contract.

1.10.3.8 The general requirements for testing and factory testing set out in the preceding Clauses 1.9.3 of this specification are also applicable to Site testing.

1.10.3.9 Testing at site shall be carried out by experienced commissioning engineers/experts as stated in personnel qualifications. Testing shall only begin when such personnel are physically on site. Functional tests and performance tests shall be inherent in test procedures. The Contractor shall record the test results in the approved test plan in such a manner that the test reports can be used as the basis for future maintenance tests. Test methods, test equipment and test equipment calibration details shall be noted on the test sheets.

1.10.3.10 Commissioning shall be carried out by the Contractor together with Employer's engineers.

1.10.3.11 During site testing and commissioning the factory as built drawings shall be marked/highlighted (to track checks on each circuit) and modified to suite the final installed systems. Two copies of these marked/highlighted and modified drawings shall be made. One copy shall be left at site while one copy shall be used by the contractor to develop final as built drawings and submission as per provision of section 1.7 of specifications

1.10.3.12 The Site test plans shall be filled by the commissioning engineers and approved by the procuring entity engineer at site. These site test plans shall be copied, and one copy left at site the other copy shall be used to develop final report and submission as per provision of section 1.7 of specifications

1.10.3.13 A complete final test report in 4 sets shall be handed over to the Project Manager not later than one month after the Plant is commissioned

1.10.4 Commissioning and Operational Acceptance

1.10.4.1 After equipment has been erected, configured, and deployed. Contractor shall undertake operations guarantee tests/ reliability run for a period of 90 days

1.10.4.2 During the period of operations guarantee tests the contractor shall be responsible for operations/administration/management and maintenance of the system. All faults shall be addressed by the contractor as per the SLA

1.10.4.3 Contractor shall replace all faulty equipment or equipment performing below required performance.

1.10.4.4 Contractor shall during this time undertake modifications so that system meets the functional, architectural and performance criteria given in specifications.

1.10.4.5 Procuring entity shall only issue the operations acceptance certificate when the system meets the specified functional, architectural and performance criteria after the lapse of the 90 days.

1.10.5 On Job Training

1.10.5.1 During the installation and commissioning periods, the Contractor's site manager, commissioning engineers/supervisors shall give 'on the job' instruction /training to the procuring entity skilled staff. The Contractor's Engineer/supervisor shall train the procuring entity's staff in such disciplines as.

(a) Installation
(b) testing
(c) Configuration
(d) Deployment and commissioning

1.10.5.2 To ease on job training, it's a requirement of this tender as specified in other clauses that the installation and commissioning shall be carried out by both contractor and procuring entity personnel. Prior to installation the contractor shall carry out structured training to the procuring entity personnel to bring them to par with contractor's personnel, this will minimise the amount of explaining to be demanded from the contractor's personnel during installation. The Installation Kick-off training shall cover all important aspects of installation and commissioning and shall ease integration of procuring entity staff to the project.

1.10.5.3 Programming and configuration shall be performed by the contractor for some systems while training the procuring entity engineers. The procuring entity engineers shall then carryout programming and configuration under supervision of contractor engineers for the other systems. Contractor shall create software tools e.g., ms office excel/access macros that shall ease programming, configuration, and database creation. These tools shall be handed over to the procuring entity and shall be used for future modifications.

1.10.5.4 The contractor shall document detailed maintenance procedures and checklists for all systems supplied as part of the contract and hand over to the procuring entity for use during plant maintenance.

1.10.5.5 The contractor shall furnish all programming and configuration tools necessary for test and maintenance of the supplied equipment.

1.10.6 Accommodation of Contractor's Personnel

1.10.6.1 Contractor shall be wholly responsible for accommodation, transportation, and any other required service by their personnel during installation and commissioning. Procuring entity shall not offer accommodation to contractor staff.

1.10.7 Health, environment, and safety

1.10.7.1 The contractor shall forward to the employer during design stage a Safety, Health, and Environmental plan –This shall Include a narration of expected safety risks, taking into account local conditions and mitigation measures that will be adopted to ensure that the projects are completed without accidents, with minimum negative impact on the environment.

1.10.7.2 Contractor shall also undertake a job safety analysis and submit for review and approval prior to site works. Job safety analysis shall be undertaken by a qualified professional.

1.10.7.3 The Contractor shall follow all Kenyan rules and regulations related to workers' safety and health as well as regarding protection of the environment.

1.10.7.4 The Contractor shall be responsible for equipping all their workers and their subcontractors with necessary personal protective equipment such as helmets, eye protection glasses, safety shoes and safety belts and enforcing the use of such. Nobody will be allowed to work in the procuring entity site without proper personal protective equipment.

1.10.7.5 No toxic material (such as Halon, PCB, and Asbestos etc.) shall be utilised neither during construction nor under operation and maintenance.

1.10.7.6 The Contractor shall at all times during the course of work prevent accumulation of debris caused by the work. He shall also remove all debris and temporary structures when finishing the work.

1.10.7.7 All surplus material should be disposed in an environmental satisfying way. Particular attention shall be given to safe disposal of environmentally hazardous substances. Workable equipment shall be handed over to the Employer

1.11 TRAINING

1.11.1 General Requirements

1.11.1.1.1 The Contractor shall submit a training syllabus/plan for the review and approval as detailed in clause 1.7

1.11.1.1.2 All training courses, notes and documentation shall be in the English language only.

1.11.1.1.3 The scope and content of courses should ensure a systematic and comprehensive coverage of all the operational functionality and maintenance requirements identified in both the design and the operations and maintenance documentation for the Works delivered under the Contract. This shall include all 'third party products' such as operating systems and their associated utilities and diagnostics.

1.11.1.1.4 All courses shall consist of a series of lectures, discussions, demonstrations/practical particularly for operators, engineers, and maintenance staff - 'hands-on' experience of the equipment involved.

1.11.1.1.5 The contractor shall supply training aids including a detailed training guide or document well prepared in advance. Contractor is expected to be well prepared for the training with necessary presentations specific for the training. Pre-recorded video presentations shall **not** be used as the primary means of training.

1.11.1.1.6 The emphasis shall be on practical training which shall be conducted using the equipment in the scope of supply.

1.11.1.1.7 The contractor shall provide certified and experienced trainers who are fluent and have excellent command of **English** language. Trainers not meeting this requirement shall be rejected and the contractor will reschedule the training with trainer meeting the requirements.

1.11.1.1.8 Trainers shall meet the personnel qualifications given in clause 1.14

1.11.1.1.9 The contractor will prepare and present certificates to participants at the end of the training

1.11.1.1.10 The training shall be to such a level that on completion of the courses, the Employer's staff shall be able to operate, configure &administer and maintain all equipment and systems provided under the Contract without assistance from the contractor.

1.11.1.1.11 Site training shall be carried out at procuring entity facilities two weeks after

delivery of equipment to site or at a later date agreed upon during the kick off meeting.

1.11.1.1.12 The contractor shall be wholly responsible for accommodation, transportation and any other required service by their personnel while offering training.

1.11.1.1.13 The training topics SHALL NOT be carried out concurrently and shall run one after the other to ensure procuring entity staff attend all the above sections.

1.11.1.1.14 As a minimum, the courses shall include, but not be limited to, the specific topics listed in the following sub-clauses, or equivalent topics, depending on the detailed design of the products supplied under the Contract.

1.11.1.1.15 The Contractor shall provide a number of different courses to accommodate the requirements of the different skills each group of personnel will need to acquire in the context of the Employer's actual operating environment.

1.11.1.1.16 Training courses to be provided shall include:

(a) Network beginners training and Network advanced training but customised to provided emphasis on the below topics due to the project requirements.
    (i) IP MPLS (theory and practical configuration/implementation), some emphasis on traffic engineering
    (ii) VLANs and QinQ tunnelling
    (iii) Carrier Ethernet (theory and practical / implementation)
    (iv) Telephone (VOIP)network set up and management, DECT setup and site planning.
(b) Radio setup and link planning
(c) Fibre splicing and testing
(d) Equipment specific trainings (Switches, routers, IOS, radio, PBX etc.)

1.11.1.1.17 The courses shall provide the attendees with a sufficient understanding of the functionality of each part of the system and its operation and maintenance requirements. As a minimum the contents shall cover:

(a) System overview and architecture.
(b) Interfaces and standards supported.
(c) System operation and configuration.
(d) System design/budget calculations.
(e) System hardware and software.
(f) System expansion and upgrade capability.
(g) Cabling requirements.
(h) Installation, testing and commissioning techniques.
(i) Fault finding and trouble shooting.
(j) Repair and routine maintenance.

1.11.1.1.18 The contractor shall prepare the course content and the syllabus of each course in the following manner:

(a) Course name
(b) Duration
(c) Locations for the training
(d) Types of staff who would benefit from the course
(e) Pre-requisite skills of course attendees
(f) Objectives, i.e. the skills the course is intended to develop
(g) Aims, i.e. how the skills developed can be used
(h) Description of course activities
(i) Description of course documentation.

1.11.1.1.19 By the end of the site training all topics in the proceeding clauses and all other topics necessary MUST be covered for the procuring entity to install and deploy the supplied equipment.

1.11.1.1.20 To ensure maximum knowledge transfer two or three procuring entity staff shall be attached to the contractor for the duration of the project from design to commissioning.

1.11.1.1.21 During commissioning, Contractor shall carry out all software, configurations, programming with the procuring entity engineers. They shall assign these tasks to the employer staff and supervise them to allow maximum knowledge transfer.

1.11.2 Course requirements

No	Courses	No of Trainees	Duration (in days)
1	Beginners Training (Networking foundation course)	15	3 days
2	Advanced Network training	15	8 days
3	Radio setup and link planning	15	3 days
4	Fibre splicing and testing	15	2 days
5	Equipment specific trainings (Switches, routers, radio, PBX, DECT, servers etc.). and network management	15	10 days

1.11.3 Beginners Training (Networking foundation course)

1.11.3.1.1 The contractor shall customize the training cover the following basic topics for personnel with minimal networking experience.

(a) Network Fundamentals
(b) Network Access -LAN & WAN, in-depth layer 2

(c) IP Connectivity and services including routing.

(d) Application and transport layer services

(e) Security Fundamentals

(f) Automation and Programmability

1.11.3.1.2 The skills gained at the end of the training shall enable the trainee to Install, configure, and operate the network.

1.11.4 Advanced Network Training

The contractor shall customize the training to provide emphasis on the following topics due to the project requirements.

1.11.4.1 IP MPLS

1.11.4.1.1 Introduction to IP MPLS and fundamentals

1.11.4.1.2 MPLS Architecture: Label Switch Routers, two types of LSR, PE and P router roles, FEC, swapping labels, MPLS packet format, Loops, TTL control.

- Hands on: Building the base network. Enabling MPLS. Simple testing and troubleshooting of MPLS.

1.11.4.1.3 Label distribution: Label review, label switch path, label distribution methods, piggybacking, Label distribution Protocols, LDP, LDP operation, LDP packets, discovery messages, session messages, advertisement messages, notification message, Label Information Base, routing tables, the LFIB, MPLS forwarding, penultimate hop popping, handling labels, LSP control modes, when to distribute labels, how long to keep labels, aggregation, label merging.

- Hands on: LDP traffic analysis.

1.11.4.1.4 Label distribution: Label review, label switch path, label distribution methods, piggybacking, Label distribution Protocols, LDP, LDP operation, LDP packets, discovery messages, session messages, advertisement messages, notification message, Label Information Base, routing tables, the LFIB, MPLS forwarding, penultimate hop popping, handling labels, LSP control modes, when to distribute labels, how long to keep labels, aggregation, label merging.

- Hands on: LDP traffic analysis.

1.11.4.1.5 MPLS Traffic Engineering and QoS: Introduction to MPLS TE, TE versus shorted path, how MPLS TE works, CR-LDP, OSPF-TE, IS-IS-TE, TE with BGP, RSVP-TE, MPLS Fast reroute, MPLS QoS.

- Hands on: Enabling MPLS-TE.

1.11.4.1.6 BFD: BFD, hello the BFD protocol.

1.11.4.1.7 MPLS VPN: Introduction MPLS VPN? MPLS VPN types, MPLS VPN comparison, MPLS L3 VPN, VRFs, MBGP, MPLS VPN architecture, VRF RD, VRF RT, the label stack, L2 VPNs, VPWS, AToM, VPLS.

- Hands on: MPLS L3 VPN setup, troubleshooting.

1.11.4.2 Carrier Ethernet

1.11.4.2.1 Introduction

What is Ethernet? LANs, MANs, WANs, Ethernet, and switches in the LAN. Traditional LAN/WAN integration, routers. The Ethernet interface for the WAN. Standards: IEEE, MEF, OIF, Ethernet Alliance.

1.11.4.2.2 Carrier Ethernet Services

E-line: EPL, EVPL. E-LAN: EP-LAN, EVP-LAN. E-Tree: EP-Tree, EVP-Tree. Ethernet Services attributes. Applications: Carrier Ethernet for businesses, Mobile backhaul. Multicasting.

1.11.4.2.3 Service attributes

Bandwidth profiles, bandwidth parameters, Class of Service, QoS, MTU, Protection mechanisms: STP, RSTP, MSTP, Link aggregation, G.8031, G.8032.

1.11.4.2.4 Transporting Carrier Ethernet

The main options. “Pure” Ethernet, Ethernet over SDH, Ethernet over WDM, Ethernet over MPLS. Ethernet switching, addresses and MAC address tables. Carrier Ethernet access technologies. EFM.

1.11.4.2.5 Ethernet over MPLS

What is MPLS, MPLS-TE, MPLS-VPN, L2 VPNs, VPLS, VPWS. MPLS Fast Reroute.

1.11.4.2.6 CET

“Pure” Ethernet, Provider bridging 802.1d, Provider Backbone Bridges 802.1ah. Traffic engineering 802.1Qay.

1.11.4.2.7 Carrier Ethernet technologies

802.1ad VLAN stacking, 802.1AX Link aggregation. 802.1Q QoS.

1.11.4.2.8 QinQ tunnelling

1.11.4.2.9 OAM

Standards, layers, interworking

1.11.4.3 VPN

1.11.4.3.1 VPN overview

What is a VPN? What is an IP VPN? VPNs vs. Private Data Networks, Internet VPNs, Intranet VPNs, Remote access VPNs, Site to site VPNs, VPN benefits and disadvantages.

1.11.4.3.2 VPN Tunnelling

VPN components, VPN tunnels, tunnel sources, tunnel end points, hardware-based VPNs, Firewall based VPNs, software-based VPNs, tunnelling topologies, tunnelling protocols, which tunnelling protocol should you use? requirements of tunnels.

1.11.4.3.3 VPN security components

Critical VPN security requirements, Encryption, and authentication, Diffie Hellman, DES, 3DES, RSA, PKI, Ca server types, pre shared keys versus certificates, Enrolling with a CA, RADIUS in VPNs.

1.11.4.3.4 PPP

(a) Encapsulation, operation, authentication.

(b) Hands on Setting up PPPoE and analysing PPP packets.

1.11.4.3.5 PPTP

(a) Overview, Components, how it works, control and data connections, GRE.

(b) Hands on Building a PPTP VPN.

1.11.4.3.6 L2TP

(a) Overview, components, how it works, security, packet authentication, L2TP/IPSec, L2TP/PPP, Layer 2 versus layer 3 tunnelling.

(b) Hands on Implementing a L2TP tunnel.

1.11.4.3.7 IPSec

(a) AH, HMAC, ESP, transport and tunnel modes, Security Association, use of encryption and authentication algorithms, manual vs automated key exchange, NAT and other issues.

(b) Hands on Implementing an IPSec VPN.

1.11.4.3.8 Intranet VPNs

Headers, architecture, label switching, LDP, MPLS VPNs.

1.11.4.3.9 VPN products and services

PE and CPE, management, various VPN products.

1.11.4.3.10 VPN issues and architectures

VPN architectures: terminate VPN before/on/ after/in parallel with firewall, resilience issues, VRRP, performance issues, QoS and VPNs. documentation.

1.11.4.4 Telephone (VOIP)network set up and management.

1.11.4.4.1 What is VoIP: Voice over IP, brief review of IP, brief review of telephones and voice.

1.11.4.4.2 Configuring IP softphones: What are softphones? Downloading, installing.

- Hands on Building the base IP network, a simple VoIP call with softphones, Internet telephony.

1.11.4.4.3 Addressing: E164, FQDN, IP addresses, URIs, DNS, SIP addressing, H.323 addressing.

1.11.4.4.4 VoIP issues: Bandwidth, Delay, Jitter, digitising voice, digitisation steps, coding, quality issues, MOS, voice compression, silence suppression, packetizing voice, prioritising voice, jitter buffers.

- Hands on Simple packet analysis.

1.11.4.4.5 Architectures: Desktop, backbone, gateway, hard phones, PoE, integrating phones and PCs, carriers, Soft switches.

- Hands on Integrating Softphones, hard phones, and analog phones.

1.11.4.4.6 IP performance and QoS: ITU delay recommendations, IP DSCP field, DiffServ, IP precedence, queuing strategies; FIFO, WFQ, custom, priority, RED, LLQ.

1.11.4.4.7 VoIP protocol stack: RTP, RTCP, mixers and translators, RSVP. Bandwidth, Erlang models, link layer overhead.

- Hands on Calculating VoIP bandwidth, analysing RTP packets.

1.11.4.4.8 ITU Recommendation H.323: Architecture, protocols, terminals, Call setup,

Gatekeepers, gateway discovery, H.323 registration with a gatekeeper.

- Hands on PC to PC using H.323.

1.11.4.4.9 IETF – Session Initiation Protocol: What is SIP? SIP protocol stack, SDP, Sip architecture, SIP messages, Initial SIP phone startup, SIP servers, proxy server, redirect server.

- Hands on PC to PC using SIP.

1.11.4.4.10 Carrier networks: Signalling systems, SS7, media gateways, Media gateway controllers, signalling gateways, MGCP, Megaco, SIGTRAN.

- Hands on PSTN interworking.

1.11.4.4.11 Video over IP: Video components, digital video, pictures and audio, video codecs, issues and solutions, video conferencing, multipoint video conferencing, video protocol stack.

1.11.4.5 DECT

1.11.4.5.1 Basics of the DECT technology.

1.11.4.5.2 System Configuration: Provide a good overview of the web interface of the DECT base stations. How to access the web interface, configure the base, add extensions and alarms and manage address books.

1.11.4.5.3 Multicell: All relevant details regarding the setup and operation of a DECT multicell with bases. Mechanisms of synchronization, create a multicell and see how to make a correct DECT Site Survey. Step by step through the configuration of a multicell and how to manage it. Detailed look at the path of the audio signal within the multicell.

1.11.4.5.4 Site Survey: All the relevant details on how to make a correct DECT Measuring. Practical tips, dimensions, and positioning of DECT bases. Detailed illustration of how to realize an optimal DECT-Measuring.

1.11.4.5.5 Provisioning: Overview of the possibilities of provisioning Snom DECT devices. Types of provisioning are available for Snom DECT devices, configure using provisioning, Requirements and specifications to meet in order to conveniently provide both individual phones and hundreds of phones with the respective configuration.

1.11.4.5.6 Troubleshooting: Techniques you will need for troubleshooting. By using screenshots and practical examples.

1.11.5 Radio setup and link planning

1.11.5.1.1 Introduction to Radio Systems:

(a) General radio system overview.

(b) Transmitter and Receiver architecture, Full Indoor & Split systems, Trunk & Access Equipment.

1.11.5.1.2 Basics on Radio propagation:

(a) Free Space Propagation, basic radio link equation, free space loss.

(b) Terrestrial radio links, propagation in the atmosphere, overview of main impairing factors.

(c) Link Budget and Fade margin.

1.11.5.1.3 Path Profile, Clearance, Obstruction Loss:

(a) Effect of atmospheric refraction, equivalent earth curvature.

(b) Fresnel ellipsoid and visibility criteria (ITU-R Recs.).

(c) Obstruction loss estimate.

1.11.5.1.4 Path Profile, Ground Reflections:

(a) Path geometry reflected ray loss and phase shift, major factors.

(b) Reflection coefficient.

(c) Rx power vs. antenna height and k-factor.

(d) Use of Rx diversity configuration.

1.11.5.1.5 Multipath Propagation:

(a) Atmospheric refractivity gradient, multiple ray trajectories.

(b) Rayleigh fading, activity factor.

(c) Narrowband/Wideband (frequency selective) fading.

(d) Prediction models.

(e) Countermeasures (equalization, diversity).

1.11.5.1.6 Rain Attenuation:

(a) EM wave interaction with atmosphere (water vapor, oxygen, raindrops).

(b) Rain attenuation vs. rain-rate, frequency, and polarization.

(c) ITU-R rain statistics. Prediction models.

1.11.5.1.7 Topics in System Installation:

(a) Indoor and Outdoor installations.

(b) Rack Assembly; branching configurations in indoor and outdoor systems; cables and waveguides.

(c) Basic criteria for grounding connections.

(d) Parabolic Antenna characteristics; Antenna Assembly.

(e) First set-up of equipment; Antenna Alignment.

1.11.5.1.8 Basic criteria in System Maintenance:

(a) Alarm Analysis and action over.

(b) Replacement procedures.

1.11.5.1.9 Networking Overview:

(a) Introduction to IP Protocol.

(b) Transport of IP Traffic in New generation of MW equipment's.

(c) Layer 2 & Layer 3 Supervisory Networks.

1.11.5.1.10 System Design:

(a) RF bands for MW systems, ITU Radio Regulations and ITU-R Recs. Classification of interference sources in linear, radial and meshed networks. Performance degradation caused by interference.

(b) Radio Hops with passive reflectors. Performance Objectives, ITU Recs. Link availability and transmission quality.

(c) Performance objectives vs. propagation impairments.

1.11.5.1.11 Propagation & Design Issues Practical problems in MW link design:

(a) Sw tools; Digital maps (resolution, accuracy, coordinate systems); Interface to other Sw apps (Google Earth, Excel, ...).

(b) Equipment & Antenna libraries (NSMA file formats).

1.11.5.1.12 Propagation models, role of ITU-R Recs. Design Exercises:

(a) Network Topology; Tx/Rx Configuration.

1.11.5.1.13 Installation & Maintenance Indoor Installation (split system):

(a) IF Cable; Grounding Connections, Rack Assembly; Indoor Unit Connection, PSU Connection.

1.11.5.1.14 Full Indoor System Installation:

(a) Rack Layout Sheet 1; Mechanic Rack Specification; Positioning Metal Fittings Rack Cable Run: Typical Layout, Elliptical Waveguide connections; Elliptical Waveguide Indoor Run & Installation.

1.11.6 Fibre splicing and testing.

1.11.6.1.1 Fibre optic transmission

Physics of light, optical modes, light propagation, light guiding, dispersion, light spectrum, fibre versus copper comparison, fibre cable types and their uses, WDM and DWDM.

1.11.6.1.2 Fibre optic cable

Single mode, multi-mode, diameters, step-index fibre, graded index fibre, loose tube, tight buffered, cable jackets, distance limitations, indoor versus outdoors.

1.11.6.1.3 Fibre optic network components

ST, SC, FC and other connectors, termination methods, joint enclosures, transmitters, light sources, laser, LED, receivers, detectors.

1.11.6.1.4 Installation

BS.7718. Safe working practices, site surveys, recommended installation procedures, cable handling issues, bending radius, techniques and tools, documentation.

1.11.6.1.5 Splicing

Joining fibres, splicers, fusion splicing, mechanical splicing, splicing procedure, cleaving, splicing parameters, splicing vs. connectors.

1.11.6.1.6 Measurement parameters and applications

Power measurement, loss measurement, return loss measurement, receiver sensitivity measurement, budget calculations.

1.11.6.1.7 Testing

Optical power meter, optical light source, optical attenuator, return loss meter, continuity testing, insertion loss testing, OTDR features and principles, OTDR

capabilities and limitations, using an OTDR, troubleshooting.

1.11.7 Equipment specific trainings

1.11.7.1 The following basic training shall be offered for all the hardware devices (Switches, routers, DECT, radio, PBX etc.) in scope of supply.

1.11.7.2 General Requirements:

1.11.7.2.1 Install, Configure, Manage

(a) Overview

(b) BIOS

(c) System Setup Utility

(d) Boot Manager

1.11.7.2.2 Remote Access Controller (RAC)

(a) Features and Functions

(b) Configuration

(c) Licensing

(d) Web Interface

(e) Direct

(f) Quick Sync

1.11.7.2.3 Lifecycle Controller

(a) Features and Functions

(b) Accessing and Navigation

(c) Updating

1.11.7.2.4 Lights out management

1.11.7.2.5 General device administration and Console configuration

1.11.7.2.6 Troubleshooting and routine maintenance

1.11.7.2.7 Assembly and installation

1.11.7.2.8 SNMP and syslog set up for network management

1.11.7.2.9 Drivers/firmware installation and upgrade

1.11.7.2.10 Download and upload of device setting files

1.11.7.2.11 Support Assist

1.11.7.3 The training shall be detailed enough to allow the procuring entity staff to install, configure and deploy any hardware equipment in scope of supply without the assistance of the supplier

1.11.7.4 Settings back up files shall be downloaded from the devices where applicable and handed over to the procuring entity

1.11.7.5 Training shall be practical and shall be conducted using the delivered equipment

1.11.8 Network management

1.11.8.1 Basic network management

1.11.8.1.1 Network management: What is network management? Benefits, issues. FCAPS model. Fault management, Configuration management, accounting, performance, security. What to manage, what not to manage. Managing network devices, managing servers.

1.11.8.1.2 Traditional network tools: Ping..., SSH, syslog, TFTP for configurations. nmap. Wireshark. Web based management. Splunk. Nessus, snort, Kali.

- Hands on syslog, network inventories.

1.11.8.1.3 What is SNMP? SNMP architecture, SNMP MIBs, SMI, the SNMP protocol, polling security.

1.11.8.1.4 Configuring SNMP: Auto discovery for management stations, NMS configuration, agent configuration, traps.

- Hands on Configuring agents and a NMS.

1.11.8.2 Monitoring with SNMP: SNMP versions: SNMP history, RFCs, standards, SNMP protocol versions, SNMPv1, SNMPv2, SNMPv3, SNMP security, SMI versions, which version should you use? Futures.

- Hands on SNMPv3.

1.11.8.2.2 MIB structure: The internet MIB branch, standard mib-2, extra parts of mib-2, private enterprise MIBs, loading extra MIBs.

1.11.8.2.3 Hands on MIB browsing.

1.11.8.2.4 SNMP summary: What SNMP is good at. What SNMP is bad at. Review of network management systems.

1.11.8.3 Performance management: Server management, Microsoft, Linux, application polling. WMI vs SNMP.

- Hands on Application polling.

1.11.8.3.2 *Flow: Polling, push vs pull, netflow, sflow, IPFIX, *flow. Streaming telemetry. Flows. Where to monitor traffic. Comparing *flow with SNMP.

1.11.8.3.3 NetFlow architecture: Generators and collectors. When flows are exported. NetFlow reporting products. SolarWinds.

- Hands on Netflow configuration. Collectors.

1.11.8.3.4 *Flow export formats: XML/NETCONF, JSON/RESTCONF, Protocol buffers/gRPC.

- Hands on Packet analysis.

1.11.8.4 Software Defined Networks: Classic SDN: What is SDN? benefits. SDN architecture. SDN applications, SDN switches, SDN controllers, Network Operating Systems. Control plane, data plane. Northbound interfaces. SDN components. Southbound interfaces. OpenFlow. ONF, OpenFlow ports, Flow tables.

1.11.8.4.1 Network virtualization: Virtual networks, virtual switches, NfV. Service chaining. NfV and SDN.

1.11.8.4.2 SDN implementations: Classic SDN, Hybrid SDN, SDN via APIs, SDN via overlays. Data centre SDN, VXLAN, Service Provider SDN, SD WAN, Enterprise SDN, WiFi.

1.11.8.4.3 SDN and open source: OpenDaylight, OpenVSwitch, Open Networking Forum, Open Network Operating System.

- Hands on OpenStack.

1.11.8.5 Automating network configuration: What is Devops? Programming and automating networks, Devops for network operations

1.11.8.5.1 Configuration management: CLI, SSH, NETCONF and YANG, REST and RESTCONF, OPENCONFIG.

- Hands on NETCONF.

1.11.8.5.2 Ansible and automating network configuration

1.11.8.5.3 Ansible architecture, Controlling machines, nodes, Agentless, SSH, modules. Inventories, playbooks, modules, network modules, jinja2 templates.

- Hands on Installing ansible, configuring network devices with ansible.

1.11.8.5.4 Network automation

1.11.8.5.5 Programming models and options, Python, Git and Github. Python network modules, ncclient, pysnmp, SSH, paramiko, netmiko, NAPALM.

- Hands on Python with network modules

1.12 TECHNICAL SUPPORT

1.12.1 General Requirements

1.12.1.1.1 Contractor shall offer technical support to procuring entity for a period of at least one year after issuance of operations acceptance certificate.

1.12.1.1.2 Terms of technical support shall be guided by SLA to be signed as part of the contract

1.12.1.1.3 Bidder shall prepare a draft SLA to cover support requirements given in this tender

1.12.2 Scope of Technical support

1.12.2.1.1 Technical support after commissioning shall cover the following systems.

(a) All equipment supplied under this contract.

(b) Complete network for all sites covered under this project.

1.12.2.1.2 Technical support shall cover faults preventing operation of the system or affecting performance of the system

1.12.2.1.3 One scheduled maintenance shall also be carried out as part of the technical support six months after commissioning.

1.12.2.1.4 Online support shall be provided to assist procuring entity for day-to-day operations.

1.12.2.1.5 Faults shall be attended to by the contractor in person or by sending their contracted agents. contractor's personnel or agent shall be physically present at site and not online support. Details of personnel to be sent to the site shall sent to the procuring entity by the contractor prior to their arrival.

1.12.2.1.6 Contractor shall stock accessories and consumables required to resolve the faults

without extra charge to employer.

1.12.2.1.7 Contractor shall replace all faulty equipment under warranty with new equipment pending determination of the cause of failure and replacement of failed part.

1.12.3 Terms of Technical support

1.12.3.1.1 The contractor responses for different categories of support / faults shall be within the response and solution times indicated below, provided the required spare parts are on the Procuring entity´s stock and delivered to the required site.

1.12.3.1.2 For Critical Faults, the Response Time (RT) shall be no more than

(a) 2 hours within working hours for Tana and Wanjii

(b) 4 hours within working hours for Masinga, Kamburu, Gitaru, Kindaruma and Kiambere.

(c) while the Solution Time (ST) is 4 working days. In resolving a Critical fault, the Supplier should provide options that allow it to become a Moderate Fault.

1.12.3.1.3 For Moderate Faults, the Response Time (RT) shall be no more than 48 hours within working hours, while Solution Time (ST) is 7 Working days.

1.12.3.1.4 For Minor Faults, the Response Time (RT) shall be no more than 48 hours within working hours, while Solution Time (ST) is 10 Working days.

1.12.3.1.5 The completion of the services on-site shall be authenticated by the Supplier's personnel by a service report, which shall be countersigned by the procuring entities' authorized representative.

1.12.3.1.6 In the event the Supplier is unable to perform the services due to reasons attributable to the procuring entities representative, the procuring entities shall be obliged to sign the Service report and the work is deemed to be done or reschedule the works.

1.12.3.1.7 If a maintenance service cannot be performed at the location of the equipment, the contractor shall make a special note in the service report and shall provide information on the necessary actions to be taken.

1.12.3.1.8 After issuance of operations acceptance certificate, the signed a Service Level Agreement (SLA) between the procuring entity and contractor will start and continue until the agreed period.

1.12.3.1.9 SLA shall also be extended or renewed unless and until terminated by either Party by giving not less than 3 months' notice in writing.

1.12.3.1.10 On any renewal of the service period, the parties shall agree on the terms of renewal of this Service Level Agreement.

1.12.3.1.11 The Supplier undertakes to maintain the said service levels throughout the duration of this agreement. In case the said service levels cannot be fulfilled, a penalty of 0.5% per day of the value of maintenance cost per month for that site will be charged to the Supplier, maximum being 20% of the Site Maintenance value.

1.12.4 Online Support

1.12.4.1.1 Online support in this scope shall be offered directly by the contractor or by the contractor appointed and paid for agents. It shall cover all the equipment and systems in scope of supply

1.12.4.1.2 Online support shall include services/assistance offered to procuring entity in order to enable it to mount, install, configure, deploy, trouble shoot or maintain equipment or systems in scope of supply of this tender

1.12.4.1.3 Online support shall be offered for a minimum of the following medium:

(a) Telephone, 8am–5pm EAT
(b) Email, 24hrs, with a response given within 8hrs of receiving the email
(c) Video telephone/chat, 8am–5pm EAT
(d) Online/web meeting within a day notice, 8am–5pm EAT
(e) Remote desktop control &support e.g. team viewer, within a day notice, 8am–5pm EAT.

1.12.4.1.4 Any other method agreed upon after contract award

1.12.4.1.5 Software support from the software developer shall not be part of the online support in this scope and shall be offered as part of the software. Software support shall be offered for a minimum of three years as detailed in the software scope of supply. Software support shall be offered directly to the procuring entity from the software developer as per the terms of the software license.

1.13 WARRANTY

1.13.1 Suppliers Warranty

1.13.1.1 The Contractor shall warrant that ALL goods supplied under the Contract are brand new, unused, of the most recent or current models, and that they incorporate all recent improvements in design and materials unless provided otherwise in the Contract.

1.13.1.2 The Contractor shall warrant that all Goods supplied under this contract shall have no defect arising from design, materials, workmanship (labour) or from any act /omission of the Contractor or manufacturer.

1.13.1.3 Contractor further shall warrant those goods supplied under this contract shall not develop defects under normal use of the supplied Goods in the conditions prevailing in the country of final destination and site conditions as specified in this tender.

1.13.1.4 Contractor shall replace any goods and software that fail within the **warranty period of two years** due to defects arising from conditions in clause (1), (2) and (3) above.

1.13.1.5 This warranty shall remain valid for **twenty-four (24) months** from the date of completion/deployment of the last site/system for **ALL** equipment and software in scope of supply.

1.13.1.6 Contractor shall warrant that supplied equipment end of sale shall not be declared within the warranty period. If, any equipment is declared end of sale within the warranty period, the contractor shall replace all such equipment with latest models at no cost to procuring entity.

1.13.1.7 The bidder guarantees supplying maintenance spares and services as well as repairing of the supplied systems if called upon to do so after expiry of the warranty period at procuring entity's cost for a period of 10 years.

1.13.1.8 Bidder shall provide a signed letter in their letterhead committing to offer a **two-year** warranty meeting the above conditions if awarded the tender.

1.13.2 Manufacturer warranty

1.13.2.1 Manufacturer's warranty shall be extended for all key equipment in scope of supply as detailed in particular technical specifications. Manufacturer warranty shall cover all defects arising from design, materials, or workmanship or from any act or omission of the Manufacturer.

1.13.2.2 All key industrial grade equipment shall have a manufacturer warranty of at least five years from the date of supply.

1.13.2.3 All key enterprise grade equipment shall have a manufacturer warranty of at least three years from the date of supply.

1.13.2.4 Manufacturer's warranty shall be clearly spelt out in submitted data sheets, catalogues or manufacturer authorisations

1.13.2.5 Contractor shall be responsible for handling manufacturer warranties for the period covered by the supplier warranty.

1.14 PERSONNEL QUALIFICATIONS

1.14.1 General Requirements

1.14.1.1 Personnel engaged by the contractor to provide design and commissioning services shall meet the following.

1.14.1.1.1 A minimum bachelor's degree in a related field of study

1.14.1.1.2 Shall be fluent and have **excellent** command of **spoken** and **written English** language.

1.14.1.1.3 Shall have a minimum of **five years working experience** since graduation.

1.14.1.1.4 Shall have worked with the equipment/system model/manufacturer supplied by the contractor for at least one year or in at least two previous projects.

1.14.1.2 Only personnel meeting requirements given in this clause1.14 and qualification criteria shall be allowed to carry out the works

1.14.1.3 Contractor shall engage specialist contractors, OEM's etc to provide personnel with qualification required for the work if needed. It is not a requirement that the contractor has all the personnel in their employ.

1.14.1.4 Filled Personnel form and recommendation letters to be provided. Recommendation letters MUST be from employers or clients who can converse in English

1.14.1.5 Procuring entity shall evaluate the proposed personnel capability to carry out the scope of job proposed by the contractor by a short interview or meeting. If procuring entity is not satisfied with the proposed personnel capabilities the contractor shall replace the personnel or subcontract to a firm with qualified personnel.

1.14.2 Network design and deployment

Network design and deployment expert shall meet the following qualifications

1.14.2.1 Degree in engineering or ICT related field

1.14.2.2 Advanced network certification

1.14.2.3 Provide documentary evidence of having at least **seven (7)** years' experience in implementing network designs and deployment for service provider or enterprise WAN project implementations including design, deployment, and commissioning.

1.14.2.4 Provide documentary evidence of having Successfully completed at least **three (3)** service provider backbone/core network design and deployment projects in the last 10 years as the technical lead for at least three firms

1.14.3 Server Administration

Server Virtualisation and configuration expert shall meet the following qualifications

1.14.3.1 Degree in engineering or ICT related field

1.14.3.2 VMware Certified Professional (VCP) for virtualisation functions

1.14.3.3 Microsoft Certified Solutions Expert (MCSE): Core Infrastructure for windows server and Microsoft services and applications deployment

1.14.3.4 Provide documentary evidence of having at least **three (3)** years' experience in implementing datacentre Virtualisation and configuration project implementations including design, deployment, and commissioning.

1.14.3.5 Provide documentary evidence of having caried out at least **three (3)** datacentre Virtualisation and configuration projects as the team lead for at least three firms

1.14.4 Network Management

Network management expert shall meet the following qualifications

1.14.4.1 Degree in engineering or ICT related field

1.14.4.2 Solar Winds Certified Professional (SCP)

1.14.4.3 Provide documentary evidence of having at least **three (3)** years' experience in implementing network management systems and server/datacentre monitoring systems project implementations including design, deployment, and commissioning.

1.14.4.4 Provide documentary evidence of having caried out at least **three (3)** network management and server/datacentre monitoring systems projects as the team lead for at least three firms

2 GENERAL TECHNICAL SPECIFICATIONS

2.1 STANDARDS

2.1.1 Ratings, characteristics, tests, and test procedures, etc. for the electrical equipment encompassed by this Specification shall comply with the provisions and requirements of British standards institute (BS) and International Electro-Technical Commission (IEC) standards or International Electrical & Electronic Engineers – IEEE unless otherwise expressly stated in Particular Technical Specifications.

2.1.2 Ratings, characteristics, tests, and test procedures, etc. for the mechanical equipment encompassed by this Specification shall comply with the provisions and requirements of British standards institute (BS) and international standardization organization – ISO standards unless otherwise expressly stated in Particular Technical Specifications.

2.1.3 All civil works shall comply with the latest Kenya building code, provisions of applicable Kenyan standards (KS) and of applicable standards by British standards institute (BS).

2.1.4 Where the BS or ISO or IEC or IEEE standards do not fully cover all provisions and requirements for the design, construction, testing, etc. The European Committee for Standardization (EN) standards, rules of CEE (International Commission for the approval of electrical equipment), the standards of CENELEC (Comité Euopeen de Normalisation Elecrotechnique) and other recognised national/international standards LISTED BELOW shall be applied. The other recognized national and international standards are:

(a) German – DIN
(b) American National Standards Institute -ANSI
(c) American Society of Mechanical Engineers – ASME
(d) American Society for Testing and Materials -ASTM
(e) Telecommunications Industry Association (TIA)
(f) Electronic Industries Alliance (EIA)
(g) International Telecommunication Union (ITU)
(h) International Society of Automation- ISA
(i) Internet Engineering Task Force, IETF

2.1.5 Equipment and works shall conform to standards of the bodies indicated clause 2.1.1-2.1.4 ONLY no other standards from other bodies shall be allowed unless specified in the particular specifications.

2.1.6 The latest revision or edition in effect at the time of Bid Invitation shall apply for all standards used or stated in this tender document. Where references are given to numbers

in the old numbering scheme from IEC it shall be taken as to be the equivalent number in the new five-digit number scheme.

2.1.7 The Tenderer shall state the Precise Standard, complete with identification number, to which the various equipment and materials are manufactured. The tender documents do not contain a full list of all standards to be used; the contractor shall give the precise standard which the equipment and work shall conform to.

2.2 GENERAL ELECTRICAL REQUIREMENTS

2.2.1 General

2.2.1.1 The equipment shall withstand without permanent weakening or deformation from short circuit current within the rating of the apparatus (including those due to faulty synchronising) as well as normal atmospheric over voltages taking into account the use of lightning arresters. Special considerations shall be given to pressure rises by short circuits and fire risk. All material and equipment shall be designed and arranged so that over pressure will be relieved in a safe direction and so that fire risk is minimised, and consequences of a fire reduced

2.2.1.2 All plastic material used in boxes, panels and boards shall be halogen free and self-extinguishable.

2.2.1.3 The contract supplies shall be designed to facilitate inspection, cleaning and repairs and for operation, in which continuity of service is the first consideration.

2.2.1.4 All conductors' current carrying parts must be dimensioned with ample cross sections so that temperatures are kept within limits in operation and under short circuits. Temperature rises on all equipment shall be kept within limits set in IEC standards provided nothing else is specified. For all current carrying parts the permissible short circuit duration shall be at least 3 second. All electrical connections shall be secured by bolts or set screws of ample size, fitted with locknuts or lock washers of approved types. The equipment shall as far as possible be factory mounted with internal cables and internal equipment installed before shipment. Plug-in components can be shipped separately.

2.2.1.5 Equipment for use in live panels shall not be flammable and shall be self-extinguishable and resistant to flame propagation

2.2.1.6 Equipment for use outdoors or in wet or damp rooms shall be constructed so that water runs off. It shall also have devices draining any inside condensation that may form. Axial bearings on such equipment must be equipped with durable sealing preventing water to ingress.

2.2.1.7 Cast iron shall not be used for chambers of oil-filled apparatus or for any part of the equipment that is in tension or subject to impact stresses. Exception is made where it can be shown that service experience has been satisfactory with the grade of cast iron and the duty proposed.

2.2.1.8 Materials shall be new; the best quality of their respective kinds and such as is usual and suitable for work of like character. All materials shall comply with the latest issues of the specified standard unless otherwise specified or permitted by the Employer.

2.2.1.9 Iron and Steel are generally to be painted or galvanized as appropriate. Indoor parts may alternatively have chromium or copper-nickel plates or other approved protective finish.

2.2.1.10 Workmanship shall be of the highest class throughout to ensure reliable and vibrations free operations. The design, dimensions and materials of all parts shall be such that the stresses to which they may be subjected shall not cause distortion, undue wear, or damage under the most severe conditions encountered in service.

2.2.1.11 All parts shall conform to the dimensions shown and shall be built in accordance with approved drawings. All joints, datum surfaces and meeting components shall be machined, and all castings shall be spot faced for nuts. All machined finished shall be shown on the drawings. All screw, bolts, studs and nuts and threads for pipe shall conform to the latest standards of the International Organization for Standardization covering these components and shall all conform to the standards for metric sizes. All materials and works that have cracks, flaws or other defects or inferior workmanship will be rejected by the Employer.

2.2.1.12 Casting shall be true to pattern, of workmanlike finish and of uniform quality and condition, free from blowholes, porosity, hard spots, shrinkage defects, cracks or other injurious defects, shall be satisfactorily cleaned for their intended purpose.

2.2.2 Electrical Equipment Materials

2.2.2.1 All materials supplied under this Contract shall be new and of the best quality and of the class most suitable for working under the conditions specified. They shall withstand the variations of temperature and atmospheric conditions arising under working conditions (including start and stop) without distortion, deterioration, or undue stresses in any parts and without affecting the suitability of the various parts of the Works for which they were designed. The equipment shall be designed for a lifetime of 25 years.

2.2.2.2 No welding, filling, or plugging of defective parts shall be permitted.

2.2.2.3 Materials that are susceptible to mould growth under tropical conditions shall be treated to exclude moisture and prevent growth of mould after all machining has been carried out.

2.2.2.4 Cables and bus bars shall be of the highest quality copper. Aluminium conductors shall not be allowed unless specified in particular specifications for a particular component only

2.2.2.5 Small iron and steel parts (other than rustles steel) of all instruments and electrical equipment, the cores of electromagnets and the metal parts of relays and mechanisms shall be treated in an appropriate manner to prevent rusting.

2.2.2.6 Copper and aluminium used as electrical conductors shall be of the electrolytic type and comply with the respective DIN or ASTM Standards.

2.2.3 Bolts, Studs, Nuts, Screws, Washers, etc.

2.2.3.1 All bolts, studs, nuts, etc., shall have a standard metric threading and conform to the relevant standards as regards shape and tolerance. They shall be of Strength Class 8.8 and marked accordingly.

2.2.3.2 All bolts, studs, nuts, washers, screws, etc., used outdoor or in wet or moist environment shall be made of stainless steel.

2.2.3.3 All bolts and nuts shall be hexagonal, either normally or of the round head socket type and secured in an approved manner against becoming loose during operation. The Contractor shall supply the net quantities plus 5% of all permanent bolts, screws and other similar items and materials required for installation of the works at the site. Any such rivets, bolts, screws, etc. which are surplus after the installation of the equipment has been completed shall become spare parts and shall be wrapped, marked and handed over to the Employer.

2.2.3.4 Taper pins shall have threaded stems with nuts where dismantling of the pins is likely to be required.

2.2.3.5 Bolts shall not protrude more than 10 mm beyond the nut but not less than three full threads.

2.2.4 Surface Treatment and Painting of Panels, Support Structures & Electrical equipment

2.2.4.1 Panels, boards, cubicles and cabinets. for indoor use in dry rooms shall have interior surfaces painted with at least one priming and one finishing coat of anti-corrosion paint. Exterior surfaces shall be adequately treated to be substantially corrosion resistant, with one priming coat, and two finishing coats.

2.2.4.2 Outdoor installations and indoor installations in wet and damp rooms shall at least have one priming coat and two layers of paint on zinc powder basis applied after perfect cleaning.

2.2.4.3 Structural supports outdoor and in wet or moist rooms and parts that cannot be readily painted, shall be hot-dip galvanised. All galvanising shall be in accordance with BS 729 or other internationally approved standards. Steel below ground shall in addition to galvanising be protected with Bitumen or a substance of similar quality.

2.2.4.4 The humid and tropical conditions shall be taken into account on selection of the paints and painting procedure.

2.2.4.5 All External surfaces panels, cubicles, cabinets, structural supports etc. shall be painted using RAL7035 colour unless specified otherwise in particular specifications

2.2.5 Insulating Liquids

2.2.5.1 All electrical equipment requiring insulating oil or other insulating liquids shall be furnished with the first filling including flushing, if required. An excess of 10% of the net amount of oil or liquid required for each component shall also be furnished by the Contractor as spare.

2.2.5.2 The Contractor shall endeavour to employ, as far as practicable, one type and make of insulating oil only for all the electrical equipment.

2.2.6 Sulphur hexafluoride gas (SF6)

2.2.6.1 The SF6 gas shall comply with the requirements of IEC 60376. In addition to the quantity of gas required to fill the equipment supplied, 20% shall be supplied as spare.

2.2.6.2 The high-pressure cylinders for shipment and storage of the SF6 gas shall comply with the applicable national regulations. All the necessary pipes, couplings, flexible tubes and valves for coupling to the switchgear for filling or evacuating all the gases to be used, with all necessary instructions for the storage of this equipment, shall be provided.

2.2.7 Nameplates and signs

2.2.7.1 All nameplates and signs shall be made of non-corrosive weatherproof material such as traffolyte, aluminium or stainless steel.

2.2.7.2 Marking shall be in corrosion resistant material with engraved and coloured lettering. All equipment shall be marked in accordance with standards and local practice. The Contractor must mark all components in a clear and unambiguous way so that it can be related to the documentation.

2.2.7.3 Letters shall be white and engraved on black background. For aluminium and steel signs black letters on metallic background shall be used. For warning signs, red background shall be used.

2.2.7.4 All panels, cubicles, switchboards, switchgear compartments, outdoor equipment and structures and all devices & equipment mounted in the panels shall be labelled with name plates. All operating mechanisms as pushbuttons, switches and handles must be marked in a precise way and necessary warning signs must be supplied.

2.2.8 Equipment Working Stress and Reliability

2.2.8.1 The design, dimensions and materials of all parts shall be such that they will not suffer damage under the most adverse conditions nor result in deflections and vibrations, which might adversely affect the operation of the equipment.

2.2.8.2 Mechanisms shall be constructed to avoid sticking due to rust or corrosion. The equipment and apparatus shall be designed and manufactured in the best and most substantial and workmanlike manner with materials best suited to their respective purpose and generally in accordance with up-to-date recognized standards of good practice.

2.2.8.3 The equipment shall be designed to cope with 0.20g seismic acceleration on their centres of gravity.

2.2.8.4 All equipment shall be designed to minimize the risk of fire and consequential damage, to prevent ingress of vermin and dust and accidental contact with electrically energized or moving parts.

2.2.8.5 Panels and switch boards shall be capable of continuous operation with minimum attention and maintenance in the exceptionally severe conditions likely to be obtained in a tropical climate

2.2.9 Degree of Protection

2.2.9.1 Enclosures for electrical equipment shall offer the following degree of protection at minimum (ref. IEC 60034, IEC 60059, IEC 60529 and IEC 60947) where it's not stated in the particular specifications:

2.2.9.1.1 Motors/Motor Terminal boxes: IP 54/IP 65

2.2.9.1.2 Dry Transformers: IP 2x

2.2.9.1.3 Limit switches: IP 65

2.2.9.1.4 Indoor switches: IP 5x

2.2.9.1.5 Outdoor switches: IP 65

2.2.9.1.6 Low voltage switchgear and control cabinets:

(a) Indoor	IP 3x
(b) Outdoor	IP 55
(c) Junction boxes	IP 65

2.2.9.1.7 Light fittings

(a) Outdoor and wet areas	IP 44
(b) Indoor	IP 2x

2.2.9.2 Printed circuit boards SHALL NOT be mounted on the panels directly. All printed circuit boards shall be contained in enclosures with an ingress protection of at least IP30 with terminal blocks and ports on the enclosures for interface.

2.2.10 Earthing

2.2.10.1 Contractor shall take the necessary measures and furnish the required material for the safe Earthing of:

2.2.10.1.1 All steel structures, metal parts and overhead ground wires.

2.2.10.1.2 All metal parts, even if these do not constitute a conducting part of an electric system of the plants, such as machinery, operating desks, piping, sewers, rails, metal tanks, lighting, fixtures, cable racks, etc.

2.2.11 Locking Devices and Padlocks

2.2.11.1 All panels, cubicles, switchboards, switchgear compartments and Facilities for applying safety isolation i.e., circuit breaker operating mechanisms, disconnectors & switches operating handles, control switches, bus bar shutters etc. shall be provided with locks. Locks with at least three keys will be provided. Padlocks will only be used where other locks are not appropriate

2.2.11.2 Three keys with labelled traffolyte holder shall be provided for each lock, key operated devices and padlocks.

2.3 GENERAL MECHANICAL REQUIREMENTS

2.3.1 Materials

2.3.1.1 Quality

2.3.1.1.1 All materials incorporated in the equipment shall be of first-class commercial quality, as customarily used for this type of equipment, having regard to strength, durability, best engineering practice and the particular service to which the equipment will be subjected, free from defects and imperfections, of recent manufacture, new and unused, and where indicated, of the grades and classifications designated herein. Materials not specifically described herein shall be the most suitable for the purpose and shall comply with the latest specifications of the British Standards Institution (BS) or an approved relevant international standard.

2.3.1.1.2 If the Contractor desires for any reason to deviate from or use materials not covered by existing specifications of the British Standards Institution, he shall state the exact nature of the deviation from existing BS specification or exception for which no BS specification exists and shall submit for the approval of the

Engineer complete descriptions and details of the materials which he proposes to use. All materials, supplies, and articles not manufactured by the Contractor shall be the products of recognised reputable manufacturers and, so far as the provisions of this Specification are covered, shall be considered equally to have been manufactured by the Contractor.

2.3.1.2 Applicable Standards

Materials for equipment furnished shall conform to the latest issue of the following standards.

2.3.1.2.1 Steel Castings: shall conform to the requirements of BS EN 10293: 2005 "Steel Castings for General Engineering Uses" and the following shall apply:

(a) Identification of casting with origin of cast shall be preserved.

(b) No castings shall be repaired or welded without written sanction from the Engineer.

2.3.1.2.2 Iron Castings: shall conform to the requirements of BS EN 1561: 1997 "Founding. Grey Cast Irons". A signed certificate stating that the castings comply in all respects with the appropriate provisions of this Specification and the results of all the specified tests shall be provided. The full nature and properties of any special cast irons proposed by the Contractor shall be submitted to the Engineer for approval.

2.3.1.2.3 Steel Forgings: Steel forgings shall have physical properties at least equal to those required by BS EN 10250-2: 2000 "Open steel die forgings for general engineering purposes. Non-alloy quality and special steels". The provisions of BS EN 10250-2: 2000 shall apply in full and the Contractor shall inform the Engineer of any forging to be carried out after heat treatment.

2.3.1.2.4 The full nature and properties of any special alloy steels proposed by the Contractor shall be submitted to the Engineer for approval.

2.3.1.2.5 Structural Steelwork: Structural Steelwork shall conform to the latest BS requirements of BS EN 10029, BS 7668 and BS EN 10113 and BS EN 10210-1.

2.3.1.2.6 Steel Plates: Important stress carrying parts shall conform to the requirements of BS EN 10028 and BS EN 10029.

2.3.1.2.7 Plate used for general structural purposes shall conform to the requirements of BS EN 10029, BS 7668, BS EN10113 and BS EN 10210-1, provided that the Contractor shall submit the proposed method of Steel Manufacture for the approval of the Engineer.

2.3.1.2.8 Corrosion Resisting Steel Plates: shall conform to the latest requirements of BS EN

10028 Parts 1 to 3 and BS EN 10028 and BS EN 10029, as appropriate.

2.3.1.2.9 Corrosion Resisting Steel: bars, billets or forgings for bolts, nuts, pins, etc., shall conform to the latest requirements of BS EN 10277 Parts 1 to 5 and BS EN 10278. Specific requirement of the material shall conform to "Chromium Rust Resisting Steels - 12 to 14 per cent Chromium". Grade shall be submitted by the Contractor, for approval of the Engineer.

2.3.1.2.10 Chrome Nickel Steel: bars, billets or forgings for bolts, nuts, pins, etc., shall conform to BS EN 10277 Parts 1 to 5 and BS EN 10278. Specific requirements of the material shall conform to "Martensitic Chromium - Nickel Rust Resisting Steel".

2.3.1.2.11 Chrome-Molybdenum Steels: with a minimum Brinell Hardness Number of 300 shall conform to BS EN 10277 Parts 1 to 5 and BS EN 10278. Grade shall be submitted by Contractor, for approval of the Engineer.

2.3.1.2.12 Chromium Steel: with a minimum Brinell Hardness Number of 250 shall conform to BS EN 10277 Parts 1 to 5 and BS EN 10278. Grade EN18. "One per cent Chromium Steel".

2.3.1.2.13 Chromium Plating of Pins: shall be generally in accordance with BS EN 1254.

2.3.1.2.14 Where the chromium plated pins or axles bear upon special bearing materials the Contractor shall comply with the bearing manufacturer's instructions for the surface finish and machining tolerances.

2.3.1.2.15 Self-lubricating bearings and washers: shall be of PTFE, tenmate or equivalent. Manufacturer and specification shall be to the approval of the employer Engineer.

2.3.1.2.16 Corrosion Resistant Steel for Castings: shall conform to the latest requirements of BS EN 10293 and shall be suitable for welding without subsequent heat treatment.

2.3.1.2.17 Bronze Castings: shall conform to BS EN 1982 provided that all rubbing bearings whether ferrous to non-ferrous, or nonferrous to non-ferrous, are mutually compatible both with regard to freedom from metallic pickup and electrolytic action, and only virgin metals are used. The various copper alloys proposed by the Contractor shall be submitted for the approval of the employer Engineer.

2.3.1.2.18 Brass and Bronze Bars and Rods: shall conform respectively to BS EN 12163 and BS EN 12167.

2.3.1.2.19 Copper, Brass and Bronze Sheet Plate and Strip: shall conform respectively to BS EN 172, BS EN 1652, BS EN 1653, and BS EN 1654.

2.3.1.2.20 White Metal Bearing Alloys: shall conform generally to BS 3332:1987 "White Metal Bearing Alloy Ingots", but proprietary alloys may be used provided always that they are entirely suitable for the use envisaged; that they are entirely

compatible for firm bonding to the backing material; that full technical details and information are submitted by the Contractor for approval of the Engineer and that only virgin metals are used.

2.3.1.2.21 Steel Pipework: shall conform to the requirements of BS EN 13480 Parts 1 to 5. All steel piping shall be seamless and manufactured by the solid pierced and drawn process.

2.3.1.2.22 Copper Pipework: shall be to the requirements of BS 1306:1975, "Copper and Copper Alloy Pressure Piping Systems".

2.3.1.2.23 Galvanising: of steelwork for structures shall conform to BS 4921:1988 "Sherardized Coatings on Iron and Steel Articles".

2.3.2 Design Stresses

2.3.2.1 General

Liberal Factors of Safety shall be used throughout the design, and especially in the design of all parts subject to alternating stresses, repetitive stresses or shock. Upon request from the Engineer, the Contractor shall furnish complete information regarding the maximum unit stresses and loading and condition criteria used in the design. Design calculation sheets shall be made available to the Engineer, upon request.

2.3.2.2 Stresses and Factor of Safety

The stresses and factor of safety used for Normal operating conditions shall be as follows: -

2.3.2.2.1 Structural steel, bolts, weld steel stresses shall not exceed the lesser of those given in BS 5400, "Steel, Concrete and Composite Bridges" or BS 449, "The Use of Structural Steel in Building".

2.3.2.2.2 Self-lubricating bronze bushings bearing stress not to exceed 21,000 KN/m2.

2.3.2.2.3 Wire ropes, shafts, gearing etc. The minimum factor of safety shall be: -

(a) Wire ropes -6
(b) Roller lifting chains- 5.
(c) Shafts subject to combined bending and twisting- 5
(d) Steel gears and pinions- 6
(e) Cast iron gears, pinions, and other components - 8.
(f) Other items 5

2.3.2.3 Maximum Unit Stresses under Normal Operating Conditions

Principal carbon and low alloy steel materials shall conform to the requirements of BS EN

10028 Part 1 and Part 2. The maximum allowable design stresses shall not exceed those laid down in Section Two, sub-section B of BS 5500:1997 "Unfired Fusion Welded Pressure Vessels". For other materials specified in these Documents, the maximum unit stresses shall not exceed the values given in the following table: -

Material	In Tension	In Compression	In Shear
Cast Irons	10% U.S.	68.95 NN/m^2	20.68 MN/m^2
Cast Steels	20% U.S. or 35% YS, whichever least	20% U.S. or 35% YS, whichever least.	25% YS.
Steel Plates	25% U.S. or 45% YS, whichever least	25% U.S. or 45% YS, whichever least	35% YS.
Other Materials	20% U.S. or 35% YS, whichever least.	20% U.S. or 35% YS, whichever least.	25% YS.

Key: **MN/m2**- Mega Newtons per square metre; **YS** - yield strength; **U.S.**- min ultimate tensile strength

2.3.3 Tests of Materials

2.3.3.1 General

All materials, parts and assemblies thereof comprising the work to be executed under these Specifications shall be tested unless otherwise directed, according to the relevant British Standard Specification for the materials concerned as described elsewhere in this Specification. For materials where no British Standard or ISO standard Specification exists, tests are to be made according to the best modern commercial methods and to the approval of the Engineer having regard to the particular type and application of the material concerned. The Contractor shall prepare specimens and perform tests and analyses to demonstrate conformance of the various materials with the applicable specifications. Should the Contractor propose to use stock materials not manufactured specifically for the equipment covered by these Specifications, he shall submit satisfactory evidence to the Engineer that such material conforms to the requirements stated herein, in which case tests of material may be partially or completely waived. Certified mill test reports of plates will be acceptable.

2.3.3.2 Additional Tests

Tests in addition to BS tests are required as follows: -

2.3.3.2.1 Copper Alloy Castings: for shaft and pin bushes, wear and bearing sleeves are to be proved sound by pressure testing after rough machining. No sealing process

will be permitted.

2.3.3.2.2 White Metal Bearing Alloys: the firmness of bonding of white metal bearing alloys to the backing material shall be completely proved by ultrasonic testing or other approved method after final machining of the bearing surfaces.

2.3.3.3 Test Reports and Acceptance

Certified copies of test reports shall be furnished in triplicate to the Engineer as soon as possible after the tests are made. The result of these tests shall be in such form as to provide means of determining compliance with the applicable specifications for the material tested. When requested, all tests or trials shall be made in the presence of a duly authorised inspector representing the Engineer. The Contractor shall keep the Engineer informed in advance of the time of starting and the progress of the work in its various stages so that arrangements can be made for inspection. No materials shall be shipped until all tests, analyses and shop inspections have been completed and certified copies of test reports have been accepted. Acceptance of materials, parts and assemblies, or the waiving of the inspection thereof by the Engineer, shall in no way relieve the Contractor of the responsibility for furnishing equipment conforming to the requirements of these Specifications.

2.3.4 Manufacturing

2.3.4.1 Manufacturers and Samples

The Contractor shall furnish to the Engineer for his approval the names of the manufacturers of all machinery and equipment which he contemplates incorporating in the work, together with the performance, capacities, and other significant information pertaining to the equipment. Samples of materials shall be submitted for approval when so directed. Equipment, materials, and articles installed or used without such approval shall be at the risk of subsequent rejection by the Engineer.

2.3.4.2 Workmanship

Workmanship shall be of the highest calibre, and in accordance with the best modern practice for the manufacture of high-grade machinery, notwithstanding any omissions from these Specifications or Drawings. All work shall be performed by workmen skilled in their various trades. The machining of renewable or interchangeable parts shall be accurate and to specified dimensional tolerances so that replacements made according to

the drawings may be readily installed with minimum of hand fitting. The Contractor shall provide and maintain in storage for at least 20 years, at his own expense, sufficient patterns, templates, jigs, gauges, drawings, or other necessary records to enable him to make and repair replacement parts. Prior to disposal of any of the above patterns, templates, jigs etc., the Employer shall be given the option to take over the item in question. All special gauges and templates necessary for field erection shall become the property of the Employer and shall be handed over in good and accurate condition. Patterns for castings shall remain the property of the Contractor.

2.3.4.3 Connections

As much of the work of fabrication and assembly, as is reasonably practicable, shall be completed in the Manufacturer's workshops. Connections shall be made by means of rivets, bolts or welds. In connections containing more than one type of fastening only rivets and fitted bolts may be considered as acting together to share the load. In all other composite connections sufficient of the type of fastening shall be provided to carry the entire load for which the connection is designed.

2.3.4.4 Tolerances

2.3.4.4.1 All tolerances and allowances shall be subject to the Engineer's approval and shall conform to BS 4500:1970 "ISO Limits and Fits".

2.3.4.4.2 Finished contact and bearing surfaces shall be true and exact to secure full contact. Journal surfaces shall be polished and all surfaces shall be finished with sufficient smoothness and accuracy to ensure proper operation when assembled. Parts entering any machine shall be carefully and accurately machined. All drilled holes for bolts shall be accurately located and drilled from templates.

2.3.4.4.3 All tolerances intended to be used for the finishes of machined surfaces shall be selected with due consideration being given to the special nature and function of the parts and to the corresponding accuracy required to ensure proper operation.

2.3.4.5 Finished Surfaces

Surface finishes shall be indicated on the shop drawings and shall be assessed as indicated in BS 1134: Parts 1 and 2 "Centre-line-average-height method for the assessment of Surface Texture".

2.3.4.6 Unfinished Surfaces

So far as practicable all work shall be laid out in the manufacturer's workshops to secure proper matching of adjoining unfinished surfaces which shall be true to the lines and dimensions shown on the drawings and shall be chipped or ground free of all projections and rough spots. When there is a large discrepancy between adjoining unfinished surfaces, they shall be chipped and ground smooth or machined to ensure proper alignment. Depressions or holes not affecting the strength or usefulness of the parts may be filled in an approved manner.

2.3.4.7 Screw Threads

2.3.4.7.1 All threads for bolts, nuts, screws, and pipes shall be generally in accordance with British Standard Handbook No.18 ISO Metric Screw Threads (BS 3643) and Pipe Threads (BS 21:1985). The precise standard of screw thread adopted shall be mutually agreed between the Contractor and the Engineer at the commencement of the Contract and must thereafter remain uniform.

2.3.4.7.2 Exceptionally large threads for specific purposes may, with the approval of the Engineer, be of special form. Smaller nuts, bolts and screws shall be turned all over from bright bar stock; larger nuts and bolts shall be turned from forgings. Threads of smaller bolts and nuts may be die cut; threads of larger bolts shall be screw cut. Impact or roll forming of threads will not be permitted but, subject to the approval of the Engineer, large threads may be finished rolled at the root.

2.3.4.8 Special Workshop Processes

The Contractor shall submit for the approval of the Engineer details of all special processes used in the manufacture of the equipment covered by these specifications. Such processes include, but are not limited to, cold metal deformation processes, thread root rolling, surface shot peening or rolling, metal spraying, electro-deposition, and other processes. The Contractor shall inform the Engineer of any proposals to mark off and/or machine any components using the co-ordinate system and machining of components by profile machines.

2.3.4.9 Drawings Symbol Coding

2.3.4.9.1 All drawings submitted to the Engineer for approval shall contain details of any heat- treatment during final manufacture; dimensional tolerances; clearance and interference fits; surface finish and special workshop processes.

2.3.4.9.2 Fluid power schematic drawings shall strictly use the standard ISO 1219 Fluid power systems and components —Graphical symbols and circuit diagrams.

2.3.4.9.3 Mechanical drawings shall adhere to ISO ICS 01.100.20 standards for Mechanical engineering drawings and all other applicable ISO standards such as ISO 81714, ISO 129, ISO 7083ETC.

2.3.4.9.4 Functional reference designation shall be in accordance with ISO/IEC 81346

2.3.5 Welding

2.3.5.1 General

Welding of structural steelwork shall be by an electric arc process. The procedure to be followed, plant and equipment to be used and the testing and inspection to be applied, shall all be to the satisfaction of the Engineer and shall conform generally to the relevant British Standard Specifications.

2.3.5.2 Parent Metal

The grade of steel shall be to the approval of the Engineer for each particular work to be constructed and shall conform to clause 3.3.1.2

2.3.5.3 Welding Electrodes

2.3.5.3.1 Electrodes for manual metal-arc welding shall be in accordance with BS EN 499: 1995 except that hydrogen-controlled electrodes only shall be used for manual metal-arc welding of mild steel, Grades 43A and 43B, when the steel thickness is 40 mm or more.

2.3.5.3.2 Hydrogen controlled electrodes shall be used for manual metal-arc welding of steels to grades 43C, D and E, and grades 50A, B and D.

2.3.5.3.3 The electrodes to be used for metal-arc welding of steels to grades 55C and E shall be subject to agreement.

2.3.5.4 Terms and Symbols

On all drawings, welding procedure sheets, etc., terms and symbols relating to the welding and thermal cutting of metal shall be in accordance with BS 499.

2.3.5.5 Shop and Site Welding

2.3.5.5.1 Shop welding shall be carried out in workshops under the specified conditions of temperature, materials, welding procedure, workmanship, welding operations,

supervision, and inspection. Machine welding will be allowed where approved machines are in use correctly controlled by qualified operators.

2.3.5.5.2 Careful attention must be given to the preparation of the surfaces of the parent metal prior to site welding and the welding shall be carried out in accordance with this Specification. Details of the proposed surface treatment shall be submitted with details of the connections to be made by site welding.

2.3.5.5.3 Site welding shall not be carried out when the plate temperature is 0˚C or below, welding shall only be allowed when special precautions approved by the Engineer are taken to prevent too rapid a rate of cooling and loss of heat.

2.3.5.5.4 Pre-heating shall comply with BS 1856, BS 2642 and the recommendations given in the Appendices to those Standards shall be adopted where relevant to the welding conditions and procedures.

2.3.5.5.5 The welding plant and equipment employed on the Works shall be of sufficient capacity to carry out the procedure laid down and suitable for the types of electrodes in use. The Contractor shall provide all necessary staging and screens for the welders; the supervisors and the inspectors shall maintain all plant and equipment in an efficient condition. Suitable tong test ammeters shall be provided by the Contractor for measuring the current except only when efficient means of so doing are incorporated as part of the welding plant.

2.3.5.6 Welding Current

The welding current shall be within the range recommended by the manufacturer of the particular electrode being used and shall be towards the upper limit of the range rather than the lower.

2.3.5.7 Tack Welds

Where a tack weld is to be incorporated in a welded joint, the welding procedure used shall correspond in all respects to that specified for the joint as a whole and the shape of the tack shall be suitable for incorporation in the finished weld.

2.3.5.8 Weld Joints Preparation

2.3.5.8.1 The forms of weld joint preparation shall be in accordance with the relevant British standard unless modified by the standard details accompanying this Specification.

2.3.5.8.2 Fusion faces, angle of bevel, root radius, etc., shall be properly prepared to give the approved weld forms. The fusion faces shall be carefully aligned, and the

correct gap and alignment maintained during the welding operation. In the preparation of the fusion faces shearing shall be limited to metal thicknesses not greater than 8 mm. All fusion faces shall be prepared by machining and 3 mm of material shall be allowed for this purpose, or, where approved, by machine flame cutting. Faces shall be kept clean and protected.

2.3.5.9 Peening

Strict instructions shall be issued to all welders that no peening shall be done.

2.3.5.10 Preheating and Temperature Conditions of Welding

2.3.5.10.1 Welding shall not in any circumstances be carried out when the ambient or plate temperature is 0°C or below. Where the combined plate or section thickness is equal to 50 mm or over and the ambient temperature is under 10°C, welding shall only be allowed where special precautions are taken to prevent a too rapid rate of cooling and loss of heat.

2.3.5.10.2 Preheating shall comply with BS 1856, BS 2642 and the recommendations given in the Appendices to those Standards shall be adopted where relevant to the welding conditions and procedures.

2.3.5.11 Intermittent Welds

Intermittent welds shall be used only where indicated.

2.3.5.12 Post-Welding Distortion and Shrinkage

The Contractor shall take every reasonable precaution to avoid post-welding distortion and shrinkage occurring in welded assemblies, and shall inform the Engineer immediately during fabrication in the event of such distortion or shrinkage proving to be uncontrollable. Special attention shall be paid to prevent distortion of the box construction of the gate structure and the embedded metalwork.

2.3.5.13 Butt Welded Joints

2.3.5.13.1 All main butt welds shall have complete penetration and, except where it is impracticable, shall be welded from both sides, the back of the first run being suitably gouged out to clean metal before the backing run is deposited.

2.3.5.13.2 The ends of the welds shall have full throat thickness. This shall be obtained on all main welds by use of extension pieces adequately secured on either side of the main plates. Additional metal remaining after the removal of the extension pieces

shall be removed and the ends and surfaces of the welds shall be smoothly finished.

2.3.5.14 Assembly of Joints

In the fabrication of plate girders and built-up members generally, all joints in each component part shall be made before such component part is welded to other parts of the members.

2.3.5.15 Welding Position

No welding operator shall be permitted to undertake work in welding positions other than those for which he has been tested.

2.3.5.16 Welding Design and Procedure

2.3.5.16.1 The design of welds and the allowable stresses shall be in accordance with BS 449 Part 2 and relevant British Standards.

2.3.5.16.2 Details, of the proposed welding procedure accompanied by diagrams showing the build-up of all main welds, together with the details of the manufacture, classification, code and size of electrodes to be used, shall be submitted to the Engineer for his written approval.

2.3.5.16.3 Welding procedure shall be such that distortion is reduced to a minimum, and local distortion is rendered negligible in the final structure.

2.3.5.16.4 Butt welds in flange plates and/or web plates shall be completed before the flange and web are welded together.

2.3.5.16.5 Approval of the welding schedule and procedure shall not relieve the Contractor of his responsibility for correct welding and for the minimising of distortion in the finished structure.

2.3.5.16.6 All welds shall be finished full and made with the correct number of runs, the welds being kept free from slag and other inclusions, all adhering slag being carefully removed from the exposed faces immediately after each run is completed, and before any additional run is started.

2.3.5.16.7 For all welds, except those on tubular work, the minimum cross section, area of run, and maximum run length per electrode shall comply with the requirements of the relevant Codes of Practice.

2.3.5.17 Qualifications of Welding Operators

The Contractor shall be responsible for ensuring that each and every welding operator employed on the fabrication and/or site work is an efficient and dependable welder.

2.3.5.18 Testing of Welding Operators

2.3.5.18.1 Operators, other than those engaged on tube welding, shall be tested as detailed in BS 4872 Part 1 and appropriate to the corresponding weld position and using specimens of the parent metal to be employed.

2.3.5.18.2 Only welding operators who satisfy the appropriate tests shall be employed on welding. Should an operator fail in a first test, two further tests shall be undertaken immediately and the operator to qualify must satisfactorily pass both these tests.

2.3.5.18.3 The provisions of BS 449, Part 2, Clause 79, shall apply with regard to types of work for which welders are qualified.

2.3.5.18.4 The names of all operators qualified as aforesaid, and particulars of the tests passed by each shall be recorded by the Contractor and agreed by the Engineer and shall subsequently be made available as and when required. The Engineer shall have the right to require the immediate suspension by the Contractor of any operator who's standard of workmanship is unsatisfactory, but the Contractor may submit the operator for re-test if he has received further instruction.

2.3.5.19 Re-Testing of Operators

2.3.5.19.1 Routine re-testing of all operators shall be carried out every 6 months.

2.3.5.19.2 The Engineer reserves the right to have any welding operator re-tested at any time during the Contract.

2.3.5.20 Test Plates

The Engineer will require test plates on all main butt welds in flange members. Test plates shall be incorporated at the side and continuous with the main weld. These test plates shall be cut from extensions of the main plates and fixed as extension pieces at the butt joint so that the metal lies in the same direction as that of the main plate. Each test plate shall be clearly marked to be identified with the flat and the end from which it has been cut. (Test plates shall be prepared in accordance with BS 709 Part 3, transverse bend).

2.3.5.21 Additional Tests by the Contractor

The following additional tests shall be carried out by the Contractor when directed by the Engineer.

2.3.5.21.1 Fillet weld inspection tests in accordance with BS 709 Chapter 6 and tension tests in accordance with BS 709 Chapter 2.

2.3.5.21.2 Test plates and tests on butt welds other than main butt welds in flange members as previously described.

2.3.5.21.3 Radiographic or other non-destructive examinations on butt or fillet welded joints and/or the test specimens. Preparation of etched sections of welds may be required for examination.

2.3.5.21.4 Charpy V-notch tests in accordance with BS 709 Chapter 4.

2.3.5.22 Independent Non-Destructive and Special Testing

2.3.5.22.1 The Engineer may also require independent radiographic or other non-destructive examinations of butt and fillet welds to be undertaken. These examinations will be carried out by or under the supervision of the Engineer.

2.3.5.22.2 The frequency of independent examinations will depend on the results obtained. Preparation of etched sections of welds may be required for examination.

2.3.5.22.3 Tensile and bending tests may also be carried out by the Engineer in accordance with BS 709.

2.3.5.23 Non-Destructive Examination of Welds

The Contractor shall satisfy themself as to the quality of all butt welds and shall carry out radiographic or ultrasonic tests on butt welded joints and/or on the test specimen referred to in clause 3.3.5.20. The extent of these tests shall not be less than 10% of the total number of butt welds stressed in compression. All butt welds stressed in tension shall be tested. The non-destructive examination of welds shall be delayed after completion of the welding for a period of 12 hours minimum to avoid the risk of protracted weld cracking not being detected.

2.3.5.24 Sub-Standard Workmanship and/or Incorrect Welding Procedures

Should the tests on the minimum percentage of butt welds stressed in compression and described in clause 3.3.5.23 or any of the tests described in clause 3.3.5.21 show, in the opinion of the Engineer, unacceptable or substandard welds resulting from bad

workmanship or incorrect welding procedures, then the extent of these tests shall be increased to a percentage decided by the Engineer to ensure acceptable standards of workmanship and/or procedure, the additional cost to be borne by the Contractor.

2.3.5.25 Record of Tests and Examination on Welds

The Contractor shall record evidence and results of all destructive or non-destructive tests and examinations and shall submit radiographs and records for examination by the Engineer or his authorised representative.

2.3.5.26 Works Supervision by Contractor

2.3.5.26.1 The Contractor shall be responsible for ensuring that all materials, welding, fabrication, and workmanship comply with this Specification and he shall provide the necessary supervision and testing to fulfil this requirement.

2.3.5.26.2 They shall, when more than one supervisor is employed, provide adequate means of identification either by means of an identification stamp or other approved means, to enable the supervisor of the work to be identified.

2.3.5.27 Correction of Weld Faults

The correction of weld faults shall be carried out under the supervision and to the entire satisfaction of the Engineer.

2.3.5.28 Acceptance of Welded Structures

The acceptance of the welded work shall depend upon correct dimensions and alignment and absence of distortion in the structure, upon satisfactory results from the examination and testing of the joints in accordance with the instructions given on the drawings, and the soundness of the welds and upon general good workmanship.

2.3.5.29 Cleaning

All welds, slag, splatter, and flux residues shall be removed from the steelwork.

2.3.6 Nuts and Bolts.

2.3.6.1 Washers shall be provided under nuts and bolt heads where required.

2.3.6.2 Each bolt and stud shall show at least one full thread beyond its nut after assembly and all studs shall be screwed home by at least one diameter.

2.3.6.3 All nuts, bolts, and other fastenings on any part of the equipment shall, where required, be securely locked by a means approved by the Engineer.

2.3.7 Lubrication

2.3.7.1 Except where self-lubricating bearings are specified all moving parts, bearings, journals, etc. shall be provided with adequate means of lubrication. Where suitable, pressure gun lubrication and the necessary guns shall be supplied by the Contractor as part of the equipment. Lubricants shall be to the approval of the Engineer and with a specification the same as used at the plant.

2.3.7.2 Adequate seals shall be provided where necessary and the works shall be designed to prevent lubricants from leaking away or splashing out during normal use.

2.3.7.3 All items of plant, oil bath lubricated, shall be provided with sighting oil level gauges positioned to allow easy access for reading and subsequent filling.

2.3.7.4 All grease nipples, and oiling points, shall be accessible without removing cover plates etc. The works shall be handed over to the Employer in running order with all moving parts properly lubricated with approved lubricants. The Contractor shall supply the first filling of lubricants plus 20% to be held in suitable containers on Site.

2.3.8 Termite Resistant Materials

2.3.8.1 Wooden cable drums, timber used for shoring trenches and other purposes and any other fibrous material used during construction shall be treated with creosote or other approved preservative to prevent action by termites. Where any material is found to be infested it shall be removed immediately and burnt.

2.3.9 Corrosion

2.3.9.1 Metals

2.3.9.1.1 Iron and steel shall in general be galvanised or painted as appropriate in accordance with the Specification. Indoor parts may be chromium or copper nickel-plated or protected by an approved anti-corrosion finish to the satisfaction of the Engineer.

2.3.9.1.2 Small iron or steel parts (other than stainless steel) of all instruments and electrical equipment, the cores of electro-magnets, the metal parts of relays and mechanisms shall be treated by an approved anti-corrosive finish to prevent rust.

2.3.9.1.3 Laminated cores or other pieces of mechanism which cannot for any reason be treated against corrosive action shall have all exposed parts thoroughly cleaned and heavily coated with enamel, lacquer or compound.

2.3.9.1.4 Where it is necessary to use two dissimilar metals in contact, (a) they shall be so selected that the potential difference between them in the electro-chemical series

is not greater than 0.5 volts (b) the potential difference shall not exceed 0.5 volts when the contact area is either immersed in water or exposed to condensation. If this is not possible, the contact surface of one or both of the metals shall be electro-plated or otherwise finished in such a manner that the potential difference is reduced to within the required limits or, alternatively the two metals shall be insulated from each other by means of an approved insulating material or by a coating or approved varnish compound to the satisfaction of the Engineer.

2.3.9.2 Screws, Nuts, Springs, Pivots, etc.

The use of iron and steel shall be avoided in instruments and electrical relays wherever possible. Steel screws, where used, shall be zinc, cadmium or chromium plated, or where plating is not possible owing to tolerance limitations, of corrosion resisting steel. All wood screws shall be of dull nickel-plated brass or other finish to be approved by the Engineer. Instrument screws (except for those forming part of a magnetic circuit) shall be of brass or bronze, springs shall be of non-rusting material e.g., phosphor bronze or nickel silver, as far as possible. Pivots and other parts for which non-ferrous material is unsuitable shall be of an approved stainless steel where possible.

2.3.9.3 Metalwork and Pipes

All metal parts and pipes such as supports, which will be submerged or come into contact with water shall be adequately protected against corrosion to the approval of the Engineer.

2.3.10 Painting and Protective Treatment

2.3.10.1 General

2.3.10.1.1 The intent of this section of the Specification is to give maximum protection to all items of plant to ensure long term safe operation and to minimise plant outage.

2.3.10.1.2 Particular attention shall be given to the underwater parts.

2.3.10.1.3 Painting shall be completed, except for cleaning and repair at site, prior to shipment. The finish paint of surfaces which are fully accessible and in an environment fully suitable for completion of painting may be completed at site before the end of the maintenance period provided that no delays to or interference with plant usage can arise. Such surfaces shall however be fully protected against deterioration that could occur in transit and during storage at site.

2.3.10.2 Standards & Workmanship

2.3.10.2.1 All steelwork is to be protected as specified below and to the requirements of the relevant British Standard, or equivalent, including the following where relevant. BS 3981, 282, 389, 388, 729, 1070, 1133, 2521-4, 2525-32, 2569, 3189, 3416, 3698, 3699, 3900, 4129, 4232 & 4592, CP 2008.

2.3.10.2.2 Full details of paints to be used are to be submitted for approval including the names of suppliers, and the Contractor is responsible for ensuring that the paints are compatible and that they are applied in accordance with the requirements of BS EN ISO 12944.

2.3.10.2.3 Wet and dry film thicknesses shall be checked in accordance with BS EN ISO 12944 to ensure that the specified dry film thicknesses are met. The specified thicknesses shall be regarded as minimum.

2.3.10.2.4 Nothing in this Specification shall limit the Engineer's power to require that faulty or otherwise obviously thin or uneven paintwork shall be recoated, repaired or replaced.

2.3.10.2.5 The maximum amount of paint treatment shall be completed in the manufacturer's works. Site work shall be limited to finishing coats and to repair of damage suffered during transport, storage, and erection, and making good at site connections, bolts and welds.

2.3.10.2.6 The painted steelwork shall be stored at works and on Site so that it is clear of the ground and laid out and stacked in an orderly manner that will ensure that no pools of water can accumulate on the surfaces. Suitable packing should be laid between layers of stacked material. Where temporary covers are used, proper ventilation shall be provided.

Special care shall be taken with steelwork stored outside, with an "interior" finish or incomplete exterior finish, to ensure that the protective system is not adversely affected by the environment or prolonged storage periods.

2.3.10.2.7 Before any steelwork is placed into store, it shall be examined for continuity and uniformity of the paint system. It shall also be inspected from time to time and maintenance painting carried out as necessary to restore the paint system to its specified condition.

2.3.10.2.8 The following provisions shall be made to reduce to a minimum, damage to the paint system during handling, transport, and erection.

(a) An adequate drying period after completion of painting shall be allowed to ensure that the paint has hardened and is resistant to damage.

(b) Special slings or lifting points or both shall be provided for handling and loading or unloading in the fabrication shops, during transit and at the Site.

(c) Methods of loading and off-loading on transit vehicles and ships, which will reduce the handling at Site to a minimum.

(d) Special supports, packing and lashings on vehicles or trucks to prevent chafing

2.3.10.2.9 In cases where site welding is to be carried out, no protective measures beyond the primer shall be carried within 100 mm of welds, until completion of the welding.

2.3.10.2.10 All contact surfaces for High Strength Friction Grip Bolts shall be treated as specified hereafter for each particular painting system.

2.3.10.2.11 Special care shall be taken after assembly to paint all edges and corners near the joints, together with the bolt heads, nuts, and washers to prevent the ingress of water.

2.3.10.2.12 The complete painting scheme, as applied to the main body of the structure, shall be given to the joints after treatment as above.

2.3.10.2.13 After erection, the steelwork shall be examined for continuity and uniformity of the paint system and where necessary it shall be cut back, cleaned, and recoated as specified.

2.3.10.2.14 The Contractor shall provide adequate supervision and inspection so as to ensure that all stages of work are carried out to the required high standard and shall comply with all the requirements laid down in BS EN ISO 12944.

2.3.10.2.15 Full facilities shall be afforded to the Engineer and his appointed inspectors to examine the work at all stages. Similar facilities shall also apply to the paint manufacturers.

2.3.10.2.16 All coatings are to be applied under covered conditions. Coatings may only be applied outside with the prior permission of the Engineer.

2.3.10.2.17 This requirement shall also apply to the surface preparation of steelwork prior to treatment.

2.3.10.2.18 All blast cleaning and coating shall be done under favourable ambient conditions which must continue throughout the drying time of the coatings.

(a) Operations at Works shall be carried out under the following conditions:

(i) Temperature of the ambient atmosphere shall lie between the ranges 7˚ to 32°C.

(ii) The ambient relative humidity shall be below 90 per cent.

(b) Operations on Site shall be carried out when the ambient conditions are favourable and are likely to continue during the drying time of the paint.

(c) Painting shall be suspended under the following conditions:

(i) When the temperature of the ambient atmosphere falls below 7°C or its relative humidity rises above 90 per cent. Painting may be carried out outside these conditions by warming the steel surface and/or by erecting some form of temporary shelter to the approval of the Engineer.

(ii) For outdoor work, during periods of inclement weather, e.g., rain, fog, or mist.

2.3.10.2.19 The Manufacturer's instructions are to be strictly adhered to.

2.3.10.3 Materials

2.3.10.3.1 Red lead primer shall be type B in accordance with BS 2523 with a dry film thickness of 0.040 mm.

2.3.10.3.2 Calcium plumbate primer shall be in accordance with BS 3698 with a minimum dry film thickness of 0.025 mm.

2.3.10.3.3 Zinc chromate primer shall have a water-resistant medium, i.e., oleoresinous or alkyd medium, pigmented with zinc chromate/red oxide, and shall have a minimum dry film thickness of 0.040 mm.

2.3.10.3.4 Etch primer shall consist of solutions of polyvinyl butyral resins in alcohol and pigmented with zinc chromate to which is added (before use as a paint) an alcoholic solution of phosphoric acid. The minimum dry film thickness shall be 0.012 mm.

2.3.10.3.5 Zinc rich primer shall consist of not less than 85% by weight of metallic zinc in an epoxide resin medium. The minimum dry film thickness shall be 0.025 mm.

2.3.10.3.6 Black bitumen paint shall be in accordance with BS 3416 and shall have a minimum dry film thickness of 0.075 mm.

2.3.10.3.7 Micaceous iron oxide paint shall be of the phenolic resin type with a minimum dry film thickness of 0.075 mm.

2.3.10.3.8 "Undercoat" paint shall be highly pigmented with a matt or eggshell sheen, oleo resinous or alkyd base paint, and shall have a minimum dry film thickness of 0.025 mm.

2.3.10.3.9 "Gloss" paint shall consist of a mixture of drying oils and alkyd resins containing finely dispersed agents, and shall have a minimum dry film thickness of 0.025 mm.

2.3.10.3.10 Galvanising shall be in accordance with the requirements of BS EN ISO 1461 with a minimum coating of 60 gm/m2.

2.3.10.3.11 Coal tar epoxy paint shall be in accordance with BS 3900. The minimum total dry film thickness for two coats shall be 0.23 mm with the thickness of each coat

being as recommended by the manufacturer.

2.3.10.4 Mechanically & Hand Cleaned Steel

2.3.10.4.1 The steel is to be thoroughly cleaned at works and all dirt, oil and loose particles removed, full use being made of power-driven tools, such as carborundum grinding discs, chipping hammers and needle guns. Excessive burnishing of the metal through prolonged application of rotary wire brushes is to be avoided. Wire brushes with steel bristles should be used as the bristles of other metals may leave deposits that cause electrolytic corrosion.

2.3.10.4.2 Surfaces shall be protected within 4 hours of having been cleaned and shall not be exposed to outside atmospheres during this period.

2.3.10.4.3 Before applying a protective finish, the surfaces shall be free from moisture, grease, dirt, weld slag and loose scale and rust.

2.3.10.4.4 In cases where site welding is required, the provisions of clause 2.3.5 shall be observed.

2.3.10.4.5 In cases where site connections are to be made using black bolts, the contact faces of the related parts shall be painted with the red lead primer only. After the site connection has been made all edges and corners near the joint together with the bolt's heads, nuts and washers shall be treated to ensure that the protection to the whole of the joint is to the standard of the adjacent members.

2.3.10.4.6 In cases where site connections are to be made using high strength Friction Grip Bolts, the contact surfaces shall be thoroughly cleaned and protected during storage and transport. Prior to erection the dry metal surface shall be inspected and if necessary re-cleaned.

2.3.10.5 Blast Cleaning

2.3.10.5.1 The steelwork is to be blast cleaned at the works in accordance with BS 7079:1989 and BS EN ISO 8503: 1995, second quality standard with an optimum profile of 0.065-0.090 mm high as specified.

2.3.10.5.2 Surfaces for preparation to Second Quality standard shall correspond with the pictorial standard SA 2 in the Swedish Standard SIS.055900 - 1967 taking due account of the initial condition of the steel as specified in the Standards.

2.3.10.5.3 After blasting, the surface is to be freed from abrasive residues by high pressure air dusting and/or vacuum cleaning. Any "rogue" peaks are to be reduced by rubbing over the surface with a mechanical grinder and the surface dusted down before painting.

2.3.10.5.4 Surfaces shall be protected within 2 hours of having been blast cleaned and shall

not be exposed to outside atmospheres during this period.

2.3.10.5.5 A prefabrication primer may be used after blast cleaning to suit a fabricator's facilities, etc. subject to the following: -

(a) The prefabrication primer is to be applied within 1½ hours of blast cleaning ensuring that the metal is in perfectly dry condition.

(b) The prefabrication primer shall be a two-pack type zinc-rich primer, containing about 90% and not less than 85% finely divided metallic zinc in epoxide resin or other approved primer. It should be suitable for continuous spray application, dry rapidly, and be touch dry within 10 minutes or less, with a dry film thickness of 0.012 mm to 0.025 mm. It should comply with BS 4129 and have the following properties.

(i) It should not interfere with fabrication by welding or other means.

(ii) It should be non-toxic and give rise to no objectionable fumes when heated during welding and cutting.

(iii) It should not affect the strength of the welds.

(iv) The primer should protect the steel effectively throughout the desired period of fabrication.

(v) The primer should form a suitable basis for the final protective paint scheme.

(vi) After fabrication, areas of bare steel, welds, etc. shall be wire brushed to remove rust and weld spatter and shall be patch primed as above. The steel is to be thoroughly cleaned to remove oil, grease and other dirt from the surface and to the satisfaction of the Engineer.

2.3.10.5.6 The steelwork shall then be treated with one coat of zinc-rich primer bound in a medium of epoxide resin to yield paint suitable in all respects for brush application with a dry paint film, 0.025mm to 0.040 mm thick, containing not less than 85% by weight of metallic zinc.

2.3.10.5.7 In cases where site welding is required, the provisions of clause 2.3.5 shall be observed.

2.3.10.5.8 In cases where site connections are to be made using black bolts, the contact surfaces of the related parts shall be painted with the prefabrication primer and the primer only.

2.3.10.5.9 After the site connection has been made all edges and corners near the joint together with the bolt heads, nuts and washers shall be treated to ensure that the protection to the whole of the joint is to the standard of the adjacent members.

2.3.10.6 Acid Dipping

Acid dipping shall be by the "Footner" pickling process or an equivalent procedure, and the steelwork shall be treated as soon as it has dried and whilst it is still warm.

2.3.10.7 Painting Systems

System No.	Surface Preparation	Paint System	Where Applied
I	Mechanically or Hand Cleaned.	Zinc Chromate Primer	Factory/shop
		Undercoat.	Factory/shop
		Gloss Coat.	Site
2	Mechanically or Hand Cleaned.	2 coats Red Lead Primer	Factory/shop
		Undercoat	Factory/shop
		Gloss Coat	Site
		Gloss Coat	Site
3	Blast Cleaned 2nd Quality.	2 Coats of Red Lead or Calcium Plum bate Primer Undercoat	Factory/shop
		Undercoat	Factory/shop
		Gloss Coat of Oil Resistant Paint	Site
4	Blast Cleaned 2nd Quality	3 Coats Red Lead Primer	Factory/shop
5	Blast Cleaned 2nd Quality	2 Coats Coal Tar Epoxy	Factory/shop
6	Blast Cleaned 2nd Quality.	1 Coat Zinc Rich Epoxy Primer	Factory/shop
		1 Coat Coal Tar Epoxy	Factory/shop
		1 Coat Coal Tar Epoxy	Factory/shop
7	Blast Cleaned 2nd Quality.	1 Coat Zinc Rich Epoxy Primer	Factory/shop
		1 Coat Coal Tar Epoxy	Factory/shop
		2 Coats Coal Tar Epoxy	Site
8	Acid Pickling	Dipped in Bitumen	Factory/shop
9	Galvanized	Etch Primer	Factory/shop
		Dipped in Bitumen	Factory/shop
10	Galvanized	Etch Primer	Factory/shop
11	Blast Cleaned 2nd Quality	2 Coats of oil resistant Enamel	Factory/shop
12	Pickle	Protective Grease	Factory/shop
		All pipes plugged at ends. Flush out	Site
13	Remove loose scale & rust	One coat cement wash	Factory/shop
14	Machined Surfaces	Protective coating	Factory/shop
		Coat with grease	Site
15	Stainless steel surfaces	Protective coating	Factory/shop
		Clean as necessary	Site
16	Sheet steel control cubicles (exterior)	Stove enamel	Factory/shop.
17	Sheet steel Control cubicles (interior)	Semi-matt white	Factory/shop

2.3.10.8 Colours, Identification

The colour schemes will be as specified or as directed by the Engineer.

2.3.11 Metal Pipes and Pipework

2.3.11.1 All pipes shall be cold drawn seamless high tensile hydraulic tube according to DIN 2391C E 355N (ST52.4 NBK).

2.3.11.2 Pipe connections shall use non-weld connection technologies (fittings, flanges etc.)

2.3.11.3 The pipes shall be electroplated.

2.3.11.4 The maximum allowable flow rate in pipes shall as per applicable ISO standard, higher velocities shall not be acceptable.

2.3.11.5 All piping, flanges, sockets, joints, seals, gaskets, etc. shall be made of materials to withstand pressure and temperature conditions involved in the operation of the equipment and provide a positive seal under all operating conditions and shall incorporate an ample factor of safety.

2.3.11.6 Provision shall be made allowing for full expansion that can take place under all conditions of operation.

2.3.11.7 Where necessary, provision shall be made for the draining and release of air in systems using valves and in addition plugged drain and air release bosses should be welded to pipes at appropriate points to facilitate hydraulic testing.

2.3.11.8 All pipework and fittings shall be of the same materials or similar unless otherwise specified or agreed by the Engineer.

2.3.11.9 All pipes shall be pressure tested at twice maximum working pressure.

2.4 GENERAL CIVIL WORKS REQUIREMENTS

2.4.1 General Requirements

2.4.1.1 This specification describes in detail the standard civil works requirements for Substations and power plants. It outlines the issues and requirements that must be considered as part of the overall design and planning process. It is a generic specification and site-specific details may be provided to supplement the advice within this document to suit the local environment and/or plant specific requirements.

2.4.1.2 The designer must comply with all current Kenyan legislation and legal requirements.

2.4.1.3 Third party considerations, designers risk assessments, developer's requirements, government agencies, etc may influence the adopted design but it is essential that the requirements of this document are embedded within the final design of the Works.

2.4.1.4 The principal function of the Civil design is to provide buildings, structures and civil infrastructure to house and support the plant equipment and ensure a safe environment for operational and maintenance staff as well as the public.

2.4.2 Design Life and Maintenance

2.4.2.1 The civil works shall be designed for a minimum life of 40 years with a minimum maintenance during this period. The designer shall consider all future maintenance requirements together with possible addition and alterations to the installed plant.

2.4.2.2 In addition to general maintenance, provision is to be made for the future removal and replacement of all items of plant. This provision shall include consideration for maintaining wayleaves and access agreements throughout the life of the Substation.

2.4.3 Standards

The British Standards (BS) and Codes of Practice (CP) specifically referred to in this Specification are listed below for convenient reference. The absence of any relevant BS or CP from the list shall not relieve the Contractor of his obligation to comply with such BS or CP as required by this Specification.

Number	Title
BS 4	Structural steel sections. Specification for hot-rolled
BS EN 197-1:2011	Specification for Portland Cement
BS EN 13043	Aggregates for bituminous mixtures and surface treatments for roads, airfields and other
BS EN 295	Vitrified clay pipes and fittings and pipe joints for drains and sewers. Performance

Number	Title
BS EN 124	Gully tops and manhole tops for vehicular and pedestrian areas. Design
BS EN 771	Specification for masonry units. Clay masonry
BS EN 197-1:2011	Cement. Composition, specifications, and
BS EN 295	Vitrified clay pipes and fittings and pipe joints for
BS 405	Specification for uncoated expanded metal carbon
BS EN 13808:2005	Bitumen road emulsions (anionic and cationic).
BS 434-2	Bitumen road emulsions. Code of practice for the
BS EN 1993-	Specification for the use of Structural Steel in
BS EN	Ductile Iron Pipes, Fittings, Accessories and Their
BS EN 752	Drain and Sewer Systems Outside Buildings (Parts
BS EN 932 Parts 1 to	Testing for General properties for aggregates.
BS EN 12620: 2002	Aggregates for concrete
BS EN 934-	Concreting Admixtures
BS EN 13279 Parts 1	Gypsum binders and gypsum plasters.
BS 1196	Specification for clayware field drain pipes and
BS EN 13139	Aggregates for mortars
BS EN 845 Parts 1, 2	Specification for ancillary components for masonry
BS EN 13101:2002	Steps for underground man entry chambers.
BS 1377	Methods of test for soils for civil engineering
BS EN 1401 – 2 & 3	Plastics piping systems for non-pressure
BS 1521	Specification for waterproof building papers.
BS EN 1610	Construction and testing of drains and sewers
BS 1722	Fences.
BS EN 771-1 to 6	Specification for masonry units.
BS 4190	Specification for ISO metric black hexagon bolts,
BS ISO 8992	Fasteners. General requirements for bolts, screws,
BS EN 10080:2005	Steel for the reinforcement of concrete. Weldable
BS 4449:2005	Steel for the reinforcement of concrete. Weldable
BS 4460	Specification for unplasticised polyvinyl chloride
BS 4483	Specification for steel fabric for the reinforcement
BS 4514	Specification for unplasticised PVC soil and
BS EN998-1 & 2	Specification for ready-mixed building mortars.
BS EN 10067	Hot-rolled structural steel sections. Bulb Flat
BS EN 10056-1	Hot-rolled structural steel sections. Equal and
BS EN 10210-2	Hot-rolled structural steel sections. Specification
BS 4987 Parts 1 and	Specification for Coated macadam for roads and
BS EN 1995	Structural use of timber.
BS 8500	Concrete. Specification for the procedures to be
BS 8500, BS EN	Methods for specifying concrete, including ready-
BS 9999:2008	Fire Precautions in the Design and Construction of
BS EN 1996	Code of practice for use of masonry
BS 5911	Precast concrete pipes, fittings and ancillary
BS 5930: 1999	Code of practice for site investigations
BS 5950	Structural use of steelwork in building.
BS 6031	Code of practice for earthworks.
BS EN 12056-	Code of practice for drainage of roofs and paved
BS EN 1991-	Loading for buildings. Code of practice for dead
BS EN 1991-1-	Loading for buildings. Code of practice for wind

Number	Title
BS EN 1991-1-	Loading for buildings. Code of practice for imposed
BS EN 1339	Precast concrete flags, kerbs, channels, edgings and
BS EN 1997-1:2004	Code of practice for foundations
BS EN 1992-3:2006	Code of practice for design of concrete structures
BS EN 14161:2011	Code of practice for pipelines. Pipelines on land:
BS EN 1992-1-	Structural use of concrete. Code of practice for
BS EN 752-1:1996,	Code of practice for building drainage.
BS EN 10210-1	Hot finished structural hollow sections of non-alloy
BS EN 12056	Gravity drainage systems inside buildings
BS ISO 1461	Hot dip galvanized coatings on fabricated iron and

2.4.4 Surveying Instruments

2.4.4.1 The Contractor shall keep on site such surveying instruments as are necessary for the complete and accurate setting out and construction of the works. These instruments shall be modern, shall be maintained in excellent condition, and shall be accurate in all respects. They shall be kept available for use by the Project Manager if so required, and their accuracy and adjustment shall be regularly checked in an approved manner.

2.4.5 Site Surveys

2.4.5.1 Topographical and Condition Surveys

2.4.5.1.1 At award of contract the Contractor shall conduct a complete topographical and condition survey of the Site and the surrounding area. These surveys shall be agreed with the Project Manager before any work starts on the site.

2.4.5.1.2 The purpose of the topographical survey of the Site and the surrounding area is to determine and agree with the Project Manager the existing levels. It is also envisaged that this data will allow the Contractor to allocate a relatively local low area in which any surface water run-off from the site can be directed for subsequent natural evaporation; ideally this zone will be well away from the working area of the site.

2.4.5.1.3 The condition survey will comprise a visual survey to record any aspect of the site and its surroundings which may have an impact on the construction or subsequent operation of the Works. The survey will include but not be limited to the following:

(a) observing the vegetation (changes in colour of vegetation may indicate changes in soil conditions)
(b) the presence of any buildings or habitation
(c) the presence of overhead obstructions, (transmission or distribution lines)
(d) tree or tree roots and any changes the removal of the trees may have upon the site e. geological outcrops or erosion
(e) signs of previous occupation e.g., wildlife
(f) access routes etc.

2.4.5.1.4 The condition survey should be accompanied by a comprehensive photographic record.

2.4.5.2 Ground Investigation

The purpose of the Ground Investigation is to determine the nature of the sub-surface soil conditions which exist within the Site and to determine the most suitable type of foundation types. The ground investigation shall be carried out in accordance with the latest edition of the "Specification for ground investigation" published by the Institute of Civil Project Managers.

2.4.5.2.1 Data Provided by Procuring entity

The accuracy of any subsoil and survey information supplied to the Contractor is given in good faith but is not guaranteed, and any variation between this information and actual site conditions will not be accepted as the basis of a claim or reason for variation of unit rates in the Contract.

2.4.5.2.2 Scope of Ground Investigation

(a) The Contractor shall satisfy himself regarding the geotechnical condition of site and any matters relating to the extent and magnitude of the proposed development. He shall carry out all soil investigations he considers necessary to establish the basis for the proposed plant and building arrangements and foundation designs. A part of this work will include a contamination survey to the site to identify the presence or otherwise of contaminated materials. Samples obtained during the investigations are to be available for inspection by the Project Manager at the site.

(b) The Contractor is to provide an interpretative geotechnical report for review by the Project Manager to confirm the criteria to be used in the foundation designs. This report shall include at least the following information:

(i) A detailed record of all factual information obtained in the field and via laboratory testing,
(ii) Identification of all elements of contaminated material providing advice on their extent and the potential impact on personal health and durability of construction materials,
(iii) Accurate logging of groundwater levels including global and perched,
(iv) The results of the investigations into the soil resistivity and thermal resistance necessary for the design of the earthing rods,
(v) Foundation design parameters,
(vi) Detailed recommendations regarding any specialist foundation solutions, including piling, ground improvement techniques, etc

(c) Within this geographical region it is possible that highly expansive soils may exist naturally and as such the above testing regime should identify their presence or otherwise. However, to ensure that the requisite testing is carried out it is recommended that at least the following properties are determined from soil samples taken from within the foundation zones, i.e., this will probably be within the top 3m of natural ground.

(i) The percentage of elements in the makeup of the soil with particular reference to montmorillonite, chilkinite and kaolinite and any other element which could cause volumetric change to occur. These percentages shall be determined for every 0.5m of depth.

(ii) The volumetric change which the sample will undergo when exposed to water

(iii) The pressures which the sample will exert when undergoing volumetric change

(iv) The long-term effect of a cycle of wetting and drying (i.e., does the swelling and shrinking repeat itself with the same intensity or do the effects diminish with repetition)

2.4.6 Datum

A datum to which all levels are to be related will be defined or established at a convenient point by the Project Manager. The Contractor shall then establish a minimum of four temporary benchmarks, approximately equally spaced round the site, which shall be related to the datum. Each temporary benchmark shall be securely set in concrete and shall be protected from damage or disturbance.

2.4.7 Setting Out

The Project Manager will establish two lines mutually at right angles from which the Contractor shall set out the works. Each of these main lines shall be defined by not less than four steel pins set in concrete at points indicated by the Project Manager. The Contractor shall supply all necessary labour and materials for this purpose.

2.4.8 Dimensions and Levels

All dimensions and levels shown on the drawings shall be verified on site by the Contractor.

2.4.9 Water, Electricity and Other Services

The Contractor shall be responsible for supplying all water, electricity and other services required for the construction of the Works and for any other purpose in connection with the Works.

2.4.10 Inclement Weather

No payment will be made to the Contractor in respect of loss of output of plant or labour due to inclement weather.

2.4.11 Labour, Plant, and Materials

The Contractor shall provide on the site, and elsewhere as required, sufficient labour, plant, materials, and all other things necessary to construct the works in accordance with the agreed programme.

2.4.12 Programme of Works

The Contractor shall construct the works in compliance with the approved work programme as detailed in general specifications.

2.4.13 Provision of Testing Equipment

2.4.13.1 The Contractor shall provide a laboratory testing facility on site for use by the Project Manager depending on the nature and scope of works as per particular specifications. This shall comprise a purpose-built facility capable of testing concrete, aggregates and soil samples as prescribed in the various codes of practice applicable to this project. As a minimum the following equipment shall be provided which shall be accurate and maintained in good condition:

2.4.13.1.1 Curing bath(s) for concrete samples plus compressive testing machines

2.4.13.1.2 Full set of testing equipment for the testing of soils, as prescribed in the various codes of practice applicable to this Project. This will include weighing scales, ovens, sieves, oedometers, shear box testing equipment, etc.

2.4.13.2 Wherever on-site testing is impractical then alternative specialist subcontractors are to be employed by the Contractor to carry out this work, all associated costs being borne by the Contractor.

2.4.14 Design Process

2.4.14.1 Management of the Design

2.4.14.1.1 The Contractor shall prepare a 'Basis of Design' (BOD) for each element of the

civil and structural works. A list of BOD's shall be prepared, and this shall be submitted to the Project Manager within twenty-eight days after the Award of Contract for review and comment. The 'Basis of Design' shall include:

(a) A concise description of the form of each element, b. A statement of assumptions made,
(b) Loading and performance criteria,
(c) The particular editions of all Standards, Codes of Practice and References used,
(d) A description of the design approach including statements on the use of any computer programs and checking procedures adopted.
(e) Working methods,
(f) Plant utilization,
(g) Construction sequence,
(h) Safety arrangements.
(i) Output file from a value engineering exercise on the proposed works

2.4.14.1.2 These documents will establish the basis for formal reviews and appraisal of the design analysis. The Contractor shall submit these to the Project Manager for review at least 2 months prior to the commencement of the relevant construction activity in order that the Contractor can consider any comments made by the Project Manager at the most opportune time.

2.4.14.1.3 The development of the BOD's and the detailed civil design shall be reflected in the design and construction sections of the Contract programme.

2.4.14.1.4 Acceptance or rejection of the Contractor's BOD, calculations or drawings by the Project Manager shall not relieve the Contractor of any of his obligations to meet all the requirements of the Contract. The Contractor shall make any changes in the design, which are necessary to comply with the Contract.

2.4.14.2 Detailed Design Submissions

2.4.14.2.1 Following the review of the Basis of Design, the Contractor shall provide such detailed design submissions supported by comprehensive design calculations and drawings of the works as considered necessary by the Project Manager for his appraisal. The design calculations and drawings shall be submitted to the Project Manager as detailed in general specification or scope of services.

2.4.14.2.2 These submissions will be reviewed at regular meetings held between the Project Manager, the Contractor and the Contractor's Civil Designer.

2.4.14.3 Loading

2.4.14.3.1 General

The loading applied to all buildings and structures shall comprise a combination of dead, imposed, wind, thermal, accidental, and seismic. All loading shall be ascertained from the applicable codes of practice and standards applicable to this project.

2.4.14.3.2 Design Loads

It is anticipated that Equipment suppliers will give the weights and sizes of all 'heavy equipment', i.e., transformers, coolers, switchgear etc. specific to each project. These are to include dismantled transportation weights. Allowances shall be made for equipment and cables which are to be hung from the roof and ceilings of the various buildings/structures with regards to the overall load to these elements.

2.4.14.3.3 Internal Overpressure

(a) A notional internal blast incident generated by an electrical fault requires the building fabric in the switch room to be designed to retain integrity under a 5kN/m2 ultimate overpressure load internally. Around the transformers the building fabric is to be designed to retain integrity under a 10kN/m2 ultimate overpressure load.

(b) Materials are to be considered at ultimate strength.

(c) The building is to be designed such that the catastrophic loss of a wall will not result in building collapse or collapse of structures above the substation.

2.4.14.3.4 Floor Loads

The Contractor is to advise on the minimum characteristic loads that the floors within the substation building are to be designed to. Characteristic design loads are based on accommodating all equipment. All other floor loads are to be in accordance with BS 6399-1 1996.

2.4.15 Materials and Workmanship General Requirements

2.4.15.1 General

2.4.15.1.1 Materials and workmanship are to be of best quality. All materials used in the works shall be new and of the best quality of their respective kinds. They shall comply with the requirements of the latest edition of any relevant Kenyan or British Standard and/or Code of Practice where such exist, and current at the date of bidding.

2.4.15.1.2 All workmanship shall be of the highest standard and shall be executed by

competent men skilled in their respective trades.

2.4.15.2 Samples

In addition to the special provisions made in this Specification for sampling and testing of materials by particular methods, samples of any materials and workmanship proposed to be used in the Works may be called for at any time during the Contract by the Project Manager and shall be furnished by the Contractor without delay and at the expense of the Contractor. Samples when approved, shall be regarded as the acceptable standard, and any material or workmanship subsequently not complying with that standard shall be rejected and replaced by those of acceptable standard at the expense of the Contractor. Sample storage boxes shall be provided by the Contractor free of cost if requested by the Project Manager.

2.4.15.3 Tests

Whenever considered desirable by the Project Manager, Inspectors may be sent to manufacturers or subcontractors' premises to test materials or inspect their manufacture. In addition, the following will apply:

2.4.15.3.1 Where specified or requested the Contractor shall obtain from the manufacturer and send to the Project Manager certificates of test, proof sheets, mill sheets, etc, showing that materials have been tested in accordance with this Specification or the relevant Kenyan or British Standard.

2.4.15.3.2 Notwithstanding any tests which may be directed to be carried out at a manufacturer's and/or subcontractor's works, the Project Manager may carry out any tests or further tests he considers necessary or desirable after delivery of materials to the site.

2.4.15.3.3 The Contractor shall provide all labour, equipment, and facilities necessary for the carrying out of tests both in works and on site.

2.4.15.3.4 The cost of routine tests required by Kenyan Standards or British Standards and this Specification shall be borne by the Contractor. The cost of other tests shall be borne in accordance with the Conditions of Contract.

2.4.15.4 Names of Suppliers and Copies of Orders

2.4.15.4.1 If so required, and before ordering material of any description, the Contractor shall submit for approval the names of makers or suppliers proposed. Copies of orders shall also be submitted if so required.

2.4.15.4.2 The Project Manager may at any time withdraw his previously given approval to obtaining materials from any maker or supplier should such maker or supplier

fail to supply materials of the specified quality or quantity in the requisite time.

2.4.15.5 Rejection of Materials and Workmanship

2.4.15.5.1 The Project Manager shall at any time have power to reject materials and workmanship not complying with this Specification or with the Drawings. Materials so rejected shall be immediately removed from site and replaced by materials of an approved standard at the expense of the Contractor.

2.4.15.5.2 Rejected workmanship shall be broken out and replaced by work of an acceptable standard including the supply of new materials by the Contractor, at the expense of the Contractor, and without delay.

2.4.16 Site Clearance and Demolition

2.4.16.1 Clearance of Vegetation

Unless otherwise directed or shown on the Drawings all bushes, trees and vegetation generally on the site shall be cleared and burned or removed to a tip provided by the Contractor. Where the Drawings or the Project Manager direct that any of these items are to remain undisturbed, the Contractor shall take all necessary action to prevent damage to them.

2.4.16.2 Demolition of Structures

Buildings or other structures or foundations to be removed shall be demolished by approved methods, which shall ensure that no damage is caused to any structures which are to remain.

2.4.16.3 Wells and Existing Excavations

Any wells or other existing excavations on the site shall be filled with approved material in layers not exceeding two hundred (200) mm, well rammed and compacted or by puddling with water. When these wells or excavations occur under, or within, three metres of new load bearing construction, they shall be filled with cement stabilised soil consisting of one (1) part cement and fifteen (15) parts sieved soil, thoroughly mixed and with a minimum quantity of water added to make a workable mix.

2.4.16.4 Explosives

Explosives shall not be used in the Works.

2.4.17 Earthworks and Excavation

2.4.17.1 Character of Ground

The Contractor must satisfy himself as to the ground conditions on the site, including the character of the strata to be excavated, obstructions, possibility of flooding and suchlike, and shall employ excavation techniques and equipment best suited to the site conditions.

2.4.17.2 Earthworks and Excavation Generally

Unless otherwise stated in the Contract the rates for earthworks and excavation shall be held to include for excavation in any material except rock.

2.4.17.3 Rock Excavation

The term "rock" shall mean a material which in the opinion of the Project Manager cannot be excavated except by means of explosives or compressed air drilling equipment. Boulders over one quarter (0.25) cubic metres in volume will be classed as rock and those of lesser volume as normal excavation.

2.4.17.4 Excavations for Foundations, etc

Excavations shall take out the minimum sizes necessary for the proper construction of the works, and excavations shall not be kept open for periods longer than that reasonably required to construct the works. The Contractor shall take all precautions necessary to ensure that the bottoms of excavations are protected from deterioration and that the excavations are carried out in such a manner that adjacent foundations, pipes or such like are not undermined, damaged or weakened in anyway. Any excavation taken out below the proper level without approval shall be made good at the expense of the Contractor using concrete or other material as directed.

2.4.17.5 Support of Excavations

The Contractor shall be responsible for the stability of the sides of the excavations and shall provide and install all timbering and shoring necessary to ensure stability. If any slips occur, they shall, as soon as practicable, be made good in an approved manner at the expense of the Contractor. Shoring shall not be removed until the possibility of damaging the works by earth pressure has passed. No payment for shoring or timber left in shall be made, unless agreed in writing by the Project Manager.

2.4.17.6 Works to be in Dry

All excavations shall be kept free from water and the Contractor shall take whatever action is necessary to achieve this. Pumping, well pointing and other means necessary to maintain the excavations free from water shall be at the expense of the Contractor and carried out in an approved manner.

2.4.17.7 Inspection and Trimming of Excavations

Unless otherwise agreed, the bottoms of all excavations shall be inspected and approved before concrete is placed. Soft areas shall be excavated and filled in with concrete or other suitable material as directed. The excavations shall be properly trimmed and levelled before the placing of blinding or foundation concrete.

2.4.17.8 Backfill

As soon as possible after the permanent works are sufficiently hard and have been inspected and approved, backfill shall be placed where necessary and thoroughly consolidated in layers not exceeding two hundred (200) mm in depth.

2.4.17.9 Disposal of Surplus

Surplus excavated material not required or not approved for fill or backfill shall be loaded and deposited either on or off site as directed. The Contractor shall not delay disposal of surplus material after receipt of instructions from the Project Manager.

2.4.17.10 Hardcore

Hardcore shall consist of clean, hard, natural broken stone, rubble or gravel all to pass an eighty (80) millimetre ring but retained on a thirty (30) millimetre ring.

2.4.17.11 Weed killer

Weed killer shall be spread over areas to be covered with site surfacing before such surfacing is laid. The weedkiller shall be of approved make which does not cause corrosion of metals. It shall be used strictly in accordance with the manufacturer's instructions.

2.4.17.12 Site Surfacing

Site surfacing shall consist of clean, hard natural gravel or crushed stone all to pass a thirty (30) millimetre ring, but all retained on a ten (10) millimetre ring. Site surfacing shall be spread after installation of services and cables, each strip and suchlike by other Contractors. It shall be spread where indicated on the

Drawings on a properly levelled or graded surface, free from weeds to a compacted thickness of one hundred and fifty (150) mm and lightly rolled.

2.4.18 Concrete, Reinforced Concrete and Mortar

2.4.18.1 General

(a) To achieve the service life specified, a high quality, durable concrete shall be provided to protect reinforcement, embedded metals and concrete against attack from aggressive chemicals such as chlorides, sulphates and other agents.

(b) The Contractor shall take the following key exposure categories into account whilst preparing the design mix(es) requirements. Design mix(es) shall be subject to the Project Company's/Project Manager's approval.

(i) Dry internal environments.

(ii) Wet internal environments.

(iii) External environments not exposed to seawater or seawater spray.

(iv) External environments exposed to seawater spray/splash zone.

(v) External environments exposed to seawater immersion.

(c) As mentioned previously the Contractor shall establish by soil investigation the aggressive chemical environmental conditions for concrete exposure. Concentration levels of airborne and below ground chloride and sulphate salts and any other aggressive chemical agents shall be determined. The below ground conditions for concrete shall be assessed in accordance with the requirements of BRE Special Digest 1 "Concrete in aggressive ground".

(d) The Contractor shall, as a minimum requirement, comply with the specified concrete mix design, and the specified additional protective measures noted herein.

(e) All structural concrete shall develop a minimum compressive cylinder strength (f'c) of 35N/mm2 at 28 days. (This shall be equivalent to a cube strength of 42N/mm2).

(f) Blinding concrete shall have a minimum 28-day cube strength of 15.0N/mm2.

(g) If slip formed construction is offered for any part of the works then a special concrete design shall be developed by the Contractor and offered to the Project Company/Project Manager for approval.

(h) For all reinforced concrete, the following minimum mix design requirements shall be provided.

Cement Type	Type I, ASTM C 150
Cement replacement	Ground granulated blast furnace slag to BS6699, BS EN 15167-1:2006
The cement and GGBS shall be blended at the point of batching in the following proportions by weight:	120kg minimum OPC but not less than 30% of the total cementitious quantity + 280kg minimum GGBS
Minimum total cementitious quantity	370 - 380kg/m3
Maximum water/cement ratio	0.42 – 0.45

(i) Admixtures shall be selected by the Contractor to accommodate his requirements for placing of fresh concrete. However, their inclusion must be approved by the Project Manager prior to their use.

(j) Compliance with any concrete mix design in this Specification shall not relieve the Contractor of his responsibility for the final concrete mix design. The Contractor shall demonstrate to the satisfaction of the Project Manager that the intended durability of the concrete mix for the required design life can be satisfied for the particular exposure environment.

(k) The Contractor shall be responsible for ensuring that all constituent materials used for the concrete works (e.g. cementitious, aggregate, reinforcement, water, admixtures etc) comply with recognised international material standards and methods of testing and meet the requirements of this Specification. The use of proposed constituent materials shall be agreed with the Project Manager prior to their use on the Project.

(l) The following values of minimum reinforcement cover shall be provided:

Concrete exposed to seawater; upper tidal range and splash zone	75mm
Concrete exposed to seawater; permanently submerged	75mm
Concrete buried below ground in contact with the ground	75mm
External superstructure, away from splash zone	75mm
Internal superstructure, beams, columns	40mm
Internal superstructure, slabs	30mm

(m) In addition, the Contractor shall provide sufficient concrete cover and overall cross-sectional dimensions to ensure the correct fire protection to the various

elements of structure (where fire protection is required) are achieved. This shall be in accordance with BS 8110.

(n) For below ground concrete protective measures shall, as a minimum be provided to meet the requirements of BRE Digest No 1 and as specified below. The contractor shall assess sulphate, chloride and pH levels existing in representative soil and groundwater samples as part of his programme of supplementary geotechnical investigation of the site. The concrete protective measures set out below shall be upgraded where necessary based on the recommendations of the Kenyan and British Codes of Practice.

Location	Sulphate levels below 6.0g/l (groundwater) 6.7g/l (soil).	Sulphate levels in excess of 6.0g/l (groundwater) 6.7g/l (soil).
Parts of structure in contact with the soil above the capillary rise zone	Bitumen emulsion paint	Bitumen emulsion paint and minimum cover to reinforcement shall be 100mm.
Parts of the structure within the capillary rise zone or below ground water level.	Bitumen emulsion paint and minimum cover to reinforcement shall be 100mm.	Bitumen emulsion paint and minimum cover to reinforcement shall be 100mm.
Precast concrete piles	Steel moulds.	Steel moulds

Note that the depth of the capillary rise zone shall be taken as 1.5m above the highest ground water level. Sulphate levels shall be determined by the Contractor's soil investigation.

(o) Bitumastic paint shall be applied on top of all blinding concrete except where horizontal shear resistance is required.

(p) Embedded materials shall be accurately fabricated and assembled to suit the construction interface required.

(q) All steel embedment's in concrete shall be accurately positioned and securely anchored either directly to the formwork or by templates prior to pouring the concrete. Pockets for later insertion of assemblies generally will not be allowed.

(r) Embedment's shall be clean both before they are installed and after placement of the concrete. Where embedment's are required for major equipment items then anchor bolts, attachments and embedment's shall be located and secured prior to concrete placement with accurately made steel templates. Tolerances shall be as specified by the equipment manufacturer but shall be not greater than ±3mm on plan and verticality. Templates shall be interconnected and braced with steel members that maintain the anchor

bolt alignment and position.

(s) Welding of embedment's, to the reinforcement cage to secure their location, will not be accepted.

(t) Corrosion protection shall be provided to all embedment's, suitable to the environment in which they are cast. Generally, the following exposure conditions shall be considered as a minimum:

(i) Dry internal environments.

(ii) Wet internal environments.

(iii) External environments not exposed to seawater or seawater spray.

(iv) External environments exposed to seawater spray/splash zone.

(v) External environments exposed to seawater immersion.

(u) The materials that will be used for embedded items shall comprise either carbon steel or stainless steel. The selection of material will be based on strength and durability requirements. Additionally, the choice of material may be dictated by interfacing issues with plant requirements.

(v) The necessity of welding plant fixings etc. to embedment's exposed at the concrete surface in exposed environments shall be considered at design stage and wherever possible alternative fixing details shall be provided in order to preserve the original corrosion protective coatings.

2.4.18.2 Cement

(a) The cement used throughout the works shall be best quality Portland cement and shall conform in every respect with BS 12 or the equivalent Kenyan Standard. Other cements may be used only with written approval, or on written instructions, and shall conform in every respect with the relevant KS and BS.

(b) Consideration shall be given to the use of ground granulated blast furnace slab (GGBS) as a cement replacement. It is permitted to substitute up to 70% of the cement with GGBS and this will provide a more durable concrete.

2.4.18.3 Special Additives

Air entraining, water reducing, set accelerating, set retarding, or other additives can be used with the prior written approval of the Project Manager, following comparative concrete durability and compression strength tests carried out on concrete made with and without additives. Tests with additives shall give durability and compressive strength at least equal to those without additives except that water reducing agents shall increase the compressive strength by ten (10) percent. The use of all additives shall be strictly supervised. Any admixtures used shall comply with the relevant part of BS EN 480. Calcium chloride or admixtures based on calcium chloride shall not be used.

2.4.18.4 Delivery and Storage of Cement

(a) The cement shall be delivered to the Site in bulk or in sound and properly sealed bags and while being loaded or unloaded whether conveyed in vehicles or by mechanical means, and during transit to the concrete mixers, must be protected from the weather by effective coverings. Efficient screens are to be supplied and erected to prevent wastage of cement during strong winds.

(b) If the cement is delivered in bulk, the Contractor shall provide at his own cost approved silos of adequate size and number to store sufficient cement to ensure continuity of work. The cement shall be placed in these silos immediately when it has been delivered on the Site. Suitable precautions shall be taken during unloading to ensure that the resulting dust does not constitute a nuisance.

(c) If the cement is delivered in bags, the Contractor shall provide at his own cost perfectly waterproof and well-ventilated sheds having a floor of wood or concrete raised at least 150mm, above the ground. The sheds shall be large

enough to store sufficient cement to ensure continuity of work. Each consignment of each type of cement shall be stacked separately therein. On delivery at the Work the cement shall at once be placed in these sheds and shall be used in the order in which it has been delivered.

2.4.18.5 Coarse Aggregate

Coarse aggregate for concrete shall be clean, hard, strong, fine grained, non-friable, non-porous and durable stone of approved quality and shall be obtained from an approved source. It shall be roughly cubical or rounded in shape and be free from dust.

2.4.18.6 Fine Aggregate

(a) The fine aggregate for concrete shall be clean, sharp sand, or other suitable and approved material, and shall be free from all impurities.

(b) The fine aggregate for mortar shall, unless otherwise specified, be rounded sand or other suitable and approved material and shall be free from all impurities. The clay, silt or fine dust shall not exceed five (5) percent by volume. The sand shall consist of particles between two point three six (2.36) mm and six hundred (600)mm in size.

2.4.18.7 Storage of Aggregates

The coarse and fine aggregates shall be stored on site in bins or on clean, dry, hard surfaces, and be kept free from all sources of contamination. Aggregates of different gradings shall be stored separately, and no new aggregate shall be mixed with existing stocks until tested and approved.

2.4.18.8 Water

Water used for mixing concrete and mortar shall be clean, fresh water obtained from an approved source and free from harmful chemicals, oils, organic matter and other impurities.

2.4.18.9 Steel Bar Reinforcement

(a) Steel reinforcement shall comply with one of the following:

- Carbon steel bars for the reinforcement of concrete – BS 4449
- Cold reduced steel bars for the reinforcement of concrete – BS 4482
- Steel fabric for the reinforcement of concrete – BS 4483.

(b) All bar reinforcement shall be hot rolled steel except where the use of cold worked steel is specified on the Drawings or otherwise approved.

(c) The bars shall be round and free from corrosion, cracks, surface flaws, laminations, rough, jagged

(d) and imperfect edges and other defects, and the tolerance by weight shall not exceed two and one half (2.5) percent.

(e) The bar reinforcement shall be new, clean and of the lengths and diameters described on the Drawings and Schedules. Bars shall be transported and stored so that they remain clean, straight, undamaged and free from corrosion, rust or scale. Bars of different diameters shall be separately bundled.

(f) Where environmental conditions dictate the use of epoxy coated or stainless-steel reinforcement bars shall be used; the use of these being at the discretion of the designer.

2.4.18.10 Steel Fabric Reinforcement

(a) Unless otherwise specified or described on the Drawings or in the Bills of Quantities, all fabric reinforcement shall comprise hard drawn steel wire fabric and shall comply in all respects with BS4483. Each consignment of steel fabric reinforcement shall be accompanied by a test certificate giving the results of tests on the material carried out in accordance with BS 4483.

(b) Steel fabric reinforcement shall be new, clean, free from corrosion, rust or millscale, and shall be transported to and stored on site so that it remains clean, undistorted and otherwise undamaged. Fabrics of different type or weights shall be separately bundled or rolled.

2.4.18.11 Tying Wire

The tying wire for reinforcement shall be one and one half (1.5) mm in diameter annealed soft iron tying wire.

2.4.18.12 Threaded Inserts

The threaded inserts for casting into concrete shall be electro-galvanized and of malleable iron or mild steel.

2.4.18.13 Waterproofing Admixture – up to here

Waterproof concrete and mortar shall be used where shown on the Drawings. Waterproofing shall be by the use of a reliable and approved brand of admixture. The admixture shall be used strictly in accordance with the manufacturer's instructions.

2.4.18.14 Availability of Materials

The Contractor shall be deemed to have satisfied himself that suitable materials for concrete and mortar can be obtained in sufficient quantities to carry out the works.

2.4.18.15 Approval of Supplies

As soon as possible after the Contract has been placed the Contractor shall submit a list giving details of the sources from which he proposes to obtain concrete and mortar materials. Only materials from approved sources shall be brought to site, but the Project Manager will be prepared to extend his approval to other satisfactory sources of supply which may be proposed by the Contractor. Approval of a source of supply shall not imply acceptance of material found not to conform to this Specification.

2.4.18.16 Preliminary Tests of Concrete Ingredients

(a) After submission of the list of approved sources of supply of concrete materials, the Contractor shall, when required obtain representative samples of water and of fine and coarse aggregate in sufficient quantities for testing as directed by the Project Manager. The tests to be carried out shall be decided by the Project Manager and shall be carried out by the Project Manager and/or at an independent laboratory. The test will normally consist of mechanical, and if necessary, chemical, analysis of the aggregate plus chemical analysis of the water.

(b) As soon as possible after the Contract has been placed, the Contractor shall prepare trial mixes of the proposed concrete mixes and subject them to various tests, including:

  (i) Compressive strength tests at 7, 14 and 28 days

  (ii) Slump tests

  (iii) Expansivity tests to aggregates and concrete

(c) Testing of the concrete samples shall be carried out by an independent authority to be agreed with the Project Manager. When concrete grades have been approved, the Contractor shall not vary the proportions without approval.

2.4.18.17 Testing on Site

(a) Samples of concrete shall be taken from the works at a rate of one sample per 20m3 or one sample per 20 batches, whichever is the lesser. Test cubes shall

be made from these samples in sets of six. All concrete testing is included in the Contract.

(b) Test cubes shall be made, cured, stored and transported and test in compression in accordance with BS EN 12350.

(c) Concrete may be assumed satisfactory if the cube strengths at 7 days are 50% of the 28-day strength. Should the 7-day values be below 50% of the final strength the concrete may still be assumed satisfactory if the 28-day test results conform with the target strengths. If the results of both the 7 day and 28 day works cube tests show crushing strengths less than those specified, the Project Manager may suspend all concreting work and order further tests to ascertain if the concrete placed in the works is acceptable. Any concrete found not to comply with the Specification shall be broken out and replaced, or otherwise rectified, to the satisfaction of the Project Manager.

(d) All remedial measures including cutting-out, reinstating, mix adjustment, further testing and the like, which, in the opinion of the Project Manager, are required shall be at the expense of the Contractor.

2.4.18.18 Measurement of Materials

In proportioning concrete, the quantity of cement shall be determined by weight and when the cement is supplied in bags the concrete shall be mixed in batches using one or more complete bags of cement. The quantities of fine and coarse aggregate should be determined by weight but where written approval has been obtained from the Project Manager may be determined by volume.

2.4.18.19 Mixing of Concrete

(a) The concrete materials shall be weight batched and mixed with mechanical mixers. The machines are to ensure that all the concreting materials including the water are thoroughly mixed together between the time of their deposition in the mixer and before any portion of the mixture is discharged. The machines must be capable of discharging their content while running.

(b) All equipment shall be thoroughly cleaned before use or re-use for other grades of concrete.

2.4.18.20 Workability of Concrete

(a) The concrete shall be of a dense, homogeneous nature produced with the minimum quantity of water necessary to ensure a compact mass sufficiently workable to enable proper placing and consolidation in corners and around reinforcement, and to give the specified finish, strength, density or other

required qualities. The water/cement ratio for each grade of concrete shall be agreed with the Project Manager.

(b) The control of the workability of concrete shall be maintained by application of Slump Tests carried out in accordance with the procedure laid down in BS 1881. Slump tests shall be made at least twice daily or as directed and a record of results kept on site for periodic review.

2.4.18.21 Transporting

Concrete shall be distributed from the mixers to final position in the works as rapidly as possible and by approved methods which will prevent segregation or loss of ingredients. All equipment shall be thoroughly cleaned before use or re-use for other grades of concrete.

2.4.18.22 Placing

(a) Not more than thirty (30) minutes after water is first added to the mix and before initial set has occurred, the final placing of the concrete shall be competed. On no account shall water be added after the initial mixing.

(b) All concrete surfaces in contact with the earth shall be suitably protected with a bituminous membrane.

(c) Concrete shall be introduced into the forms, between pre-determined construction joints, as near as practicable to its final position in a manner which will not cause segregation of the mix or displacement of the reinforcement or forms.

(d) Concrete shall not be dropped from a height greater than one (1) metre unless 'tremmie' techniques are adopted. The placing and consolidation of concrete shall be done in a manner which will not disturb previously placed concrete.

2.4.18.23 Compacting of Concrete

Concrete shall be consolidated by an approved method of ramming, tamping or vibration. It shall be carefully worked round reinforcement and embedded fixtures, into corners and against the forms to produce a dense uniform mass free from defects. Care shall be exercised to ensure the whole depth is thoroughly compacted without disturbance to parts of the work already placed. Excessive ramming and tamping shall be avoided.

2.4.18.24 Mechanical Vibration

(a) All concrete shall be vibrated unless otherwise directed. Vibration shall be additional to hand compacting and numbers and types of vibrators shall be approved before use. Vibrators shall be the immersion type operated at an approved frequency and external formwork vibrators may only be used on agreed sections of the works.

(b) Operators of vibrating tools shall have received adequate instruction and training in their use. Every care shall be taken to avoid contact of vibrators with the reinforcement or previously placed concrete. Excessive vibration shall be avoided.

2.4.18.25 Construction Joints

(a) Concreting shall be carried out continuously up to approved construction joints with moulded bonding chases. Unless otherwise approved or instructed concrete shall be placed to the full depth of slabs, beams and the like and shall be placed in horizontal layers not exceeding one and one half (1.5) metres deep in walls, columns and similar members.

(b) Construction joints shall be formed in the horizontal and vertical planes by means of stop boards which allow the reinforcement to run through. Where practicable, laitance shall be removed whilst the concrete is still soft so as to expose the coarse aggregate. Where concrete already deposited has set but not set hard the laitance shall be removed and the coarse aggregate exposed by wire-brushing and washing.

(c) At joints where the placed concrete has set hard any skin or laitance shall be removed by hacking, care being taken to avoid damage to the aggregate.

(d) Immediately before concreting proceeds the roughened joint surface shall be thoroughly cleaned and loose matter removed, then treated with a layer, 12mm thick, of cement mortar 1:1 mix. The concrete shall be immediately deposited and punned into the cement mortar.

(e) Where construction joints will be permanently visible, the cement mortar shall be kept back from the exposed face of the concrete.

2.4.18.26 Contraction Joints

Contraction joints in concrete slabs and walls shall be formed in positions and to details shown on the Drawings or as directed by the Project Manager. The joints shall be straight and vertical except where otherwise approved and concrete surface levels on both sides of the joint shall be flush. The joints shall be sealed with 'Compriband' bituminised polyurethane foam strip, pre-compressed before

insertion and installed in accordance with the recommendation of the manufacturers, Compriband (Great Britain) Ltd, or 'Pliastic' tropical grade rubber bitumen compound, produce of Expandite Ltd, poured hot into horizontal joints or other approved product of equal properties and quality.

2.4.18.27 Expansion and Deflection Joints

(a) Expansion and deflection joints shall be formed in positions and to the details shown on the Drawings or as directed.

(b) Joints shall be straight and vertical except where otherwise approved and concrete surface faces shall be flush on both sides of the joint.

(c) The joints shall be filled with 'Flexcell' non-extruding wood fibre bitumen impregnated boarding and sealed with 'Pliastic' tropical grade rubber bitumen compound, or other approved products of equal properties and quality.

2.4.18.28 Protection of Concrete

(a) Proper protection shall be provided to prevent cement from being taken or washed away and the concrete from being diluted during the process of storing, handling, transporting, apportioning and mixing the materials, and transporting, placing, compacting and curing the concrete.

(b) All foundations constructed below the water table and within the capillary rise zone are to be suitably protected from chemically aggressive ground conditions by tanking with a bitumen type membrane if required by the Ground Investigation Results.

(c) Care should be taken to ensure that concrete during hardening is not disturbed by direct or indirect loading, movement or projecting reinforcement, vibration or other similar effects. All concrete shall be protected from the harmful effects of sunshine, wind and rain and foundation concrete shall also be protected from damage by storm or subsoil water.

2.4.18.29 Curing

(a) It is vitally important that prolonged moist curing is carried out in order to achieve long-term durability. Exposed surfaces shall be protected from wind and low humidity until the concrete has reached sufficient maturity.

(b) Start the curing immediately after finishing to prevent rapid surface drying.

(c) Keep the surface continuously moist or by the application of impermeable sheeting for at least 10 days to avoid plastic shrinkage cracking caused by faster surface moisture evaporation than the rate of moisture migrating to

the surface.

(d) For floor construction where a surface treatment such as power floating or the like is to be used curing agent should be applied immediately after the completion of the surface treatment.

2.4.18.30 Bending of Reinforcement

All steel bars are to be accurately bent cold to the shapes and sizes indicated on the Drawings and Schedules unless otherwise approved. Bending dimensions shall be in accordance with BS 8666 unless otherwise stated. Re-bending of bars and bending in position in the works shall not be allowed.

2.4.18.31 Welding of Reinforcement

(a) Spot or track welding for positioning bars in heavily reinforced areas will only be allowed with the express permission of the Project Manager. Extension of lengths of reinforcement by welding will not be permitted.

(b) Welding will be approved only in low stress members, and lap welding will not be approved in any circumstances.

2.4.18.32 Fixing of Reinforcement

(a) Before fixing in the works bars shall be seen to be free from pitting, mud, oil, paint. loose rust or scale or other adherents harmful to the bond or strength of the reinforcement. Bars shall be fixed rigidly and accurately in position in accordance with the working drawings, unless otherwise approved by the Project Manager.

(b) Reinforcement at all intersections shall be securely tied together with soft annealed tying wire the ends of which shall be cut and bent inwards. Cover to the reinforcement shall be as stated previously and sufficient spacers and chairs or precast concrete or plastic of approved design shall be provided to maintain the specified cover and position. No insertion of bars in previously placed concrete shall be permitted. Projecting bars shall be adequately protected from displacement. The fixing of reinforcement in the works shall be approved before concrete is placed.

2.4.18.33 Formwork

2.4.18.33.1 Formwork shall be constructed from timber, metal, plastic or concrete, lined as necessary for special finishes and designed with the quality and strength required to ensure rigidity throughout placing, ramming, vibration and setting of the concrete, without detrimental effect.

2.4.18.33.2 Formwork shall be erected true to line, level and shapes required using a minimum of approved internal ties. Faces in contact with the concrete shall be true and free from defect, jointed to prevent loss of water or fines, in panels or units which permit easy handling, and designed to permit side forms to be struck independently of soffit shuttering. Ties or spaces remaining embedded shall have the minimum cover specified for reinforcement. Forms for exposed concrete beams, girder casings and columns shall provide for a twenty-five (25) mm chamfer on external corners. Formwork described as wrot shall be planed timber, plywood, smooth steel or other material of a similar smooth surface. Samples showing the standard of finish may be required.

2.4.18.33.3 Forms for concrete surfaces not exposed shall be described as 'rough' and may be timber as left from the saw or approved similar material.

2.4.18.33.4 Construction joints in the works shall be so arranged to provide a 'starter' to which the forms for the next lift may be clamped. Wedges and clamps shall be kept tight during vibration operations. Before commencement or resumption of concreting, the interior of forms shall be cleaned and free of sawdust, shavings, dust, mud or other debris and openings shall be formed to facilitate this cleaning and inspection. The inside of the forms shall be treated with a coating of an approved substance to prevent adhesion. Care shall be taken to prevent this substance being in contact with the reinforcement.

2.4.18.34 Inspection and Approval of Formwork

All formwork moulds and reinforcement shall be subject to inspection and approval by the Project
Manager immediately prior to the placing of concrete.

2.4.18.35 Removal of Formwork

2.4.18.35.1 Formwork shall be kept in position, fully supported, until the concrete has hardened and gained sufficient strength to carry itself and any loads likely to be imposed upon it. Stripping must be affected in such a manner and at such a time that no shock or other injury is caused to the concrete. The responsibility for safe removal rests with the Contractor but the Project Manager may delay the time of striking if he deems it necessary.

2.4.18.35.2 Minimum periods, in the absence of agreement to the contrary, between completion of concreting and removal of forms are given below but due regard must be paid to the method of curing and prevailing conditions during this period.

2.4.18.35.3

Removal of formwork	
Positions in works	Minimum Period before removal
Removal of shuttering to sides of rafts, walls, beams and columns.	2 days
Removal of shuttering to slabs, beams and arches (props left under)	6 days
Removal of props to slabs, beams and arches.	16 days
Lifting to precast members	16 days

2.4.18.36 Precast Concrete Members

2.4.18.36.1 Precast concrete members shall be used in the works where specified in particular specifications or on the Drawings or as approved by the Project Manager.

2.4.18.36.2 All the requirements for concrete, formwork and reinforcement shall apply equally to the moulds for precast members and concreting shall be carried out in one continuous operation.

2.4.18.36.3 Precast members shall not be disturbed or lifted until the minimum periods specified for formwork removal have elapsed.

2.4.18.37 Replacement of Damaged Concrete

In the event of any portion of the concrete work being damaged so that in the opinion of the Project Manager it does not fulfil the requirements of the Contract, the replacement or reinstatement shall be carried out at the expense of the Contractor to the directions of the Project Manager.

2.4.18.38 Finish of Concrete Surfaces

2.4.18.38.1 Concrete cast against formwork

The following finishes to concrete surfaces, unless otherwise specified or shown on the drawings, shall be as follows: -

(a) **Class A1:** All permanently exposed surfaces, including exposed sides of foundations.

Class A1 surfaces shall be dense, fair, smooth, even, free from honeycombing, water and air holes and other blemishes, true to line and surface and free from board or panel marking. They shall be of uniform colour. Rendering of defective surfaces shall not be permitted, and, if ordered by the Project

Manager, the Contractor shall at his own expense cut out to expose reinforcement and make good any unsatisfactory work. All areas so treated shall be rubbed down and kept moist for several days.

(b) **Class A2:** Surfaces to be covered by backfill, plasters or the like.
Class A2 surfaces shall be dense, even, free from honeycombing and true to line and surface.

2.4.18.38.2 Concrete not cast against formwork

The following finishes shall be provided unless otherwise specified or shown on the drawings: -

(a) **Class B1:** All permanently exposed surfaces, including tops of equipment foundations, wall copings, windowsills, precast items (except paving flags).

(b) **Class B2:** Paving flags and paths. Floors and slabs to be surfaced with blocks, tiles or waterproofing materials.

(c) **Class B3**: Roads, buried concrete and floors or slabs to be covered by screed.

(d) Class B1 surfaces shall first be levelled and screeded to produce a true surface. After the moisture film has disappeared, and the concrete has hardened sufficiently, the surface shall be finished with a steel trowel under firm pressure to give a smooth, dense, even and hard surface free from all marks and defects.

(e) Class B2 surfaces shall be levelled and screeded to produce a true surface and be finished with wooden or steel float to give a level surface free from screed marks. Excessive floating shall be avoided.

(f) Class B3 surfaces shall be levelled and screeded to produce a true and uniform surface.

2.4.18.39 Holes, Pockets, Threaded Inserts, etc

Holes, cavities, and fixings shall be provided in the works only at the positions indicated on the drawings or as directed and they shall be incorporated as necessary during the work of concreting. Unless otherwise agreed a tolerance in position of plus or minus (5) mm shall be allowed. Inserts and bolts shall be fixed square in the works by means of temporary bolts or nuts, and then concrete cast around them. The projecting portions of such fixings, and concrete within fifty (50) mm of them, shall be bitumastic painted and all threads well-greased on completion of the work. Holes and pockets shall be stripped down clean on completion.

2.4.18.40 Ties to Blockwork

Galvanized steel dowel ties ten (10) mm diameter, one hundred and fifty (150) mm long shall be bedded for half their length in the structural concrete where it abuts concrete blockwork infill panels. Ties shall be fixed at their correct positions to meet blockwork joints at a maximum of one (1) metre centres. Positions of ties will not normally be indicated on the Drawings.

2.4.18.41 Blinding

Under all foundations and elsewhere as indicated on the Drawings a layer of concrete grade fck/fck cube15/20 shall be laid immediately the excavation is carried down to foundation level. The blinding surface shall be thoroughly clean before foundation concrete is deposited thereon. Sumps shall be provided where necessary to facilitate the control of drained water.

2.4.19 Structural Steel

2.4.19.1 Steel sections shall be new, and shapes shall conform to the Kenyan and/or British Standards. All structural steel sections shall be hot rolled with a minimum grade 460 in accordance with BS EN1994. As a minimum the following shall apply:

Hot rolled sections	BS 4 Part 1 and addenda
Hot rolled hollow section	BS EN 10210
Weldable structural steels	BS EN 10025
Black bolts, screws, and nuts	BS 916

2.4.19.2 The structural steelwork shall be designed, fabricated, and erected in accordance with BS 5950: "The structural use of steelwork in building" - unless otherwise described, directed or permitted.

2.4.19.3 Auto/manually fabricated welded sections shall only be permitted when a suitable rolled section does not exist i.e., when section required is greater than the largest rolled section size available from the manufacturer/mill.

2.4.19.4 All bolts in elevated steelwork connections shall be minimum grade 8.8 high strength bolts to suit the required design. All holding down bolts shall be minimum grade 4.6. Finishes etc. shall be selected such, to eliminate galvanic corrosion. Bolt finishes shall conform with the finishes applied to the steelwork elements to which they connect. Welded connections will comply with the relevant Kenyan or British standard.

2.4.19.5 The Contractor shall select coating systems on consideration of climatic conditions prevailing at the site. Such systems shall have a design life to first maintenance of at least

20 years. As a minimum an atmospheric environment category of C5-M, C4 or Im2 should be considered for all structures, as defined in BS EN ISO 12944. The C5-M classification shall apply to all areas within 100m of a seashore line, the C4 classification shall apply to areas more than 100m from the shoreline and the Im2 shall apply to all submerged structures.

2.4.19.6 In the case of paint applied systems these shall consist of shop applied coatings and site applied finishing coat(s) all in accordance with BS EN ISO 12944. The final site coat(s) shall be applied after steelwork erection/alignment and bolt tightening activities have been completed, unless otherwise agreed with the Project Manager.

2.4.19.7 Where zinc coatings are proposed as protection against corrosion the guidelines of BS EN ISO 14713 (Protection against corrosion of iron and steel in structures – Zinc and Aluminium coatings – Guidelines) shall be used. Galvanized steel elements exposed to seawater spray, those located in

2.4.19.8 the seawater structures and those in drainage sumps etc shall be suitable for a Class C5 exposure as defined in BS EN ISO 14713.

2.4.19.9 Some items of secondary steelwork shall be hot dip galvanized to BS EN ISO 1461 i.e. steel flooring, ladders, sheeting rails, purlins, access stair stringers, treads and handrails.

2.4.20 Grouting

2.4.20.1 Non-shrink grouts are to be used for grouting machine base plates and column bases.

2.4.20.2 Where specifically noted on final construction drawings or directed by the Project Manager, grouting shall be with premixed, expansive cement, non-metallic, inorganic, non-shrink grout. Grout shall be manufactured by a firm normally engaged in the manufacture of such items, having a proven record of successful installations, and acceptable to the Project Manager. Grout shall be mixed and placed in strict accordance with the manufacturer's recommendations. Compressive strength of grout shall be not less than 350kg/cm2 after 7 days and not less than 600 kg/cm2 after 28 days.

2.5 AUXILLIARY POWER SUPPLY EQUIPMENT

2.5.1 General Auxiliary Power Supply Requirement

2.5.1.1 Auxiliary power for the purposes of this clause (2.5) shall mean power supply powering control, metering, protection devices, computing, and networking equipment.

2.5.1.2 The electricity supplies for auxiliary supply will be as follows:

2.5.1.2.1 415 volts 3-phase 50 Hz 4-wire for heavy power application such as OLTC motors.

2.5.1.2.2 240 volts' single phase 50 Hz for light power application such as lighting, indication, anti-condensation heaters and oil pumps.

2.5.1.2.3 110 volts DC for control, metering, indication and protection devices and all power circuit breakers closing, tripping and spring charging supplies.

2.5.1.2.4 110 volts DC for power operated isolators and earthing switches.

2.5.1.2.5 24V/48V DC for electronics supply where specified.

2.5.2 Alternating Current (AC)

2.5.2.1 All mains auxiliary supplies shall be switched and protected with a circuit breaker. Double-pole circuit breakers shall be used to break single-phase ac mains supplies. For multi-phase supplies, each phase shall be switched simultaneously.

2.5.2.2 Miniature circuit breakers shall be used in auxiliary AC power circuits rated 63 amps and below unless otherwise stated in particular specifications. They shall be approved as circuit breakers and have a breaking capacity sufficient to break the short circuit at the place of use (i.e., no upstream backup fuses for reduction of fault level shall be necessary).

2.5.2.3 Except where prior approval is obtained, wires external to the equipment shall be colour coded as stated elsewhere this specification.

2.5.3 Direct Current (DC)

2.5.3.1 All DC circuits shall be switched and protected by appropriately rated circuit breakers, the circuit breakers must be approved for the relevant DC voltage and current, fuses to be used for ratings of 1A and below only unless otherwise specified in the particular specifications.

2.5.3.2 Double pole circuit breakers shall be used for switching and protection of all DC supply circuits rated above 1A, they shall be rated appropriately to break DC short circuit without the necessity of upstream backup fuses.

2.5.3.3 Where found necessary, backup fuses shall be used to prevent tripping of main DC supplies

2.5.3.4 If electronic equipment or system require the use of local internal batteries approval must be obtained. Where approval is given, batteries used inside equipment shall be: totally sealed, leak-proof type, have no possibility of explosion even at ambient temperature above 40˚C, available in the local market and rated below 5V. Use of internal batteries shall be avoided unless where specified

2.5.3.5 Equipment supplied under this contract shall be rated for direct use 0f 110VDC without external power supply units. Where this is not possible or appropriate 24VDC or 48V DC auxiliary supply shall be used. Other than 110VDC, only 24VDC and 48V DC shall be allowed for auxiliary DC supply for control, metering, protection and communication equipment.

2.5.4 Fuses

2.5.4.1 Carriers and bases for fuses and links shall be in accordance with IEC 60269 standard and colour coded to permit identification of the circuit rating.

2.5.4.2 The contacts of the fixed portion of the fuse or link shall be shrouded so that accidental contact with live metal cannot be made when the moving portion is withdrawn.

2.5.4.3 Main supply fuse links shall, unless otherwise specified, be of the high rupturing capacity cartridge type. Where fuse carriers are mounted vertically, the incoming (supply) circuit shall be connected to the top terminals. Where fuses are used, the Contractor shall ensure that proper discrimination between main and sub-circuits is maintained.

2.5.4.4 Where LV power fuses above 63 amps are specified, they shall be of high rupturing capacity cartridge, type NH gl, according to DIN VDE 0636 and IEC 60269. All fuse bases shall have a load switching capacity and a thermal rating equal to the rating of the largest fuse it can accommodate. Fuse replacement shall be possible without use of special tools and with IP 20 protection against live parts.

2.5.4.5 Fuse holders shall be equipped with at least 1SPDT auxiliary contacts for fuse blown indication.

2.5.4.6 Fuses embedded in devices e.g., terminal blocks etc shall have a fuse blown LED indication.

2.5.5 Miniature Circuit Breakers

2.5.5.1 Miniature circuit breakers shall be designed and tested in accordance with IEC 60947 and supplementary requirements of this specification.

2.5.5.2 They shall be suitably rated for both the continuous and short circuit loadings of the circuits they are protecting under all service and atmospheric conditions stated in the specification and ensure that correct discrimination is maintained between main and sub-circuits.

2.5.5.3 Where circuit breakers are used in circuits containing inductive loads, e.g. operating coils, it is essential that they are suitable for satisfactory operation in the circuit in which they are used, i.e. account is taken of the circuit time constant.

2.5.5.4 MCB used for DC circuits shall be double pole and rated for DC applications.

2.5.5.5 All MCB's shall be provided with two auxiliary contact(s) for remote indication of circuit breaker operation and interlocking purposes.

2.5.5.6 Means shall be provided to prevent the circuit breakers being inadvertently switched to the 'OFF' position.

2.5.5.7 Circuit breakers shall be mounted in such a manner so as to give easily visible indication of breaker position and shall be grouped and spaced.

2.5.6 Motor Protection Circuit breaker, MPCB

MPCB's shall be special kind of MCCB's for three phase loads rated below 100A. They shall meet the following requirements.

2.5.6.1 Designed for motor and other inductive loads overload protection. They shall be used for protection of all three phase control circuits/supplies such as such as VT inputs and outputs, voltage monitoring relays input etc.

2.5.6.2 The MPCB's shall be suitably rated for the application, with overload settings as low as 0.1A for metering & control circuits protection.

2.5.6.3 Shall have an adjustable overload setting, with a dial on the front side for adjustment. Overload shall be settable from at least 70% to 100% MPCB rating.

2.5.6.4 The current ratings given in the specifications consider that the Overload shall be settable from at least 70% to 100%. Overload setting and trip classes shall be computed during design.

2.5.7 Power Supply Units (PSUs) General Requirements

2.5.7.1 PSUs shall be of approved design and such that they do not impose parasitic or harmonic voltages on the station battery system or electronic equipment.

2.5.7.2 Protection circuits incorporated into PSUs shall be such that any overload of the output or short circuit current does not damage any components within the PSU.

2.5.7.3 PSUs shall incorporate over-voltage and overcurrent protection devices to protect the components that comprise the output load.

2.5.7.4 All PSUs shall have at least one SPDT alarm contact to annunciate failure of the PSU.

2.5.8 48V DC Switched Power Supply units

2.5.8.1 General requirements

2.5.8.1.1 Some panel devices shall be powered with 48VDC that shall be sourced from panel mounted power supply units with input voltage of 240VAC and 110V DC

2.5.8.1.2 Redundancy diode shall be installed in all the panels to connect the output of the two power supplies

2.5.8.2 Minimum specifications

No.	Feature	Requirements
1.	Nominal input voltage	100VAC…240VAC, 90VDC…300VDC
2.	Input voltage range	85 VAC…264 VAC 90 VDC…300VDC (UL 508 250VDC)
3.	Type of supply voltage	AC/DC
4.	Electric strength max.	300VAC
5.	Short-term input voltage	300VAC
6.	Nominal power rating	960W
7.	Nominal power consumption at full load	1046VA
8.	AC Frequency range	45Hz …65Hz
9.	Current consumption	8.7A(120VAC),4.5A(230VAC) 9.4A(110VDC),4.6A(220VDC)
10.	Inrush current limitation	<15A (typical)
11.	Inrush current integral I^2t	<1.6 A^2s
12.	Power failure bypass	>20ms (120VAC) >22ms (230VAC)
13.	Typical response time	<0.65s
14.	Protective circuit	Transient surge protection Varistor
15.	Input fuse, integrated	20A (fast blow internal)
16.	Discharge current to PE	< 3.5 mA
17.	Efficiency	> 93 % (for 230 V AC and nominal values)

No.	Feature	Requirements
18.	Nominal output voltage	48 V DC ±1 %
19.	Setting range of the output voltage (USet)	30 V DC ... 56 V DC (> 48 V DC, constant capacity restricted)
20.	Nominal output current (In)	20A (-25degs….60degs, Uout = 48VDC)
21.	POWER BOOST (IBoost)	22.5 A (-25°C ... 40°C permanent, UOUT = 48 V DC)
22.	Selective Fuse Breaking (ISFB)	100 A (12 ms)
23.	Magnetic circuit breaker tripping	B2 / B4 / B6 / B10 / C2 / C4 / C6
24.	Derating	60 °C ... 70 °C (2.5%/K)
25.	Feedback voltage resistance	max. 60 V DC
26.	Protection against overvoltage at the output (OVP)	< 60 V DC
27.	Active current limitation	Approx. IBOOST = 22.5 A (for short-circuit)
28.	Output power	960 W
29.	Max. Power dissipation in no-load condition	13A
30.	Power loss nominal load max.	74W

(a) The supplied PSU shall be compliant to the following standards:

(i) Rail applications: EN 50121-4, EN 50121-3-2,

(ii) Standard - Electrical safety: IEC 61010-2-201 (SELV)

(iii) Standard – Protection against shock currents, basic requirements for protective separation in electrical equipment: EN 50178

(iv) Standard – Safety extra-low voltage: IEC 61010-1 (SELV), IEC 61010-2-201 (PELV)

(v) Standard - Safe isolation: IEC 61010-2-201

(vi) Standard - safety for equipment for measurement, control, and laboratory use: IEC 61010-1

2.5.9 Inverter Power Supply Units

2.5.9.1 General Requirements

2.5.9.1.1 The device shall be used to supply 240V AC pure sine wave power from 110V DC or 48V DC sources for devices without an inbuilt DC power supply unit for devices specified to utilise DC supply.

2.5.9.1.2 The device shall support Sinusoidal pulse width modulation (SPWM) technology with pure sine wave output.

2.5.9.1.3 The device shall utilize CPU control technology, have a powerful load capability and high compatibility, shall utilize advanced reverse noise technology and shall have fault protection.

2.5.9.1.4 The device offered shall be complete with all hardware components, accessories, features, and devices necessary for a complete functional site deployment irrespective of whether these features have been specified.

2.5.9.2 Minimum Specifications

No	Description	Requirement
1.	Power rating	As per device requirement
	DC Input	
2.	Rated Input Voltage (VDC)	• 48VDC option • 110VDC option
3.	DC Input Voltage	• 48V (40 – 60) • 110V (90 – 130)
4.	Rated Input Current (A)	≥120% Device requirement
	AC Output	
5.	Rated Capacity (VA)	As per device requirement
6.	Output Power (W)	As per device requirement
7.	Voltage and Frequency	230V 50Hz
8.	Voltage Precision (V)	± 1.5%
9.	Frequency Precision (V)	50 Hz ± 0.1%,

No	Description	Requirement
10.	Output wave	Pure Sine Wave
11.	Wave Distortion Total Harmonics Distortion (THD) (Resistant Load)	≤ 3 % (Linear Load)
12.	Dynamic Reaction Time (Load 0 <---> 100%)	8 % (load 0 <----> 100%)
13.	Power Factor (PF)	0.8
14.	Overload	120% for 30s
15.	Inversion Efficiency (80% Resistant Load)	≥ 70 – 85
16.	Transfer Time (ms)	≤ 5 ms
17.	Isolation (IN/OUT)	1500 Vac, 1min
18.	Noise (1m)	≤ 40 dB
19.	Operating Temperature	-20°C to +50°C
20.	Humidity	0 ~ 90%, non-condensing
21.	Protection	• Low / High Input Voltage, • Output Overload / Short circuit, • Reversed Input Connections Protection

2.5.9.3 Product Certifications

2.5.9.3.1 Device must be tested and approved for use in the EU or USA or Canada. Proof of testing and certification MUST be provided

2.5.9.3.2 Product certification from an EU or USA or Canada reputable firm MUST be provided along with the bid

2.5.10 Electrical Sockets

2.5.10.1 Single phase electrical sockets installed for lamps, hand tools, measuring equipment etc., shall be the British standard, BS 1363, type with 3 square pin sockets and with earth

connection.

2.5.10.2 Single phase sockets shall be rated at least 16A (lower rating shall not be used).

2.5.10.3 Three phase sockets shall be according to IEC 60309 (CEE type).

2.5.10.4 Contractor shall use sockets available in the local market.

2.5.10.5 A Rack mount socket strip composed of at least four British type (IEC Type G) sockets shall be rack mounted on the front side of each panel if included in the scope of supply

2.5.10.6 The rack mount socket strip shall have an illuminated switch facing the front side of panel

2.5.10.7 Double socket Euro type (CEE 7/3) DIN mount socket strip shall be mounted inside all cabinets.

2.5.10.8 Double socket British type (IEC type G) DIN rail mount socket strip shall be mounted inside all cabinets.

2.5.10.9 Socket Strips power supply input shall be hardwired directly to wiring terminal blocks.

2.5.11 Power distribution Units (PDU)

2.5.11.1 General requirements

2.5.11.1.1 Two 16 outlet PDU's shall be installed in each cabinet where specified.

2.5.11.1.2 PDU's shall be rack mounted with a steel enclosure and mounting.

2.5.11.1.3 PDU enclosure shall have cord retention brackets for securing power outlet cords.

2.5.11.1.4 Each PDU shall be rated for a continuous current rating of 32A @ 40°C ambient temperature.

2.5.11.1.5 It shall have an internal manual reset circuit breaker for overload and short circuit protection. Trip resetting shall be possible from the rear

2.5.11.1.6 The PDU shall have power input cord hardwired to a double pole AC MCB.

2.5.11.1.7 PDU shall have a sensor to measure the current used by the PDU and each of its attached devices.

2.5.11.1.8 The PDU shall be accessible remotely via an ethernet, it shall support Web (HTTPS), Telnet, SNMP, SSH etc. access. PDU shall be connected to the ethernet network for remote monitoring.

2.5.11.1.9 PDU shall have at least three LEDs for General warnings, overload warning and power input status.

2.5.11.1.10 All the cabinet IT equipment power supply inputs shall be connected to the PDU's by the contractor. For devices with redundant power supply units each power supply unit input shall be connected to a different PDU.

2.5.11.1.11 PDU's shall be supplied and installed complete with all the usual & necessary accessories, feature and devices required for power supply of server cabinet mounted IT equipment.

2.5.11.1.12 Power cords supplied shall be enterprise grade rated for continuous operation at rated current at 40°C temperature. The cords conductor shall be stranded high grade electrolytic copper conductors at least 1.0mm2 thick.

2.5.11.1.13 Power cords shall be clearly labelled with Printed indelible PVC labels.

2.5.11.1.14 The PDU shall be enterprise grade designed for 24/7 operation at the following environmental conditions:

(a) Temperature: 0 to 50°C (continuous)

(b) Altitude: ≥ 1000mASL

(c) Installation location: indoor with natural aeration only

2.5.11.2 Minimum Specifications

PDU shall meet the following minimum specifications.

No	Feature	Requirements
1.	Type of PDU output connectors	IEC 60320/C13 (female)
2.	Number Output connectors	≥Sixteen (16)
3.	Nominal Voltage Rating	220–240V AC
4.	Input Voltage range	210–250V AC
5.	Input Frequency range	45–60Hz
6.	PDU continuous input current rating @ 40°C ambient temperature.	≥32A
7.	Overload protection	32A
8.	Maximum outlet current rating	≥12A
9.	Nominal power supply rating	≥7400W
10.	Mounting type	1U/2U rack
11.	Power outlet cord connector type	C13 to C14
12.	Power outlet cords continuous current rating @ 40°C ambient temperature.	≥10A
13.	Number of power cords to be supplied per PDU	≥sixteen (16) *(unutilised cables to be provided as spares)*
14.	PDU Operating temperature	0 to 50°C continuous
15.	PDU Enclosure & support brackets	Robust steel construction.

2.5.11.3 Product Certifications

(a) Device must be tested and approved for use in the EU or USA or Canada. Proof of testing and certification MUST be provided

(b) Product certification from an EU or USA or Canada reputable firm MUST be provided along with the bid.

2.5.12 Panel Cooling Ventilation Fans

2.5.12.1 General requirements

2.5.12.1.1 Dual redundant ventilation fans to be installed for exhausting excess heat from the cabinet where specified.

2.5.12.1.2 If specified in particular specifications the fans shall have control interface with tacho signal output integrated as standard, allowing the fan to be controlled and its speed monitored.

2.5.12.1.3 Shall be a roof exhaust unit for mounting on the top of the enclosure or panel mount for mounting on the doors.

2.5.12.1.4 Shall be made of Painted mild steel, and injection-moulded thermoplastic (ABS-FR) self-extinguishing, and flammability rating of V0 as per UL 94

2.5.12.1.5 Shall be supplied with an integrated filter including filter mat. Fan filter shall be designed for panel ingress protection of at least IP54.

2.5.12.1.6 Fan shall provide a forced Air flow of at least 680 m^3/h with filters.

2.5.12.1.7 Suitably rated MPCB to be installed for fan motor overload protection. Fan to be hardwired to the MPCB.

2.5.12.2 Minimum Specifications

No	Feature	Minimum Requirements
1	Air throughput without filters	≥900m^3/h
2	Air throughput with 1 outlet filter:	≥680 m^3/h
3	Air throughput with 2 outlet filters:	≥820 m^3/h
4	Rated operating voltage	200-240 V AC, 50/60 Hz
5	Dimensions W x H [mm]:	≤323 x 323
6	Required mounting cut-out W x H [mm]:	≤292 x 292
7	Storage temperature range:	-25°C to +70°C
8	Operating temperature (ambience):	-25°C to + 55°C
9	Protection category with fine filter mat	≥IP 54
10	Colour	RAL 7035

2.6 CONTROL DEVICES GENERAL REQUIREMENTS

2.6.1 Instruments/Transducers

2.6.1.1 General Requirements

2.6.1.1.1 Pressure sensors and transmitters shall be of corrosion proof material, degree of protection IP 54, and vibration class I (ISO 2372). Their scale shall indicate bar. The measuring pipe shall be equipped with stop chock. If the indicator is exposed to vibration, it shall be filled with damping liquid (glycerine).

2.6.1.1.2 Limit switches for pressure, temperature and flow (even if combined with the indicators) shall be of class 1, conforming to IEC 60536 without noticeable hysteresis. Where more than one limit is required, each limit shall be independently settable. Set points shall be easily readable.

2.6.1.1.3 Limit switches not mounted in enclosures shall be of the proximity type without need for separate power supply and equipped with light emitting diodes to indicate position where necessary.

2.6.1.1.4 Flow meters shall be graded in litres/s or M3/s from zero to 150% above required value. They shall be electronic without moving mechanical parts.

2.6.1.1.5 Electronic transmitters shall be rated for 24V DC unless otherwise specified

2.6.1.2 Resistance temperature detectors (RTD)

2.6.1.2.1 They shall be industrial grade PT 100 type protected to suit the environment where there are to be used.

2.6.1.2.2 They shall conform to the IEC 60751: 2008 Standard

2.6.1.2.3 They shall meet accuracy class B as per IEC 60751 i.e Class B = ± (0.30 + 0.005* t) for (-50 to 500°C). Accuracy of ±0.8˚C at 100˚C

2.6.1.2.4 Shall have an operating range of at least –200˚C to + 500˚C

2.6.1.2.5 Shall be wire wound with good vibration resistance

2.6.1.2.6 They shall either be four wire or three wire connection type. Two wire types SHALL NOT be accepted for any application.

2.6.1.3 Pressure transmitters

Digital pressure transmitters shall have a minimum of the following features: -

2.6.1.3.1 The pressure switch instrument shall be microprocessor based with key programming facility.

2.6.1.3.2 The instruments shall have relays with switching points (set point where the relay is activated) and switch-back points (set point where the relay is deactivated). The

instruments should also have precise pressure adjustments of 0.1bar.

2.6.1.3.3 Integrated pressure sensor with strain gauge on stainless steel membrane.

2.6.1.3.4 An accuracy of 0.5 % - 1 % full scale.

2.6.1.3.5 4-digit digital display for pressure value display to one decimal place.

2.6.1.3.6 The instruments shall have either

(i) Four (4) switching points & relays.

(ii) Two (2) switching points & relays.

(iii) Analogue 4 to 20mA output pressure signal

(iv) Combination of (i) & (iii)

(v) Combination of (ii) & (iii)

(vi) Analogue 4 to 20mA output signal & one (1) switch point CO relay

2.6.1.3.7 It shall be possible set to display values in bars as unit of measurement.

2.6.1.3.8 Instruments shall be ideal for frequent switching.

2.6.2 Indicating lamps and Push buttons & Selector switches

2.6.2.1.1 All status and position indication lamps shall be of the light emitting diode type and be replaceable without use of soldering or special tools. A switch for lamp test shall be put in all panels, neighbouring panels can be grouped together with one test switch.

2.6.2.1.2 All indication contacts shall be galvanic isolated and potential free.

2.6.2.1.3 Indicating lamp assemblies shall be of the switchboard type, insulated for 110 V DC service, with appropriately coloured lens and integrally mounted resistors for 110-volt service. The lens shall be made of a material, which will not be softened by the heat from the lamps.

2.6.2.1.4 For the Circuit Breakers, isolators and motors status indications, Red indicating lamps shall be used for "ON/CLOSED" position, green lamps for "OFF/OPEN" position Indication and Amber for Transition

2.6.2.1.5 For alarms/warnings, yellow indicating lights shall be used while for trips/faults, red indicating lamps shall be used

2.6.2.1.6 All semaphores SHALL be of LED type.

2.6.2.1.7 Emergency push buttons shall meet the following.

(a) Shall have a large red mushroom head.

(b) Shall be protected from accidental operation by a glass cover.

(c) Emergency push button shall remain latched when operated until reset.

(d) Resetting shall be done by twisting or rotating the button.

2.6.2.1.8 Illuminated pushbuttons shall consist of a command push button and a status LED lamp. The LED lamp shall indicate the status of the device/primary circuit commanded by the push button.

2.6.2.1.9 Discrepancy switches shall be used for operation of switchgear, they shall have the following specifications

(a) They shall be operated by Push, turn and control
(b) They shall have an integrated LED for position indication
(c) Shall be rated for 110V DC or 24 V DC depending on application
(d) Shall have a big knob made of transparent polycarbonate completely illuminated by a coloured LED inside.
(e) LED shall be lit depending on the position of the switch and the controlled device
(f) Each discrepancy switch shall at minimum have four (4) SPDT contacts

2.6.3 Control Contactor Relays

2.6.3.1.1 These relays shall be used for control and tripping purposes

2.6.3.1.2 They MUST meet ALL the following specifications:

(a) **Number Contacts**: 4poles 4 SPST OR 8 poles 8 SPST depending on application
(b) **Contacts current rating at 110VDC**: At least 3A
(c) **Magnetic coil voltage rating**: 24VDC/110VDC with a range of +/- 20%
(d) **Magnetic coil maximum power rating for closing and holding**: 4W
(e) **Structure**: Relays shall be a single unit i.e. without a separate base for mounting and shall have a capability to plug an auxiliary unit on top with 4 contacts poles (4 SPST)
(f) **Base unit**: Relay base unit shall have four contacts poles (4 SPST) and the operating coil
(g) **Auxiliary plug in unit**: relays shall have an auxiliary plug in unit with four contacts poles (4C/O)
(h) **Connection type**: screw-type terminals
(i) **Type of connectable conductor cross-section** (for auxiliary and control current circuit): at least 2X4mm2 solid conductors or 2X2.5mm2 stranded cores with bootlace.
(j) **Mounting type**: Snap-on mounting on a DIN rail
(k) **Size of relays**: S00
(l) **Resetting**: Relays shall be self-resetting
(m) **Protection class on the front**: IP20
(n) **Degree of pollution**: 3
(o) **Insulation voltage**: 690 V
(p) **Surge voltage resistance:** 6kV
(q) **Mechanical service life (switching cycles):** at least 30,000,000

2.6.3.1.3 These relays shall be provided with voltage free contacts for operating with

associated circuits. The contacts shall be amply rated for their A.C or D.C duty with snap action where possible and magnetic blow – out devices. Surge suppressor devices shall be provided across relays coils and contacts.

2.6.4 Coupling/Interfacing relays

2.6.4.1 General

2.6.4.1.1 These relays shall be used to isolate two systems at the same voltage or different voltages. Digital inputs and output Signals from and to the plant control system shall be coupled to the new systems via these relays where specified in the particular specifications

2.6.4.1.2 There shall be two types of coupling relays

(a) Highly compact micro-relay modules with 1 SPDT or solid state micro plug in relays

(b) Miniature interface auxiliary relays modules with 4 SPDT electromechanical plug in relays

2.6.4.2 Highly compact micro-relay modules (optocouplers)

2.6.4.2.1 Highly compact micro-relay modules shall be used to interface contact outputs or inputs between two systems using different common supply, for circuit isolation or wherever else it may be necessary as per design or particular specification

2.6.4.2.2 They shall consist of a power terminal block and a plug in micro relay

2.6.4.2.3 The power terminal block shall have the following general features:

(a) Integrated filter to protect against interference voltages or currents

(b) The housing shall be made of Polyamide PA non-reinforced

(c) Shall permit operating voltages of up to 250VAC

(d) Shall accommodated a solid state or electromechanical relay

(e) Permit a continuous current of 10 A

(f) Safe isolation according to DIN EN 50178 between coil and contact

(g) Screw connection terminals

(h) Support wide range of input voltages from 12 V DC to 230 V AC

(i) Shall have Integrated yellow LED and interference suppression circuit on the input circuit

(j) Output circuit Protection against polarity reversal and surge protection

(k) Support conductor cross section of 0.2 mm² ... 4 mm² for solid / stranded connections

(l) Contact material- AgNi

(m) Dimensions W / H / D - 6.2 mm / 80 mm / 94 mm or equivalent

(n) Insulation - input/output 4 kV (50 Hz, 1 min.)
(o) Ambient temperature (operation) - 20 °C ... 55 °C
(p) Mechanical service life - min 2 x 107 cycles
(q) Standards/regulations - IEC 60664, EN 50178, IEC 62103
(r) DIN rail mounting

2.6.4.2.4 Plug-in micro relays (electromechanical) shall have the following general features:

(a) Typical input current at rated voltage shall be within range of 3-7mA
(b) Shall have a response time of less than 5ms at rated voltage
(c) Contact material shall be made of silver nickel AgNi
(d) The contacts shall be double throw (SPDT)
(e) Switching voltage up to 250V AC/DC depending on the application
(f) Power contacts up to 16 A
(g) High degree of protection IP67
(h) Safe isolation according to DIN EN 50178 between coil and contact
(i) Dimensions W / H / D - 5 mm / 28 mm / 15 mm or equivalent
(j) Insulation - input/output 4 kV (50 Hz, 1 min.)
(k) Ambient temperature (operation) - 40 °C ... 85 °C
(l) Mechanical service life - min 2 x 107 cycles
(m) Standards/regulations - IEC 60664, EN 50178, IEC 62103

2.6.4.2.5 Plug-in solid-state relays shall have the following general features:

(a) Typical input current at rated voltage shall be within range of 3-7mA
(b) Shall have a typical switch-on time of 20µs at rated voltage
(c) Contact material shall be made of silver nickel AgNi
(d) Switching voltage up to 250V AC/125V DC depending on the application
(e) Contacts continuous current of up to 5 A
(f) High degree of protection IP67 and Vibration and shock-resistant
(g) Dimensions W / H / D - 5 mm / 28 mm / 15 mm or equivalent
(h) Insulation - input/output 2.5 kV (50 Hz, 1 min.)
(i) Ambient temperature (operation) - 25 °C ... 60 °C
(j) Standards/regulations - IEC 60664, EN 50178, IEC 62103

2.6.4.3 Miniature interface auxiliary plug-in relay modules

2.6.4.3.1 These relays shall be used for interface circuits where contact multiplication is required and other interfacing functions as per particular specification or design requirements

2.6.4.3.2 The relay module shall consist of a plug-in relay, socket and a holder

2.6.4.3.3 The relays shall have 4 c/o (4 SPDT) contacts rated 6 A continuous current

2.6.4.3.4 Rated coil voltage shall be 110VDC 0r 24VDC depending on application

2.6.4.3.5 Relay shall have gold contacts Cadmium-free

2.6.4.3.6 Shall have an integrated LED and freewheeling diode

2.6.4.3.7 Shall have Integrated test button for manual actuation and locking of output contacts

2.6.4.3.8 Relay Shall have clearly visible mechanical status indication

2.6.4.3.9 The socket shall have screw connection terminals.

2.6.4.3.10 The relay shall be held in place by a wide thick plastic holder

2.6.4.3.11 The Holder shall have Snap-on mounting on DIN rail

2.6.4.3.12 The socket shall not be wider than 27mm

2.6.4.3.13 Basic ratings:

(i) **Plug in relay**

Rated control supply voltage, Ur	24VDC or 110VDC
Coil Operating voltage	Ur ±20%
Coil power consumption	<1W
Output circuits	11-12/14, 21-22/24, 31-32/34, 41-42/44
Contact material	AgNi/Au 5 µm
Maximum switching voltage	250 V DC / 250 V AC
Contacts rated operational current	6A
Maximum switching (breaking) power	1500 VA
Contact resistance	≤ 100 mΩ
Mechanical lifetime	> 2 x 10^7 switching cycles
Electrical lifetime	> 10^5 switching cycles
operating time	<16ms
rated insulation voltage	>250VAC
Rated impulse withstand	
between coil and contacts	2.5 kV AC
between open contacts	1.5 kV AC
between c/o (SPDT) contacts	≥ 2 kV AC
Clearance between coil and contacts	≥ 1.6 mm
Creepage distance between coil and contacts	≥ 3.2 mm
Degree of protection	IP 40
Ambient temperature range	-40...+70 °C
Product standard	EN 60810-1, EN 60255-23, IEC 61810-7

(ii) **Socket**

Rated current	12A
Degree of protection	IP 20 B (EN 60529)
Temperature range	-40...+85 °C

Connection type	screw connection
Maximum number of wires per connecting terminal	2
Wire size with wire end ferule	2 x 1.5 mm^2
Wire size without ferule	2 x 2.5 mm^2
Mounting	DIN rail (EN 50022)
Socket Material	PA 6+GF - V2
contacts Material	CuZn33
contact surface	5 µ tinned
terminals	8 µ galvanized
combi screw M3	8.8 Steel, 5µ nickelized
Insulation voltage	> 3 kV
Isolation between coil and contacts	EN 61984
Clearance and creepage distance	EN 61984

2.6.5 Trip circuit/coil supervision relays.

2.6.5.1 Trip circuit/coil supervision relays shall be provided for circuit breakers trip circuit/coil supervision and Lockout trip relay circuit/coil supervision.

2.6.5.2 Trip circuit supervision relays shall have a time delayed drop off (100 millisecond minimum) and shall be provided with self-resetting indicators or approved equipment.

2.6.5.3 Monitoring of breaker trip coil in both open and close position shall be provided.

2.6.5.4 Relays will have green LED which will light when circuit is okay

2.6.5.5 Relays shall have a minimum of two SPDT heavy duty contacts with at least 3A continuous current rating at 125V for interface to existing control and automation system.

2.6.5.6 The relay shall be designed and have rugged construction for reliability / dependability over a wide temperature range, even under extreme environmental conditions.

2.6.5.7 The supervision current shall always be less than 1.5 mA to avoid unwanted operation of the trip coils.

2.6.5.8 Shall be panel mounted, flush mounted on the front of the panel with connections from the rear.

2.6.6 DC Supply supervision relay

2.6.6.1 The relay shall be capable of monitoring the DC supply to which it is connected and indicating failure. It shall have at least 4NC potential free contacts

2.6.6.2 The relay shall have a `time delay on drop-off' of not less than 100 milliseconds and be provided with operation indicator/flag/LED clearly visible. Green LED shall be lit on the relay when supply is available and okay

2.6.6.3 The relay shall detect supply DC failure after DC voltage falls below 70–90% (dependent on application) rated or exceeds 120% rated for a time exceeding 100ms.

2.6.6.4 Green colour supervision lamps of clustered LED type shall be provided on the panel to indicate availability of healthy DC supply.

2.6.7 AC Voltage monitoring relays

2.6.7.1 They shall monitor under and over voltage in each phase for a three-phase relay. There shall be a dial for setting the under-voltage level and another dial for setting the over voltage level.

2.6.7.2 They shall detect Phase failure from over or under voltage as described above or from frequency failure and output an alarm

2.6.7.3 They shall monitor Phase sequence and output an alarm in case of failure

2.6.7.4 They shall have an Adjustable hysteresis for output contact drop off or pick up

2.6.7.5 They shall have an Adjustable time delay for output contact drop off or pick up

2.6.7.6 Shall have at least four (4) SPDT contacts

2.6.7.7 Shall have at least three status indication LED's. They shall have a green LED for healthy status, yellow LED status for unhealthy status and a blinking LED for time delay.

2.6.8 Panel Indication meters

2.6.8.1 General requirements

2.6.8.1.1 All Panel mounted instruments and meters shall be flush-mounted, back-connected, dust-proof and heavy-duty. They shall have a removable cover, either transparent or with a transparent window.

2.6.8.1.2 Panel indication shall be of digital type unless where specified in particular specifications.

2.6.8.2 Analogue panel indication meters

Where Analogue panel meters are specified, they shall have at minimum the following features:

2.6.8.2.1 scale plates shall be of a permanent white circular or rectangular finish with black pointer and markings,

2.6.8.2.2 shall have a clear transparent non-reflective window and clearly readable long scale.

2.6.8.2.3 Shall be of accuracy class 1.5 or better, the maximum error shall be not more than one and a half (1.5) percent of full-scale range.

2.6.8.2.4 Their cut out shall be DIN standard 1/4DIN, or 1/8 DIN.

2.6.8.3 Digital Panel Indication Meters

2.6.8.3.1 There shall be four types of digital panel meters depending on inputs, these are:

(a) Digital indication meter for Instrument/process signals with a 4-20mA DC

current input

(b) Digital DC voltmeter/Ammeter with a DC input voltage whose range is selectable and an external shunt for DC current ammeter.

(c) Digital AC ammeter with an AC current input from a CT

(d) Digital AC voltmeter with an AC voltage input (phase-phase or phase-neutral)

2.6.8.3.2 The meters shall site programmable/configurable for scaling, range set up etc. They shall have at least three buttons on the front for this purpose.

2.6.8.3.3 Indication meters shall meet or exceed accuracy Class 1, according to IEC 62053-11.

2.6.8.3.4 Display **MUST** have at least 5-digit characters sized at least 14mm for all digital meters.

2.6.8.3.5 They shall be panel mounted, flush mounted on the front of the panel with connections from the rear.

2.6.8.3.6 They shall have buttons and menu for configuring their parameters such as

(a) Input range

(b) Output range

(c) VT/CT ratio

(d) Scaling factor

2.6.8.3.7 They shall meet the following minimum specifications.

(i) Inputs and accuracy range

Input Range	Resolution	Input Resistance	Error at 25°C
DC Current for digital Instrument/process signals indication meters			
±20.000 mA	1.0 µA	10 Ω	0.01% FS ± 2 counts
DC Voltage for digital DC voltmeter/Ammeter			
±200.00 mV	10 µV	1 GΩ	0.01% FS ± 2 counts
±20.000 V	1 mV	10 MΩ	0.01% FS ± 2 counts
±300.00 V	10 mV	10 MΩ	± 0.4 V
AC Current for digital AC ammeters			
0-5.000 A	1 mA	0.01 Ω	± 20 mA
AC Voltage for digital AC voltmeter			
0-300.0 V	100 mV	1 MΩ	± 0.8 V
0-600.0 V	100 mV	1 MΩ	± 0.8 V

(ii) Display

Readout	5 LED digits, 7-segment, 14.2 mm (.56"), red or
Range	-99999 to 99999

Indicators	Minus sign, decimal point,2 red LED lamps (configurable)
Display update rate	3 per second

(iii) A-to-D Conversion

A-to-D rate	>50 per second
Output update rate	
Signals > 50 Hz	>50 per second
Signals >3 to 50Hz	Signal frequency
Signals > DC to 3 Hz	3 per second

(iv) Maximum input Signal

Max applied voltage	600 VAC for 20, 200 and 300 V ranges, 125 V AC for other ranges
Current protection	8x for 20 mA, 1x for 5 A

(v) Power supply

Voltage range	85-264 VAC or 90-300 VDC
nominal	110VDC ± 20%,
Consumption	less than 3VA

(vi) Excitation Output (if specified in particular specifications)

level	24 VDC ± 5%, 50 mA
Output isolation	50 VDC to meter ground

(vii) Analog Output (if specified in particular specifications)

Output levels	4-20 mA, 0-20 mA, 0-10V, -10 to +10V (jumper selectable)
Scaling	Zero and full scale adjustable from -99999 to +99999
Resolution	16 bits (0.0015% of full scale)
Isolation	250V RMS working, 2.3 kV RMS per 1 min test

(viii) Relay Outputs (if specified in particular specifications)

Relay types	Two independent SPDT relays
Current ratings	8A at 250 VAC /24 VDC
Output common	Isolated commons for each SPDT relay
Isolation	250V RMS working, 2.3 kV RMS per 1 min test

(ix) Serial Data I/O (if specified in particular specifications)

Interface	RS485, RJ45 or terminal block connection.

Protocols	Modbus RTU
Data rates	300 to 19200 baud
Isolation	250V RMS working, 2.3 kV RMS per 1 min test

(x) Environmental

Operating temperature	0°C to 55°C
Storage temperature	-40°C to 85°C
Relative humidity	95% at 40°C, non-condensing
Ingress Protection	IP65

(xi) Dimensions

panel Cut-out	1/8 DIN 92mm X 45mm OR 1/4 DIN 92mm X 92mm depending on particular specifications or design requirement
Front dimensions	96mm X 48mm OR 96mm X 48 mm depending on particular specifications or design requirement
Device overall depth	less than 125mm without the connections

(xii) Connections

Type	Screw type
wire size	2X2.5mm2

2.6.9 Microprocessor Based Controllers

2.6.9.1.1 Microprocessor Based Controllers Inclusive of Programmable Logical Controllers (PLC) can be used for control functions. Such equipment shall be designed for industrial environment and application in high voltage plants. The control equipment must be fed from the general station DC supply.

2.6.9.1.2 The control equipment must be equipped with internal “watchdog” function giving external potential free alarm for internal faults. The operational status shall be frozen by fault or abnormal function so it can be re-established after restart. The process must be shut down to a safe stage if fatal faults occur in the controller.

2.6.9.1.3 Analogue and digital inputs and outputs must be galvanic isolated and potential free and must, together with the enclosure, screen against disturbance from electromagnetic field occurring by short-circuit, switching over voltages or lightning discharges. The control equipment shall be tested according to IEC 60255 and fulfil relevant EMC requirements for Industrial Environment.

2.6.9.1.4 Digital inputs and outputs shall be tested and approved for switching of DC

voltages supplied by the main plant battery (AC values are irrelevant).

2.6.9.1.5 Control Programmes shall be stored in non-volatile memory or similar storage medium and shall not be destroyed or changed by power failure (i.e., Separate backup battery shall not be used). The memory shall contain the last program version and the defined initial values.

2.6.9.1.6 All programming of control sequences shall be documented in a self-explanatory way not requiring special program knowledge for understanding (function block programming or similar)

2.6.9.1.7 Communication between various controllers must use open protocols to be approved by the Project Manager.

2.6.9.1.8 The Controllers shall be delivered with software and software licences needed for testing, setting ad reconfiguration. If hardware other than laptop is required for this such shall be included in the supply.

2.6.10 Industrial Ethernet switches

Shall meet the following requirements.

2.6.10.1.1 Rugged Rated for reliability in harsh environments

(a) Immunity to EMI and heavy electrical surges

(b) Zero-Packet-Loss Technology

(i) Meets IEEE 1613 Class 2 (electric utility substations)

(ii) Exceeds IEC 61850-3 (electric utility substations)

(iii) Exceeds IEC 61000-6-2 (generic industrial)

(c) -40° C to +85° C operating temperature (fan less)

(d) Ingress Protection of at least IP40

(e) 18 AWG (1.27mm) galvanized steel enclosure

(f) Shall not contain moving parts e.g., fans

2.6.10.1.2 Shall be DIN/rack or panel mounted.

2.6.10.1.3 Shall have 24V/48V/110V DC supply unit with terminal block connections

2.6.10.1.4 Shall have a critical alarm relay with at least one SPDT contact

2.6.10.1.5 Compliant with IEC 61850-9-2 Sampled Values and IEC 61850-8-1 GOOSE Message

2.6.10.1.6 Compliant with IEE 802.3, 802.3u, 802.3x, 802.3ab, 802.1d, 802.1p, 802.1Q, 802.1Q-2005, 802.1w', Link Aggregation etc.

2.6.10.1.7 Store & Forward switching method with Switching latency not exceeding10.5 µs

2.6.10.1.8 Shall be a managed switch with Operating System supporting the following features.

(a) Simple plug-and-play operation – automatic learning, negotiation, and crossover detection
(b) MSTP 802.1Q-2005
(c) RSTP (802.1w) and Enhanced Rapid Spanning Tree
(d) eRSTP network fault recovery
(e) Quality of service (802.1p) for real-time traffic
(f) Port rate limiting
(g) Port configuration, status, statistics, mirroring, security
(h) SNTP time synchronization (client and server)
(i) Web-based, SSH, CLI management interfaces
(j) SNMP v1/v2/v3
(k) Remote monitoring (RMON)
(l) Rich set of diagnostics with logging and alarms

2.6.10.1.9 Operating System shall support the following Cyber security features

(a) Multilevel user passwords
(b) Secure File Transfer Protocol (SFTP) using SSH
(c) Web-based management using SSL
(d) RADIUS-Authentication service for device management
(e) 1024-bit RSA encryption for key management and key exchange
(f) Integrated router/firewall/VPN.
(g) Full IPsec virtual private networking.
(h) VPN with 3DES, AES128, AES256 support.
(i) Enable/disable ports,
(j) MAC-based port security.
(k) Port-based network access control (802.1x);
(l) VLAN (802.1Q) to segregate and secure network traffic.
(m) SNMPv3 encrypted authentication

2.6.10.1.10 Precision Time Protocol (PTP) support (where specified).

(a) Shall support time synchronisation on all the ports at an accuracy exceeding 1µs
(b) All ports shall support transparent clock, slave clock or master clock time synchronisation features as per IEE1588 v2.

2.7 PANELS AND CABINETS

2.7.1 Industrial Grade Cabinets

2.7.1.1 General requirements

2.7.1.1.1 Panels and cabinets shall be of robust construction, formed of a steel frame and covered with smooth steel plate. The steel plate shall be folded sheet steel of not less than 2.0mm thick and properly stiffened to prevent distortion. Panels shall normally be covered at their rear with hinged doors. The frames of the boards and panels shall be designed to permit firm anchoring on the floor. The frames shall permit easy erection, and allowance shall be made for extension of the board by similar additional panels. All enclosures shall be ventilated so that the temperature inside the enclosure does not rise more than 5deg Celsius above ambient even with possible heaters connected.

2.7.1.1.2 All Equipment and materials for use in Switchboards, panel and cabinets shall not be flammable and shall be self-extinguishable and resistant to flame propagation. All plastic materials to be used in the panels shall have flammability rating of at least V-0 as per UL 94.

2.7.1.1.3 Outdoor-cabinets and cabinets for moist environments shall be provided with thermostat-controlled heaters to inhibit collection of moisture. The heater must be arranged not to overheat any cables or equipment. Openings for drainage of condense shall be provided at the lowest point in the cabinets.

2.7.1.1.4 Panels and other enclosures shall be designed with an ingress protection suitable for the equipment mounted inside. However, as a minimum all outdoor panels and cubicles shall have IP rating of 55 or higher and for indoor panels and cubicles IP rating of 54 and higher.

2.7.1.1.5 All major or important compartments containing electrical equipment shall be provided with a single phase 16 A square pin socket and internal LED lighting facilities switched off by a door switch.

2.7.1.1.6 Unless otherwise specified or agreed upon, all instruments, apparatus and devices on the panel fronts shall be provided for flush mounting. Panels with flush mounted devices shall be provided with transparent cover. The cover shall be a hinged to allow resetting and adjustment. All terminals and all equipment shall be accessible without dismantling other components. Equipment shall not be mounted in swing-out doors. However, proper swing out frames may be used provided they can be opened will full load without twisting or distorting the panel. Windows shall be provided in front of rack mounted equipment.

2.7.1.1.7 All panels shall be provided with LED Lamp lighting fixture rated for 240V AC/110V DC/24VDC supply, controlled by panel door switch and fuse. The number of such LED lighting fixtures shall be at least two per panel.

2.7.1.1.8 All panels, boards and cabinets doors shall be provided with handles and key operated locks. All doors and removable covers shall be gasketed all round with neoprene gaskets, ventilating louvers with screen and filters.

2.7.1.1.9 The panel shall be provided with 240V, 50Hz. 15 A, 3 pin British type universal socket with switch. The socket with switch shall be mounted inside the panel at convenient location.

2.7.1.1.10 The new panels, cabinets and switchboards shall be constructed to fit in the existing space where the current panels, boards & cabinets are located with cable entry from bottom.

2.7.1.1.11 They shall have easy access to the wiring inside through the rear side of the panel.

2.7.1.1.12 The panels shall be factory wired with the reception terminal blocks for connection to the instrumentation transformers, circuit breakers tripping coils, alarm circuits and plant equipment.

2.7.1.1.13 The panels shall be mounted on approved form of anti-vibration mounting.

2.7.1.1.14 Relays, electronic modules/cards, and devices shall be identified with labels permanently attached to the device.

2.7.1.1.15 All relays shall be firmly supported on their bases to avoid mal-operation due to vibrations when the unit is running.

2.7.1.1.16 Printed circuit boards SHALL NOT be mounted on the panels. All printed circuit boards shall be contained in enclosures with an ingress protection of at least IP20 with terminal blocks and ports on the enclosures for interface.

2.7.1.1.17 The bottom of the panels shall be sealed by means of removable gasketted steel plates. Gland plates for the bottom entry shall be at 100mm above the floor

2.7.1.1.18 A base plate for each panel shall be provided not exceeding 10cm in height.

2.7.1.1.19 All panels shall incorporate a common internal copper Earthing bar onto which all panel earth connections shall be made. Suitable stud or holes with the right screws shall be provided for connection to the main earth.

2.7.1.1.20 Appropriate eye bolts shall be provided to facilitate for easy lifting of the panels.

2.7.1.1.21 Panels and switchboards shall be labelled on the front and back at the top.

2.7.1.1.22 Marshalling cabinets, panels or boxes containing terminal blocks only shall be at least 400mm wide with a hinged door/s.

2.7.1.1.23 Device tagging shall be as per ISO/IEC 81346 and VGB RDS PP standards.

2.7.1.1.24 Terminal identification shall be as per IEC 61666.

2.7.1.1.25 All ethernet ports of all equipment mounted in the cabinets shall be connected to the patch panels using STP patch cords. Ethernet connections between devices on the cabinets shall be via patch panel ports but not directly between device to device except for fibre optic patch cords which may be connected directly between devices.

2.7.1.2 Wiring

2.7.1.2.1 All panel internal wiring shall be stranded flexible copper conductor with, suitable for operation at voltages below 1000 V and in compliance with the provisions of the applicable IEC Recommendations. Conductors shall not be smaller than 2.5 mm² for current & voltage transformer circuits and 1.0mm² for all other control circuits. The selection of conductor sizes for current transformer circuits shall be supported by calculations.

2.7.1.2.2 Wire runs shall be neatly arranged in trunks and properly clamped Wiring shall be securely supported, neatly installed by lacing and tying, readily accessible and connected to equipment terminals and terminal blocks. Flame retardant, plastic wiring channels/troughs with strap on plastic covers shall be used for this purpose. Sufficient space in channel for modification of wiring shall be kept. For wiring within boards, the "bunch" pattern shall be adopted. Ample space shall be provided for running of cable within the enclosures.

2.7.1.2.3 The screens or screened pairs of multicore cables shall be earthed in accordance with a coherent Earthing philosophy to be worked out by the Contractor and approved by the Project Engineer. The screen and earth wires shall be terminated in terminals dedicated for this use. All free conductors in connecting cables shall be terminated in terminals that shall be temporarily connected to earth and special marked as specified in proceeding clauses.

2.7.1.2.4 All conductors cross section must be checked against max load current, allowable burden on measuring transformers, short circuit values, voltage drop, protection requirements and selectivity. Conductors however shall have minimum cross sections as follows:

(a) Measuring cables from VT & CT output - 2.5 mm2
(b) Control and other measuring cables - 1.0 mm2
(c) PLC wiring - 0.5 mm2
(d) Power cables according 120 % max load current with a minimum of 2.5 mm2
(e) Analogue signal cable-shielded twisted pairs-0.75mm2
(f) Networking cables- shielded twisted pairs -cat6A.

2.7.1.2.5 The standard phase colours for AC supply conductors including CT & VT output are Brown for L1 phase, Black for L2 phase, Grey for L3 phase, blue for neutral and Green with yellow stripe for Earth/ground wires as per relevant recent IEC standard.

2.7.1.2.6 For auxiliary DC Supply, Red for Positive and White for negative. Conductors for instrumentation and control signals shall be coloured according to DC voltage, source, and function. To differentiate DC wiring a coherent method of wire colour

identification shall be developed for the project and approved by the employer. Colours specified for AC circuits shall not be used for DC circuits.

2.7.1.2.7 Multi-stranded conductor ends shall be fitted with a suitable crimped thimble (bootlace ferrule type). The thimble shall be of correct type and length according to the core size and crimple tools shall be specially adapted to the thimble and cross section used. Each wire shall be separately terminated unless otherwise approved.

2.7.1.2.8 All connections shall be made at numbered terminal blocks; joints, splicing or paralleling of wires will not be accepted.

2.7.1.2.9 Accidental short circuiting of certain wires is likely to result in malfunction of equipment, such as closing or tripping of a breaker or positive and negative wires, these wires shall not be terminated on adjacent terminal blocks.

2.7.1.2.10 It shall be possible to work on small wiring for maintenance or test purposes without making a switchboard/panel dead.

2.7.1.2.11 Wire termination shall be made with solder less crimping type of tinned copper lugs which firmly grip the conductor. Insulation sleeves shall be provided at all the wire terminations.

2.7.1.2.12 Engraved core identification plastic labels, factory marked to correspond with panel wiring diagram shall be fitted at both ends of each conductor. Wire labels shall fit tightly on the wire and shall not fall off when the wire is disconnected from terminal blocks. These markers shall be of an approved type attached to the conductor insulation.

2.7.1.2.13 The wire numbers shall be a combination of source device tag: terminal and destination device tag: terminal.

2.7.1.2.14 The wire labels shall be factory numbered, indelibly marked by engraving with black letter on a white background PVC casting. All wires directly connected to trip circuit breaker or devices shall be distinguished by white letter on a red background PVC casting.

2.7.1.2.15 The method of wire labelling shall be subject to approval by the Employer; Wire label shall contain both origin device/terminal block terminal Number and destination device/terminal block terminal. If single numeric digit ferrule is to be used Number 6 and 9 shall not be used

2.7.1.2.16 The unused space on the front or rear of the panels shall be kept clear of wiring to facilitate addition of devices without rewiring associated portion of the panels.

2.7.1.2.17 The contractor shall be responsible for the completeness and correctness of the internal wiring and for the proper functioning of the connected equipment.

2.7.1.3 Phase arrangement

The standard phase arrangement when facing the front of the panel shall be L1-L2-L3-N, and L-N from the left to right, from top to bottom, and front to back for A.C three-phase and single-phase circuits. For DC circuit it shall be N-P from left to right, P-N from top to bottom and front to back. All relays, instruments, other devices, buses and equipment involving three-phase circuit shall be arranged and connected in accordance with the standard phase arrangement wherever possible.

2.7.1.4 Terminal blocks

2.7.1.4.1 General requirements

(a) All panel wiring shall terminate at terminal blocks, the terminal blocks shall be of the moulded type and provided with barriers to separate power from control cables. It shall be possible to replace a single terminal block without dismantling a whole column. They shall be clearly marked, the designations being those entered in the respective wiring diagrams. ALL terminal blocks shall be capable of receiving 2.5mm2conductors.

(b) Only one conductor shall be connected to each side of a terminal block and the branch-offs shall be made by interconnecting the necessary number of neighbouring blocks by means of shorting plugs.

(c) Terminal blocks using screws acting directly on the wire (conductor) as well as spring type terminal blocks are NOT acceptable. To avoid squeezing of the wire the screw pressure shall be applied by a pressure plate having smooth edges. 'OBA' terminal blocks are not acceptable. Only terminal blocks that are operated using screw drivers are acceptable.

(d) Terminal blocks for different voltages SHALL NOT be mixed between one another. All conductors in a multi-core cable shall be terminated on the same terminal block column if they are of the same voltage. The blocks shall be grouped for each voltage, and they shall be clearly marked for easy identification of the system voltage. Terminations on T.B. shall be grouped function wise on one region of T.B. (may not be full T.B)

(e) There shall be at least 20 % spare terminal blocks on each block.

(f) All spare contacts/terminals of the panel mounted equipment and spare cores/conductors of cables terminated in a panel shall be wired up to terminal blocks with ferrule numbers starting with U.

(g) Moulding materials making up the terminal blocks shall be self-extinguishing or resistant to flame propagation, substantially non-hydroscopic and shall not carbonized when tested for tracking. The insulation between any terminal and framework between adjacent terminals

shall with stand test of 2kV RMS for one minute. The moulding shall be mechanically robust to withstand handling while making terminations.

(h) Terminal blocks shall be located at least 300mm from the bottom of the panel and shall be easily accessible. All terminal blocks shall be vertically oriented in a panel; horizontally aligned terminal blocks shall NOT be accepted. Marshalling Panels containing terminal blocks only shall be at least 400mm wide.

(i) Each Individual Terminal Block shall be marked with a distinctive Number, which shall be the same Number used in the drawings, for identification purposes. The TB number shall be engraved in black numbers in white background.

(j) Each set of terminal Block shall be identified by a label to distinguish it from another set of terminal blocks with similar Numbers for the individual terminal blocks. The labels used will match those used in the drawings.

2.7.1.4.2 Terminal blocks for control circuits

(a) Shall be used for all control/metering/protection circuits (all other circuits apart from those described in clause 3.6.4.2 rated up to 125V DC wiring:

(b) Shall be rated as follows:

(i) Voltage: ≥600V AC,

(ii) Continuous current rating @ 40˚C ambient: ≥16 A,

(iii) Rated impulse withstand voltage: ≥6KV

(iv) Cross sectional area: ≥6mm2

(c) Shall have a Knife disconnect/isolator between the wire terminals

(d) Shall have two slots on both sides of the knife disconnect for inserting shorting plugs or “banana” test plugs.

(e) Each terminal block shall have two terminals for wire connections on each side of the terminal block i.e., four connections per terminal block

(f) Shall be suitable for connecting multi-stranded conductors of cross-sectional area of 1 mm2 – 4mm2 with edge processing (bootlace)

2.7.1.4.3 Power terminal blocks

(a) Shall be used for single phase and three phase power feeder circuits rated below 150A.

(b) Shall be rated as follows:

(i) Voltage: ≥1000V AC,

(ii) Continuous current rating @ 40˚C ambient: 75–250 A,

(iii) Rated impulse withstand voltage: ≥8KV

(c) Shall be flame resistant and suitable for operating voltages of 1kV.

(d) Shall consist of threaded studs and nuts M4-M12, partition plates and covers. Cable lugs (eye/horseshoe) shall be used to terminate the cables to the power terminal blocks

(e) Nuts shall be locknut, locking nut type that can resist vibrations

(f) The conductors shall be attached to the terminals using crimped cable lugs. Each connection shall be secured by tightening the hexagonal nut. The cable lugs shall be put between the washers on the clamp support.

(g) The terminals shall have an integrated hinge cover, with a high degree of finger safety. When closed, the cover shall lock onto the terminal and protect the contact from accidental contact.

(h) Neighbouring terminals shall have Shock protection provided by partition plates. The cover strips shall be locked into the guides of the partition plates and held with clips to prevent them slipping to the side.

(i) Shall be suitable for connecting conductors of cross-sectional area 2.5mm^2 – 50mm^2.

(j) Circuits rated over 150 A shall use bus bar connections and not terminal blocks.

2.7.1.5 Labelling

2.7.1.5.1 All Panels, switch boards, cubicles, and all front mounted equipment as well as equipment mounted inside the panels shall be provided with individual labels with equipment designation engraved for identification. The labels or escutcheon plates shall be mounted directly above the respective equipment with English description and also where appropriate the Device tag as per ISO/IEC 81346 and VGB RDS PP standards

2.7.1.5.2 The Device Name/Number shall correspond to the Name/Number used in the drawings. All panel devices shall also be provided tag numbers corresponding to the ones shown in the panel internal wiring drawing to facilitate each tracing of wiring. These labels shall be mounted directly by the side of the respective equipment and shall not be hidden by the equipment wiring.

2.7.1.5.3 Labels shall be made of Aluminium anodized plate or plastics suitable for electrical panel labelling e.g., traffolyte, PVC etc. The Material shall meet UL flammability rating. The plates shall be made of weatherproof and corrosion-proof materials and shall not be deformed under the service conditions at the site.

2.7.1.5.4 The entries on the plates shall be indelibly marked by engraving with black letter on a white background or vice versa or as agreed during design.

2.7.1.5.5 All devices e.g., relays, timers, MCB's, instruments etc. shall be given tags as per

ISO/IEC 81346 and VGB RDS PP standards with name of device, corresponding to the ones shown in the panel internal wiring drawings.

2.7.1.5.6 Major equipment shall be provided with a rating plate containing the necessary information specified in the relevant IEC standards.

2.7.1.6 Auxiliary Supply

2.7.1.6.1 Contractor shall reconnect the existing AC / DC supply for Switches, Panel illumination, space heater etc. and supplies for control and protections of existing panels. Where deemed necessary a fresh connection shall be made from the power distribution boards, the contractor shall be expected to supply cables and associated switchgear e.g., circuit breakers where necessary.

2.7.1.6.2 Devices and equipment shall be suitable or adopted for 110V (±20%) DC supply and 240V/415V (±10%) AC supply which is existing at the station.

2.7.1.7 Earthing (Grounding)

2.7.1.7.1 There shall be exposed and accessible earthing bars in all panels connected to the existing station Earthing/grounding system. Cables shall be earthed and shielded in accordance with earthing philosophy worked by contractor. All connections between equipment and the Earthing network shall be exposed (not embedded) and easily accessible for checking of the transition points.

2.7.1.7.2 Contractor shall take the necessary measures and furnish the required material for the safe Earthing of:

(a) All steel structures, metal parts and overhead ground wires.

(b) All metal parts, even if these do not constitute a conducting part of an electric system of the plants, such as machinery, operating desks, piping, sewers, rails, metal tanks, lighting, fixtures, cable racks, etc.

(c) All operational electric systems such as power and instrument transformers, lightning arresters etc.

2.7.2 IT Server cabinets

2.7.2.1 General requirements

2.7.2.1.1 42U Rack type free standing cabinet

2.7.2.1.2 Colour shall be either be:

(a) RAL 7035 - light grey or

(b) RAL 9005 fine texture - black or

(c) Graphite Metallic equivalent

2.7.2.1.3 Cabinet dimensions shall be within the limits below:

(a) Height: 2000mm – 2300mm

(b) Width:600mm–1000mm

(c) Depth:950mm–1200mm

2.7.2.1.4 Cabinet Shall have:

(a) Perforated sheet steel front door.

(b) Split(double), perforated sheet steel rear doors,

(c) Multi-piece roof plate for side cable entry on both sides,

(d) Open base frame, without side panels.

(e) Two 482.6 mm (19") vertical mounting rails, front, and rear, on depth stay.

(f) Side panels, two-piece with quick-release fastener, security lock

(g) Accessories such as tool-free “snap-in technology” options for air flow, cable management, shelves, power distribution units and all other necessary and specified accessories

(h) All unutilised mounting racks shall be blanked from the front with easily removable blanking plates.

2.7.2.1.5 The following devices shall be provided and installed on the panel

(a) Two (2) sets of keys (front and rear)

(b) Top mounted roof exhaust cooling fans

(c) Roof exhaust cooling Air throughput ≥750m3 /h

(d) Roof exhaust cooling fan mounting size ≥290mmX290mm.

2.7.2.1.6 All panel mounted equipment shall be labelled using Aluminium anodized plate or engraved plastic Castings as detailed in clause 2.7.1.5 and 2.2.7

2.7.2.1.7 Terminal blocks shall be provided for all electrical wiring meeting requirements of clause 2.7.1.4

2.7.2.1.8 All equipment in the cabinet electrical wiring terminals shall all be wired to terminal blocks

2.7.2.1.9 All ethernet ports of all equipment mounted in the cabinets shall be connected to the patch panels using STP patch cords. Ethernet connections between devices on the cabinets shall be via patch panel ports but not directly between device to device except for fibre optic patch cords which may be connected directly between devices.

2.7.2.2 Frames

2.7.2.2.1 Frame shall be made of sheet steel metal plate of at least 1.5 mm in thickness

2.7.2.2.2 Shall consist of pre-configured rack consisting of Torsional stiff, welded symmetrical frame of rolled 16-fold vertical members connected with two horizontal frames of rolled 9-fold members with integral channel for accommodating the adjacent panel seal and protecting it against possible effect of aggressive media.

2.7.2.2.3 All frame members, with integral system holes on a 25 mm DIN pitch pattern, allow convenient interior installation by simple fitting and securing of equipment. All sections have chamfered edges. The vertical frame members each have two depth-recessed horizontal mounting rails that can be used for flexible attachment of installation components.

2.7.2.2.4 Enclosures are bay-able on all sides: on the left, right, front and rear and at the top or round corners.

2.7.2.2.5 Baying of cabinets shall be accomplished without disturbing any installed cables or rack mounted equipment

2.7.2.2.6 Baying of cabinets shall be easily accomplished with simple tools

2.7.2.2.7 Baying cabinets will not add any additional overall width to a contiguous row.

2.7.2.3 Front Door

2.7.2.3.1 Sheet steel front door with a specific honeycomb perforation, vented surface area, 85% perforated.

2.7.2.3.2 Four-point locking rod, comfort handle for semi-cylinder, with security lock.

2.7.2.3.3 Four hinges, with captive hinge pins, hinge opening angle with stand-alone siting 180°, door hinge may be swapped to opposite side without dismantling locking rods.

2.7.2.4 Rear Door

2.7.2.4.1 Sheet steel rear doors, vented, vertically divided, for space-saving installation of the enclosures and easy access to the components.

2.7.2.4.2 Specific honeycomb perforation, vented surface area, 85% perforated. doors with foamed-in seal.

2.7.2.4.3 Main door with four-point locking rod, comfort handle for semi cylinder, with security lock.

2.7.2.4.4 Adjacent door with additional internal swing lever handle and two-point locking rod.

2.7.2.4.5 Main and adjacent door with four hinges, hinges with captive hinge pins, hinge opening angle with stand-alone siting on both sides 180°.

2.7.2.5 Roof

2.7.2.5.1 Multi-piece roof plate across the entire enclosure depth.

2.7.2.5.2 Cable entry outside the mounting rails is possible

2.7.2.5.3 Cut-out for accommodating a fan module integrated in the roof.

2.7.2.5.4 Panel cooling fan to be mounted with ratings as specified in the proceeding clauses.

2.7.2.6 Base plate

2.7.2.6.1 Open base frame, gland plates, and other accessories for cable termination to be provided.

2.7.2.7 Mounting Rails

2.7.2.7.1 With two 482.6 mm (19") vertical mounting rails, front and rear. The static total load capacity of both mounting rails shall be at least 15,000 N.

2.7.2.7.2 Universal mounting rails shall support installation of industry standard 19” rack mount server, network and electronic components, infinitely depth variable attached to depth stays.

2.7.2.7.3 The attachment of the mounting rails shall be flexible and tool-less using quick release fasteners or screw-fasteners as an alternative.

2.7.2.7.4 Mounting rails, front and rear, including additional pitch pattern of holes according to standard EIA 310 E.

2.7.2.7.5 All height units shall be labelled and numbered in the opposite direction. U labelling of both mounting rails shall be readable from the front for easy one-man assembly.

2.7.2.7.6 Each U space shall be marked on the middle hole of each U. Each U shall consist of three holes and measure 1.75" or 44.45 mm high. Each U space marking shall be printed, not adhesive backed.

2.7.2.7.7 All depth stays with integral pitch pattern for fast determination of the mounting distance and the remaining front free space (clearance).

2.7.2.7.8 19" mounting rails shall have two additional sets of mounting holes, shall match hole pattern of the frame and allow for the installation of various accessories, i.e. vertical cable management, horizontal cable management, power strips, etc.

2.7.2.7.9 Front mounting rails, prepared for tool-less accommodation of cable routing aids and organization of a structured cabling in maximum packaging density or for equipment with a sensor strip for automatic identification of the installed components by means of Radio Frequency Identification (RFID).

2.7.2.7.10 Rear mounting rails prepared for two-sided accommodation of a Power Distribution Unit (PDU) in 1 U form factor for enclosure electrification, without waste of installation volume thanks to space-saving side mounting between mounting rail and side panel in the Zero-U space.

2.7.2.7.11 Enclosures widths equal to or greater than 28"/700 mm allow for 19", 21", and 23" rack mounting of components and/or allow for the offsetting of 19" rails, left or right, to allow for additional cable management and air plenum space.

2.7.2.8 Grounding

2.7.2.8.1 All enclosure components such as doors, sidewalls, roof, etc. Shall be bonded directly to the frame Grounding points.

2.7.2.8.2 A copper busbar shall be mounted on the cubicle for grounding the electrical equipment.

2.7.2.8.3 Conductors of 4 mm^2 diameter and a central ground point for connection to the building service connection shall be provided

2.7.2.8.4 The mounting rails shall be connected to the frame by 4 mm conductors.

2.7.2.8.5 Cabinet shall comply with IEC 60950 safety standard applicable to mains-powered or battery-powered information technology equipment.

2.7.2.9 Cable management

2.7.2.9.1 All cables (patch cords, power cords etc.) shall be guided neatly in the cabinet.

2.7.2.9.2 Horizontal & vertical cable managers shall be supplied and installed for guiding all cables in the cabinet

2.7.2.9.3 Cable managers shall be made of halogen free & flame-retardant materials.

2.7.2.9.4 Cable ties shall not be used to support cables to frames or to mounting rails. When used, cable ties shall only be used to guide and arrange cables in the cable managers.

2.7.2.9.5 All cables shall be labelled clearly with an indelible printed/engraved PVC label

2.7.2.9.6 All external cables shall terminate to a terminal block or a patch panel. All cabinet devices ports and terminals shall be wired/connected to patch panels or terminal blocks for connection to external cables

2.7.2.9.7 All ethernet ports of equipment mounted in the cabinets shall be connected to the patch panels. Ethernet connections between devices on the cabinets shall be via patch panel ports but not directly between device to device except for fibre optic patch cords which may be connected directly between devices.

2.7.2.9.8 Ethernet twisted pair patch panels shall be rack mounted on the front or rear side of the cabinets.

2.7.2.9.9 The cabinet wiring shall be very neat and shall allow easy access and aeration of the internal equipment. Spaghetti wiring shall NOT be accepted. All wiring shall neatly run in the cable managers, conduits and cable trays and neatly tied for cable guiding.

2.7.2.9.10 All networking cables shall be guided around the panel using cable trunks

2.8 POWER & CONTROL CABLES AND CONDUCTORS

2.8.1 General Requirements

2.8.1.1 ALL power and control cables SHALL BE STEEL-WIRE ARMOURED (SWA) except for single core cables which shall all have Aluminium steel wire armour

2.8.1.2 The cables shall be marked with item designation in both ends as well as by entrances in enclosures. The cable marking shall be fireproof

2.8.1.3 All cables shall meet requirements of IEC60502

2.8.1.4 Cable markers shall be installed at the beginning and end of the cable

2.8.1.5 Cables shall be neatly arranged, well supported and labelled at the glanding or termination point

2.8.1.6 No joints shall be allowed.

2.8.1.7 Cables shall be wound on strong drums arranged to take a round spindle of a section adequate to support the loaded cable drum during installation and handling. The drums shall be lagged with closely fitting battens that shall be securely fixed to prevent damage to the cable. Wooden drums shall be constructed of seasoned timber to prevent shrinkage of drums during shipment and subsequent storage at site. Each drum shall be clearly marked including indication of direction of rolling.

2.8.1.8 The ends of the cables shall be suitably sealed to prevent ingress of moisture. The end of the cable left projecting from the drum shall be securely protected against damage by mishandling during transport and storage.

2.8.1.9 All control wiring shall be carried out with 1100V grade multi strand flexible copper conductor wires with HRPVC insulation and shall be flame retardant, vermin and rodent proof. Cables with twisted pairs for analogue signals (4-20mA,0-10V etc.) shall be shielded to reduce EM interference.

2.8.1.10 All conductors shall be multi-stranded copper. The conductor shall be new, clean, uniform in size, shape and quality, smooth and free from scale, splits, sharp edges and other harmful defects. The conductor shall be in accordance with IEC 60228. The conductor shall be filled with swelling powder to stop axial ingress of moisture.

2.8.1.11 The maximum continuous current carrying capacity and maximum permissible continuous conductor temperature, and the factors for determining such rating and temperature shall be based on recommendations found in BS 7671 requirements for industrial installations and IEC 60287, subsequent amendments and all conditions prevailing on the Site

2.8.1.12 All conductors cross section must be checked against max load current, allowable burden on measuring transformers, short circuit values, voltage drop, protection requirements and selectivity. Conductors however shall have minimum cross sections as follows:

(a) Measuring cables from VT & CT output - 2.5 mm2

(b) Control and other measuring cables - 1.0 mm2

(c) Power cables according 120 % max load current with a minimum of 2.5 mm2

(d) Analogue signal cable-shielded twisted pairs-0.75mm2

(e) Networking cables- shielded twisted pairs -cat6

2.8.1.13 The standard phase colours for AC supply conductors including CT & VT output are Brown for L1 phase, Black for L2 phase, Grey for L3 phase, blue for neutral and Green with yellow stripe for Earth/ground wires as per relevant recent IEC standard. Conductors for instrumentation and control signals shall be numbered clearly along the whole cable length for easy identification. For auxiliary DC Supply cables, Red for Positive and White for negative.

2.8.1.14 For panel wiring single core cables (wires) colours specified in clause 2.7.1.13 shall be used for AC wiring. To differentiate DC voltages and sources a coherent method of wire colour identification shall be developed for the project and approved by the employer. Colours specified in clause 2.7.1.13 shall not be used for DC circuits except red and white.

2.8.2 Cable Laying and Routing

2.8.2.1 The final routing of HV and LV cables in indoor and outdoor installations shall be determined by the project engineer, from the directives given in Particular Specifications, and the principles shown in the layouts on the drawings. All cable routing must adapt to obstacles as tubes and ventilation channels. All penetrations of fire zone separations shall have the same fire classification as the separation itself.

2.8.2.2 Cables shall be laid on corrosion resistant (aluminium or hot dipped galvanised) cable trays and racks and by raising cables fixed to cable ladders. The trays shall be dimensioned and fixed so that it allows one man to climb on it in addition to the cable load. Each tray shall have at least 15 % spare capacity. The distance between each tray shall at least be 300 mm. For exposed outdoor installations cables shall be laid in covered cable trenches, plastic or steel ducts, depending on the available space.

2.8.2.3 Branch offs to individual equipment shall be fixed and supported all the way to the connection box. Cables and cable supports shall be properly fixed and secured against movement under short-circuit and strain caused by erection work. Particular attention shall be given to termination in confined areas where personnel may climb under erection and maintenance. Flexible tubes of “spiral type” shall not be used whereas tubes of “plica” type can.

2.8.2.4 Low power cables, i.e. cables for control, metering, etc. shall not be run in close parallel to high power cables or earth wires but shall be run at the greatest possible separating distance. The minimum distances are:

2.8.2.5 High and medium voltage versus control and measuring cables 800 mm

2.8.2.6 Low voltage power cables versus control and measuring cables 400 mm

2.8.2.7 Necessary EMC consideration shall be taken in accordance with EMC standards.

2.8.2.8 Additionally, cables for extra low power, i.e. mA and mV circuits and cables connected to low power solid state electronic circuits, shall be laid in separate sheet steel trays with covers.

2.8.2.9 Single-phase power cables shall be run in trefoil configuration, single-phase AC power cables shall be run in parallel. Special care shall be taken so that closed magnetic circuits do not form around single-phase cables.

2.8.2.10 Cables shall be laid in full runs and not spliced unless approved by Project Engineer. Termination of multi-stranded conductor ends shall be with a suitable crimped thimble as specified above. All other cable lugs or similar shall be of crimped type adapted to the cable type and cross-section used. The tools used should be special approved for the lugs and cable type used.

2.8.2.11 All cables shall be well marked with heat and oil resistant markers

2.8.2.12 The cable supplier's instructions regarding handling and bending radius shall be

2.9 STRUCTURED CABLING GENERAL REQUIREMENTS

2.9.1 Patch Panels

2.9.1.1 Twisted Pair Ethernet Patch Panels

2.9.1.1.1 Twisted pair patch panels shall be rack mount or panel mount 24 port CAT 7 (RJ45) shielded networking patch panels

2.9.1.1.2 All devices RJ45 ethernet ports in a panel other than management (console) RJ45 ports shall be wired to a patch panel.

2.9.1.1.3 All network patch cords shall be labelled with a suitable printed indelible ink cable marker.

2.9.1.1.4 All patch panel ports shall be well labelled, with computer generated (printed) indelible ink labels

2.9.1.1.5 Patch panels connector A shall be RJ45 (8p8c)

2.9.1.1.6 Patch panels connector B shall be RJ45(8p8c)

2.9.1.1.7 Patch panels shall be shielded and suited for 600Mhz operation for category 7 10Gb ethernet cables termination

2.9.1.1.8 Rack mounted panels shall be sized for mounting on 19" racks

2.9.1.1.9 Patch panel shall be designed for operation at continuous temperature of between 0 & 40°C.

2.9.1.1.10 Patch panels must be tested and approved for use in the EU or USA or Canada. Proof of testing and certification MUST be provided

No.	Feature	Requirements
1	Number of ports	As per scope of supply
2	Product Type	Feedthrough
3	Connector type	Cat6A
4	Supported connector capacity	600Mhz and 10Gb ethernet
5	PoE Power Budget (Watts)	30
6	PoE Type	Type 3 PoE++/UPoE (60W, IEEE 802.3bt)
7	Connector Side A	RJ45 female
8	Connector Side B	RJ45 female
9	Operating Temperature	-10 to 60 °C
10	Flammability Rating	UL 94 V-0
11	Green Features	RoHS, lead-free, halogen-free, PVC free
12	Plastic Materials	Flame retardant thermoplastic
13	Mounting	• 1U • 19-inch

No.	Feature	Requirements
14	Material Panel	18 gauge cold rolled steel, black e-coat
15	Standards Compliance	• ANSI/TIA-568-C.2 • ISO/IEC 11801 Ed.2.2 • ETL Tested • IEEE 802.3an • IEEE 802.3af (PoE) • IEEE 802.3at (PoE+) • IEC 60603-7 • IEC 60603-7-41 • ANSI/TIA-1096-A

2.9.1.2 Fibre Optic Ethernet Patch Panels

2.9.1.2.1 Fibre optic patch panels shall be rack mount, wall mount, DIN mount or panel mount suitable for terminating both single mode and multimode fibre optic cables

2.9.1.2.2 The panels shall be factory pre-populated and tested fibre patch panel with factory pre-loaded LC or SC or FC adapters with pigtails as per particular specifications or scope of supply

2.9.1.2.3 Panels enclosure shall be made of Sturdy 16-gauge steel construction with a durable powder coat finish

2.9.1.2.4 Rack mount Panel shall contain a moving tray for built-in cable management for holding and arranging the cables. This drawer mechanism shall enable easy access to the rear of the panel and eliminates the need for removing the panel from above.

2.9.1.2.5 Four cable entry cut outs shall be provided for cable entry including four cable entry glands.

2.9.1.2.6 Panel shall contain strain relief saddles to provide cable strain relief within the panel.

2.9.1.2.7 Various accessories, including splice cassettes, fusion protection sleeves, protection sleeve holders, etc., shall be provided for termination of at least four, four pair fibre optic cables.

2.9.1.2.8 Four fibre management clips shall be included to provide orderly excess cable storage while maintaining minimum bend radius.

2.9.1.2.9 Grounding points shall be provided on the rear of the panel, which, in conjunction with a F/O Cable Ground Kit, shall allow grounding of armoured fibre optic cables.

2.9.1.2.10 The panel shall include at port caps for protection of all unused port modules.

2.9.1.2.11 Rack mounted panels shall be sized for mounting on 19" racks.

2.9.1.2.12 Patch panel shall be designed for operation at continuous temperature of between 0 & 40°C.

2.9.1.2.13 Patch panels must be tested and approved for use in the EU or USA or Canada. Proof of testing and certification MUST be provided.

No.	Feature	Requirements
1	Patch Panel adapters	LC connectors
2	Cable management	• Moving tray drawer mechanism for rear access of cables • Strain relief saddles for cable strain relief • Fibre management clips for orderly excess cable storage • Four cable entry cut outs and glands
3	Termination accessories	• Splice cassettes • Fusion protection sleeves • Protection sleeve holders
4	Operating Temperature	-20 to 60 °C
5	Splice Tray	ABS Resin, UL 94 V-0
6	Cable Gland	ABS & Nylon Resin UL94V2
7	Cable Routing Spool	Nylon Resin UL 94 V-0
8	Green Features	RoHS, lead-free, halogen-free, PVC free
9	Plastic Materials	Flame retardant thermoplastic
10	Mounting	As specified
11	Metal Material Panel	16 gauge cold rolled steel, black e-coat or equivalent
12	Standards Compliance	• ANSI/TIA-568-C.2 • ISO/IEC 11801 Ed.2.2 • ETL Tested • IEEE 802.3an • IEEE 802.3af (PoE) • IEEE 802.3at (PoE+) • IEC 60603-7 • IEC 60603-7-41 • ANSI/TIA-1096-A

2.9.2 Media converters

2.9.2.1 Copper to Gigabit Fiber Media Converters

2.9.2.1.1 The device shall be fully designed to operate in extreme temperatures.

2.9.2.1.2 The device shall be easily mounted on a DIN rail or inside distribution boxes using native DIN Rail enclosure with grounding clip

2.9.2.1.3 The device shall support Smart Link Pass-Through mode, when the Link Mode switch is placed into the 1000BASE-X link on one port will reflect the state of the other 1000B BASE-X media converter port. This feature can be used whether fiber auto-negotiation is enabled or disabled.

2.9.2.1.4 The device shall support Auto-MDIX (automatic medium-dependant interface crossover) detects the signaling on the copper ethernet interface to determine the type of cable connected (straight-through or crossover) and automatically configures the connection when enabled.

2.9.2.1.5 The device shall also correct for wires swapped within a pair.

2.9.2.1.6 The device shall adjust for up to 120ns of delay skew between the 1000Base-T pairs

2.9.2.1.7 The device shall support Fiber Fault Alert when the state of the 1000Base-X receiver is passed to the 1000Base-X transmitter.

2.9.2.1.8 The device shall support Pause signalling which is an IEEE feature that suspends data transmission between two devices if one of the devices becomes overwhelmed. The media converter is transparent to Pause frames.

2.9.2.1.9 The device shall be Transparent to VLAN tagged packets.

2.9.2.1.10 The device shall support Full and half duplex operation.

2.9.2.1.11 The device shall be Transparent to jumbo packets up to 10KB.

2.9.2.1.12 The device shall perform a loopback on each 1000Base-X fiber interface.

No	Feature	Requirements
1	100Base-TX or 1000Base-T or 10/100/1000BaseT	RJ45 connector
2	Fixed Fiber or Small Form Factor Pluggable (SFP) slot	Dual multimode or single mode (Duplex) fiber - SC, ST
3	Magnetic Isolation	1.5kV
4	Fiber Optic Cable	Multimode: 62.5 / 125, 50/125, 85/125, 100/140 micron Single Mode: 9/125 micron (ITU-T 625)

No	Feature	Requirements
5	Filtering	1026 MAC Addresses
6	Packet Bit Error Rate (BER)	$<1X10^{-12}$
7	Operating Temperature	-40 C to 75 C
8	Storage Temperature	-40 C to 85 C
9	Operating Humidity	5% to 90% non-condensing
10	Storage Humidity	5% to 95% non-condensing
11	Operating Altitude	Up to 3,048 meters (10,000 feet)
12	Heat Output (BTU/HR)	7.37
13	MTBF (Hours)*	577,432 @ 30 °C
14	Chassis	Metal with an IP20 ingress protection rating
15	Substation & Hazloc	IEC 61850-3 IEEE1613 EN 61000-4-16 ATEX Class 1 Zone 2 ANSI/ISA 12.12.01, Class 1 Division 2 Groups A-D
16	Emissions	FCC 47 Part 15 Class A, EN55032 (CISPR32) Class A EN55011 (CISPR11) ICES-003 EN61000-6-4 (Emissions for industrial environments) CISPR 32:2015/EN 55032:2015 (Class A) CISPR 24:2010/EN 55024:2010 EN61000-3-2
17	Immunity	EN55026 EN 61000-4-2 (ESD) EN 61000-4-3 (RS) EN 61000-4-4 (EFT) EN 61000-4-5 (Surge) EN 61000-4-6 (CS) EN 61000-4-8 (PFMF) EN 61000-4-11

No	Feature	Requirements
		IEC/EN 61000-6-2 (General Immunity for Industrial Environments)
18	Electrical Safety	IEC 62368-1(ed 2) EN 62368-1:2014 UL 61010-1 and UL 61010-2-201 (including CB) UL/ULC/EN 62368-1 (including CB) CAN/CSA C22.2 No. 62368-1-14 CE
19	Laser Safety	EN 60825-1:2007 Fiber optic transmitters on this device meet Class 1 Laser safety requirements per IEC-60825 FDA/CDRH standards and comply with 21CFR1040.10 and 21CFR1040.11.
20	Environmental	Reach, RoHS and WEEE Compliant
21	Other	ECCN: 5A991 HTSUS Number: 8517.62.0020 Limited Lifetime Warranty

2.9.2.2 Fiber to Fiber Gigabit Media Converters

2.9.2.2.1 The device shall support 1000Base-X fiber interfaces negotiate according to 802.3 clause 37.

2.9.2.2.2 The device shall support Smart Link Pass-Through mode, when the Link Mode switch is placed into the 1000BASE-X link on one port will reflect the state of the other 1000Base-X media converter port. This feature can be used whether fiber auto-negotiation is enabled or disabled.

2.9.2.2.3 The device shall support Fiber Fault Alert when the state of the 1000Base-X receiver is passed to the 1000Base-X transmitter.

2.9.2.2.4 The devices shall support signal regeneration maintains signal integrity and allows for maximum fiber to fiber connections without degradation.

2.9.2.2.5 The device can be cascaded. Two or more media converters can be chained in a link to achieve even greater distances.

2.9.2.2.6 The device shall support Pause signalling which is an IEEE feature that suspends data transmission between two devices if one of the devices becomes overwhelmed. The media converter is transparent to Pause frames.

2.9.2.2.7 The device shall be transparent to 802.1Q VLAN tagged packets.

2.9.2.2.8 The device shall support Full and half duplex operation.

2.9.2.2.9 The device shall be Transparent to jumbo packets up to 10KB.

2.9.2.2.10 The device shall perform a loopback on each 1000Base-X fiber interface.

2.9.2.2.11 The device shall meet the following specifications:

No	Feature	Requirements
1	Fibre Connectors	1000Base-X Available in SC, ST and LC connector models
2	Packet Bit Error Rate (BER)	<1X10-12
3	Operating distance:	As specified
4	Operating Temperature	0° C to 50° C (32° F to 122° F)
5	Storage Temperature	minimum range of -25° C to 70° C
6	Operating Humidity	5% to 90% non-condensing
7	Storage Humidity	5% to 95% non-condensing
8	Operating Altitude	Up to 3,048 meters (10,000 feet)
9	Heat Output (BTU/HR)	8.53
10	MTBF (Hours)*	Without power adaptor: 432,138 With power adaptor: 274,804
11	Chassis	Metal with an IP20 ingress protection rating
12	Emissions	FCC Part 15 Class A, EN55022 Class A CISPR 22 Class A CISPR 32:2015/EN 55032:2015 (Class A) CISPR 24:2010/EN 55024:2010 EN61000-3-2
13	Immunity	EN55024 5/13
14	Electrical Safety	UL 60950-1 IEC 60950-1(ed 2); am1, am2 EN 60950-1:2006+A11:2009+A1:2010+A12:2011+A2:2013 CE
15	Laser Safety	EN 60825-1:2007 Fiber optic transmitters on this device meet Class 1 Laser safety

		requirements per IEC-60825 FDA/CDRH standards and comply with 21CFR1040.10 and 21CFR1040.11.
16	Environmental	Reach, RoHS and WEEE Compliant
17	Other	ECCN: 5A991 HTSUS Number: 8517.62.0020 Limited Lifetime Warranty

2.9.3 CWDM Multiplexer

2.9.3.1 General Requirements

2.9.3.1.1 Shall operate as a CWDM Multiplexer and Demultiplexer.

2.9.3.1.2 Shall be fully designed to operate with 18 CWDM Data streams over Double Single Mode Fiber.

2.9.3.1.3 Shall be fully line protocol neutral allowing 1/10G Ethernet, SDH/SONET and 8/4/2/1G Fiber Channel.

2.9.3.1.4 Shall be passive, requiring no power supply or cooling.

2.9.3.1.5 The device shall be fully designed to equip with bandpass or skip filters extending the maximum distance of CWDM connections.

2.9.3.1.6 Shall be 1 rack-unit in size fitting any standard equipment rack.

2.9.3.2 Minimum specifications:

No	Feature	Requirements
1	Number of Channels	18 according to ITU-T G.694.2
2	Fibre Connectors	LC
3	Operating Temperature	-5 to +70 (°C)
4	Storage Temperature	minimum range of -40° C to 85° C
5	Relative Humidity	0% to 90% non-condensing
6	Filter Technology	TFF (Thin Film Filter)
7	Filter Type	Bandpass filters
8	Channel spacing	20 nm
9	First Channel Passband Center Wavelength	1271nm
10	Passband	≤6.5nm

No	Feature	Requirements
11	Insertion Loss: Passband	≤ 3.2dB
12	Insertion Loss: 1% Monitor Port	≤ 23.8dB
13	Isolation Adjacent Channels	≥ 30dB
14	Isolation Non-Adjacent Channels	≥40dB
15	Channel Passband Ripple	≥0.3dB
16	Polarization Dependant Loss (PDL)	≤0.15dB
17	Polarization Mode Dispersion (PMD)	≤0.20 ps/nm
18	Directivity	≥50dB
19	Return Loss	≥45dB
20	Maximum Power Handling	≤300mW
21	Standards Compliance	• ITU-T G.694.2 • TIA/EIA 604-10 for LC UPC Connectors • CE • ISO • RoHS • Telecordia GR-20
22	Storage Humidity	5% to 95% non-condensing
23	Operating Altitude	Up to 3,048 meters (10,000 feet)
24	MTBF (Years)*	≥ Hundred (100)
25	Chassis	Metal with an IP20 ingress protection rating

2.9.4 SM Small Form-Factor Pluggable (SFP) Transceiver Modules

2.9.4.1 General Requirements

2.9.4.1.1 The device shall support Gigabit Ethernet communication.

2.9.4.1.2 The device shall be designed to operate in extreme temperatures for Industrial Grade SFP transceivers.

2.9.4.1.3 The device shall be fully Compliant with SFP MSA.

2.9.4.1.4 The device shall be fully Compliant with SFF-8472 Digital Diagnostic Monitoring Interface.

2.9.4.1.5 The device shall operate the following LX, BX and SX long reach single mode fibres.

2.9.4.1.6 The device shall support LC duplex fibre connector.

2.9.4.1.7 The device shall have a Bail latch.

2.9.4.1.8 Shall bet Hot swappable.

2.9.4.1.9 Shall be RoHS compliant.

2.9.4.2 Single mode, 1G, Over 115km

2.9.4.2.1 The device shall be fully designed to provide high performance Gigabit Ethernet communication up to 115km using single mode fibre.

2.9.4.2.2 The device shall be fully designed to operate within a wide temperature range: (-10 to 70 °C)

2.9.4.2.3 The device shall be fully compliant with SFP MSA for 1000Base-LX

2.9.4.2.4 The device shall be fully compliant with SFF-8472 Digital Diagnostic Monitoring Interface.

2.9.4.2.5 The single mode SFPs shall at minimum meet the following specifications:

No	Feature	Requirements
1	Transmit	Power 0 to 5.0 dBm
2	Receiver Sensitivity	-30.0 to -9.0 dBm
3	Power Budget	30 dB
4	Speed	Up to 1G
5	Mode	SM (Single-Mode)
6	Interface	LX
7	Connector	LC
8	Cable Type	9/125 µm
9	Wavelength (Tx)	1540 to 1570 nm
10	Wavelength (Rx)	1270 to 1600 nm
11	Nominal Distance	115 km (71.5 mi)
12	Operating Temperature	-10 to 70 °C (14 to 158 °F)
13	Storage Temperature	-40 to 85 °C (-40 to 185 °F)
14	Operating Relative Humidity	0% to 85% non-condensing
15	MTBF (Hours)*	392 years

16	Laser Eye Safety	Compliant with: • IEC/EN 60825 Class 1 Performance • IEC/EN 60950
17	RoHS	EU RoHS Directive 2002/95/EC Compliant
18	Manufacturer Warranty	5 years

2.9.4.3 Single mode, 1G, above 40km

2.9.4.3.1 The device shall be fully designed to provide high performance Gigabit Ethernet communication up to 40km using single mode fibre.

2.9.4.3.2 The device shall be fully designed to operate within a wide temperature range: (-40 to 85 °C)

2.9.4.3.3 The device shall be fully compliant with SFP MSA for 1000Base-LX

2.9.4.3.4 The device shall be fully compliant with SFF-8472 Digital Diagnostic Monitoring Interface.

2.9.4.3.5 The single mode SFP shall at minimum meet the following specifications:

No	Feature	Requirements
1	Transmit	Power 0 to 5.0 dBm
2	Receiver Sensitivity	-22.0 to 0.0 dBm
3	Power Budget	22 dB
4	Speed	Up to 1G
5	Mode	SM (Single-Mode)
6	Interface	LX
7	Connector	LC
8	Cable Type	9/125 µm
9	Wavelength (Tx)	1540 to 1570 nm
10	Wavelength (Rx)	1270 to 1600 nm
11	Nominal Distance	40 km (24.9 mi)
12	Operating Temperature	-40 to 85 °C (-40 to 185 °F)
13	Storage Temperature	-40 to 85 °C (-40 to 185 °F)
14	MTBF (Hours)*	482 years
15	Electromagnetic Interference (EMI)	FCC Class B Compliant
16	Laser Eye Safety	IEC/EN 60825-1 Compliant

17	RoHS	EU RoHS Directive 2002/95/EC Compliant
18	Manufacturer Warranty	5 years

2.9.4.4 Single mode, Bidirectional, 1G, above 40km

2.9.4.4.1 The device shall be designed to provide high performance bidirectional Gigabit Ethernet communication up to 40km using single mode fibre.

2.9.4.4.2 The device shall be designed to operate within a wide temperature range: (-40 to 85 °C)

2.9.4.4.3 The device shall be fully compliant with SFP MSA and IEEE 802.3ah for 1000Base-BX40-U

2.9.4.4.4 The device shall be fully compliant with SFF-8472 Digital Diagnostic Monitoring Interface.

2.9.4.4.5 The single mode SFP shall at minimum meet the following specifications:

No	Feature	Requirements
1	Transmit	Power -2.0 to 3.0 dBm
2	Receiver Sensitivity	-23.0 to -3.0 dBm
3	Power Budget	21 dB
4	Speed	Up to 1G
5	Mode	SM (Single-Mode)
6	Interface	BX
7	Connector	LC
8	Cable Type	9/125 µm
9	Wavelength (Tx)	1260 to 1360 nm /1480 to 1500 nm
10	Wavelength (Rx)	1480 to 1500 nm / 1260 to 1360 nm
11	Nominal Distance	40 km (24.9 mi)
12	Operating Temperature	-40 to 85 °C (-40 to 185 °F)
13	Operating Relative Humidity	5 to 95% (non-condensing)
14	Storage Temperature	-40 to 85 °C (-40 to 185 °F)
15	MTBF (Hours)*	336 years
16	Electrostatic Discharge (ESD) to the Electrical Pins	Class 1 Performance in MIL-STD-883E, Method 3015.7
17	Electrostatic Discharge (ESD) to the Duplex LC Receptacle	Compliant with IEEC 61000-4-2

18	Electromagnetic Interference (EMI)	Compliant with FCC Part 15, Class B
19	Immunity	Compliant with Variation of IEC 61000-4-3
20	Laser Eye Safety	• US FDA 21CRF 1040.10 and 1040.11 Compliant • IEC/EN 60825-1 and 60825-2 EN 60950 Compliant • Compliant with Class 1 laser product
17	RoHS	EU RoHS Directive 2011/65/EU Compliant
18	Manufacturer Warranty	5 years

2.9.4.5 Single mode, CWDM, 1G ,40km

2.9.4.5.1 Shall provide high performance Gigabit Ethernet communication over CDWM up to 40km using single mode fibre.

2.9.4.5.2 Shall be designed to operate within a wide temperature range: (0 to 70°C).

2.9.4.5.3 The device shall be fully compliant with SFP MSA and IEEE Std 802.3-2005 for 1000Base-LX.

2.9.4.5.4 The device shall be fully compliant with SFF-8472 Digital Diagnostic Monitoring Interface.

2.9.4.5.5 The single mode SFP shall at minimum meet the following specifications:

No	Feature	Requirements
1	Transmit	Power -5 to 5.0 dBm
2	Receiver Sensitivity	Minimum Sensitivity of -24dBm
3	Power Budget	19 dBm
4	Extinction Ratio	≥ 9dB
5	Packet Bit Error Rate (BER)	<10-12
6	Speed	Up to 1G
7	Mode	SM (Single-Mode)
8	Spectral Width (-20dB)	≤ 1nm
9	Centre Wavelengths	1270, 1290, 1310, 1330, 1350, 1370, 1390, 1410, 1430, 1450, 1470, 1490,

No	Feature	Requirements
		1510, 1530, 1550, 1570, 1590 and 1610 nm
10	Side Mode Suppression Ratio (SMSR)	>30dB
11	Transmitter Total Jitter	< 266 ps
12	Transmitter Dispersion Penalty	< 1 dB
13	Connector	LC
14	Optical Rise/Fall Time	< 260 ps
15	Nominal Distance	40 km (24.9 mi)
16	Operating Temperature	0 to 70 °C (32 to 158°F)
17	Operating Relative Humidity	5 to 95% (non-condensing)
18	Storage Temperature	-40 to 85 °C (-40 to 185 °F)
19	Electrostatic Discharge (ESD) to the Electrical Pins	Compliant with MIL-STD-883E, Method 3015.4
20	Electrostatic Discharge (ESD) to the Duplex LC Receptacle	Compliant with IEEC 61000-4-3
21	Electromagnetic Interference (EMI)	Compliant with: • FCC Part 15, Class B • EN55022:2010
22	Laser Eye Safety	• US FDA 21CFR • IEC/EN 60825-1 and 60825-2 • EN 60950-1 Compliant
23	RoHS	EU RoHS Directive 2015/863/EU Compliant
24	Manufacturer Warranty	5 years

2.9.4.6 Single mode,1G, 25km

2.9.4.6.1 The device shall provide high performance Gigabit Ethernet communication up to 25km using single mode fibre.

2.9.4.6.2 The device shall be designed to operate within a wide temperature range: (-40 to 85 °C).

2.9.4.6.3 The device shall be fully compliant with SFP MSA for 1000Base-LX

2.9.4.6.4 The device shall be fully compliant with SFF-8472 Digital Diagnostic Monitoring Interface.

2.9.4.6.5 The single mode SFP shall at minimum meet the following specifications:

No	Feature	Requirements
1	Transmit	Power -5.0 to 0.0 dBm
2	Receiver Sensitivity	-24.0 to 0.0 dBm
3	Power Budget	19 dB
4	Speed	Up to 1G
5	Mode	SM (Single-Mode)
6	Interface	LX
7	Connector	LC
8	Cable Type	9/125 µm
9	Wavelength (Tx)	1260 to 1360 nm
10	Wavelength (Rx)	1260 to 1610 nm
11	Nominal Distance	25 km (15.5 mi)
12	Operating Temperature	-40 to 85 °C (-40 to 185 °F)
13	Storage Temperature	-40 to 85 °C (-40 to 185 °F)
14	MTBF (Hours)*	174 years
15	Electromagnetic Interference (EMI)	FCC Class B Compliant
16	Laser Eye Safety	IEC/EN 60825-1 Compliant
17	RoHS	EU RoHS Directive 2002/95/EC Compliant
18	Manufacturer Warranty	5 years

2.9.4.7 Single mode,1G ,10km

2.9.4.7.1 The device shall provide high performance Gigabit Ethernet communication up to 10km using single mode fibre.

2.9.4.7.2 The device shall be designed to operate within a wide temperature range: (-40 to 85 °C)

2.9.4.7.3 The device shall be fully compliant with SFP MSA and IEEE 802.3 for 1000Base-LX

2.9.4.7.4 The device shall be fully compliant with SFF-8472 Digital Diagnostic Monitoring Interface.

2.9.4.7.5 The single mode SFP shall at minimum meet the following specifications:

No	Feature	Requirements
1	Transmit	Power -9.5 to -3.0 dBm
2	Receiver Sensitivity	-19.0 to 0.0 dBm
3	Power Budget	9.5 dB
4	Speed	Up to 1G
5	Mode	SM (Single-Mode)
6	Interface	LX
7	Connector	LC
8	Cable Type	9/125 µm
9	Wavelength (Tx)	1270 to 1355 nm
10	Wavelength (Rx)	1265 to 1600 nm
11	Nominal Distance	10 km (6.2 mi)
12	Operating Temperature	-40 to 85 °C (-40 to 185 °F)
13	Operating Relative Humidity	5 to 95% (non-condensing)
14	Storage Temperature	-40 to 85 °C (-40 to 185 °F)
15	MTBF (Hours)*	761 years
16	Electrostatic Discharge (ESD) to the Electrical Pins	Class 2 (> 2000 V) Performance in MIL-STD-883C, Method 3015.4 JEDEC/EIA JESD22-A114-A
17	Electrostatic Discharge (ESD) to the Duplex LC Receptacle	Compliant with Bellcore GR1089-CORE
18	Electromagnetic Interference (EMI)	Compliant with FCC Class B
19	Immunity	Compliant with Variation of IEC 61000-4-3
20	Laser Eye Safety	• US FDA CDRH AEL Class 1 Compliant • IEC/EN 60825-1, 60825-2 and EN 60950 Class 1 Compliant
21	RoHS	EU RoHS Directive 20002/95/EC Compliant
22	Manufacturer Warranty	5 years

2.9.4.8 Multi-mode,1G, 300m/500m

2.9.4.8.1 The device shall provide high performance Gigabit Ethernet communication up to 0.5km using multi-mode fibre.

2.9.4.8.2 The device shall be designed to operate within a wide temperature range: (-40 to 85 °C)

2.9.4.8.3 The device shall be fully compliant with SFP MSA and IEEE 802.3 for 1000Base-SX

2.9.4.8.4 The device shall be fully compliant with SFF-8472 Digital Diagnostic Monitoring Interface.

2.9.4.8.5 The device shall support LC duplex optical interface.

2.9.4.8.6 The device shall be fully designed to operate with 50/125 µm and 62.5/125 µm multi-mode fiber

2.9.4.8.7 The multi-mode SFP shall at minimum meet the following specifications:

No	Feature	Requirements
1	Transmit Power	-9.0to -2.5 dBm
2	Receiver Sensitivity	-18.0 to 0.0 dBm
3	Power Budget	9.0 dB
4	Speed	Up to 1G
5	Mode	MM (Multi-Mode)
6	Interface	SX
7	Connector	LC
8	Cable Type	50/125 µm or 62.5/125 µm
9	Wavelength (Tx)	830 to 860 nm
10	Wavelength (Rx)	770 to 860 nm
11	Nominal Distance (50/125 µm)	0.5 km (0.3 mi)
12	Nominal Distance (62.5/125 µm)	0.3 km (0.2 mi)
13	Operating Temperature	-40 to 85 °C (-40 to 185 °F)
14	Operating Relative Humidity	5 to 95% (non-condensing)
15	Storage Temperature	-40 to 100 °C (-40 to 212 °F)
16	MTBF (Hours)*	≥697 years
17	Laser Eye Safety	IEC/EN 60825 Class 1 Performance

No	Feature	Requirements
18	Electrical Safety	IEC/EN 60950 Compliant
19	RoHS	EU RoHS Directive 20002/95/EC Compliant
20	Manufacturer Warranty	5 years

2.9.4.9 Copper, 1G, 100m

2.9.4.9.1 Shall provide high performance Gigabit Ethernet communication up to 100m.

2.9.4.9.2 The device shall be designed to operate within a wide temperature range: (-40 to 85 °C).

2.9.4.9.3 The device shall be fully compliant with SFP MSA and IEEE 802.3ab for 10/100/1000Base-T

2.9.4.9.4 The Copper SFP shall at minimum meet the following specifications:

No	Feature	Requirements
1	Speed	10/100/1000 Mbps
2	Connector	RJ45
3	Cable Type	> CAT-5e
4	Duplex	FDX/HDX
5	Wiring Standard	TIA/EIA T568A/B
6	Nominal Distance	100 m (328.1 ft)
7	Isolation	1.5kV
8	Cable Type	50/125 µm or 62.5/125 µm
9	Operating Temperature	-40 to 85 °C (-40 to 185 °F)
10	Storage Temperature	-40 to 85 °C (-40 to 185 °F)
11	Mean Time Between Failures (MTBF)	984 years
12	Electromagnetic Interference (EMI)	FCC Class A, CE Class A, VCCI Class A, C-Tick Compliant
13	RoHS	EU RoHS Directive 2002/95/EC Compliant
14	Manufacturer Warranty	5 years

2.9.5 Networking cables

2.9.5.1 Twisted Pair Ethernet Patch cords

2.9.5.1.1 General Requirements

(a) Shall be factory pre-made shielded category 7 cables with screened twisted pairs and gold plate shielded connectors.

(b) Cable shall be Shielded Twisted Pair Cable (SSTP), Category 7 (600 MHz), 4 pairs, Solid, 23 AWG, with 4 separately foil-shielded pairs, overall braid shielded and an FR- PVC cable jacket.

(c) Cables shall have a durable, halogen free, flame-retardant PVC jackets.

(d) Connector shall be shielded factory pre-made CAT 6A RJ45 8P8C male connector with gold plate shield and factory-pre-made dense FR-PVC jacket or factory-pre-made Tera™ male connectors where specified.

(e) All RJ45 8P8C connectors must be gold plate shielded and at least cat6A type.

(f) Patch cords shall be factory pre-made with a suitable length as per scope of supply but with minimum length of 2 meters.

(g) Patch cords shall be designed for operation at continuous temperature of between 0 & 40°C.

(h) Patch cords shall meet requirements of ANSI/TIA/EIA-568-B.1 standard.

2.9.5.1.2 Minimum Specifications

No.	Feature	Requirements
1	Cable type	Factory made Twisted pair S/FTP Cat 7
2	Current Rating	1.5 A
3	Power over Ethernet	PoE Type1,2,3,4 and PoH
4	Power over Ethernet	< 10 mΩ/m @ 10 MHz
5	Operating Temperature	-10 to 75° C
6	Flammability Rating	UL 94 V-0
7	Green Features	RoHS, lead-free, halogen-free, PVC free
8	Plug Housing Materials	Polycarbonate
9	Contact Materials	gold plating
10	Plastic Materials	Flame retardant thermoplastic
11	Screen	360 degree
12	Enclosure Marking	P/N, length, performance level, QC
13	Number of Plug Insertion Cycles	≥2500
14	Connector	Cat 6A RJ45

No.	Feature	Requirements
15	Wire Size Range (Nominal)	23 AWG
16	Bend Radius	≤50mm
17	Cable Construction	S/FTP
18	Length	• 2-5m • 10-20m
19	Jacket type	LSOH
20	Wiring	T568A (straight through)
21	Standards Compliance	• ISO/IEC 11801-1 Ed 1.0 • ANSI/TIA-568.2-D • IEC 60603-7, 60603-7-51 • LSOH: IEC 60332-3-22, IEC 60332-1, IEC 60754, and IEC 61034

2.9.5.2 Single Mode Fibre optic patch chords

2.9.5.2.1 General Requirements

(a) They shall be Single mode duplex connector Fibre optic patch cords.
(b) Shall have factory pre-terminated connectors on both ends (four connectors)
(c) Fibre Patch Cable shall be Single mode 9/125 OS2 fibre designed for Gigabit Ethernet Speeds
(d) Shall conform to TIA/EIA 492AAAA and IEC60793-2-10 A1b standards and RoHS specifications.
(e) The SM jacket shall be at least 3.00mm in diameter.
(f) Fibre patch cords shall be designed to operate at -20°C to +70°C and have a minimum installation bending radius of 5.0 cm and a minimum long-term bending radius of 3 cm.
(g) SM jacket shall be flame retardant
(h) Patch cords shall be designed for operation at continuous temperature of between 0 & 40°C.

2.9.5.2.2 Minimum Specifications

No.	Feature	Requirements
1	Mode	Single Mode 9/125 OS2 Duplex
2	Connector	As specified
3	Repeat plug:	< 0.25 dB, each 500 times plug
4	Min reflection loss	< 20 dB
5	Max return loss	>50dB
6	Fiber Type	G657A2
7	Jacket Material	LSZH
8	Cable Diameter	≥3.0mm
9	Min bending radius	≤3cm
10	Operating temperature range	-20 ~ 70 °C
11	Operating Humidity	20% to 80% non-condense
12	Connector materials	ceramic plug core
13	Min bandwidth	500 MHZ. Km / 1300 nm
14	Size	2-5m

2.9.5.3 Indoor Twisted Pair Ethernet cables

2.9.5.3.1 General Requirements

(a) Shall be Shielded Twisted Pair Cable (SSTP), Category 7 (600 MHz), 4 pairs, Solid, 23 AWG, with 4 separately foil-shielded pairs, overall braid shielded and an FR- PVC cable jacket

(b) Every pair shall be separately shielded with polyester aluminium foil, which covers 100% of the twisted pair

(c) Cable Jacket shall be halogen free and flame retardant.

(d) Cable roll length shall be 300m or 1000 feet

(e) Cable shall be designed for operation at continuous temperature of between 0 & 40°C.

2.9.5.3.2 Minimum Specifications

No.	Feature	Requirements
1	Category	CAT7
2	DC Resistance	<7.32 Ω/100m
3	DC Resistance Unbalance	2 %

No.	Feature	Requirements
4	Mutual Capacitance	5.6 nF/100m
5	Capacitance Unbalance	<160 pF/100m
6	Characteristic Impedance (ohms)	• 1-100 MHz: 100 ± 15% • 100-600 MHz: 100± 22%
7	NVP	72%
8	LCL	40-10 x log(f)dB
9	Delay Skew	≤25ns/100m
10	Operating Temperature	-20 to 75°C
11	Bend Radius (min)	≤50mm
12	Jacket Material	LSOH
13	Outer Shield	Tinned Copper Braid
14	Individual Pair Shield	Aluminium Polyester Foil Tape
15	Conductor	• ≥0.56mm • 23 AWG solid bare copper
16	Conductor Insulation	• HDPE • FRPE
17	Standards Compliance	• ISO/IEC 11801: Ed 2.2 • IEC 61156-5: Ed 2.0 (Category 7) • EN 50288 • EN55022 • EN 50173 • EN55024 • IEEE 802.3an • LSOH: IEC 60332-1, IEC 60754, and IEC 61034

2.9.5.4 Outdoor Twisted pair Ethernet cables

2.9.5.4.1 General Requirements

(a) Shall be Shielded Twisted Pair Cable (SSTP/SFTP), Category 7 (600 MHz), 4 pairs, Solid, Outdoor, 23 AWG, with 4 separately foil-shielded pairs, overall braid shielded and jacketed with two FR-PVC compounds.

(b) Cable shall meet IEC 61156 requirements Fire protection - CMX and IEC

60332-1, UL 1581 VW-1 fire safety standards.

(c) Every pair shall be separately shielded with polyester aluminium foil, which covers 100% of the twisted pair.

(d) Materials:

(i) Conductive material: bare copper

(ii) Conductor insulation: PO, film-porous-film structure

(iii) The outer cable jacket: FR-PVC

(iv) The inner cable jacket: FR-PVC

(v) General shield: tinned copper braid - 60% minimum

(vi) Drain wire: tinned copper.

(e) Cable roll length shall be 300m or 1000 feet.

(f) Cable shall be designed for operation at continuous temperature of between 0 & 40°C.

2.9.5.4.2 Minimum Specifications

No.	Feature	Requirements
1	Category	CAT7
2	DC Resistance	<7.32 Ω/100m
3	DC Resistance Unbalance	2 %
4	Mutual Capacitance	5.6 nF/100m
5	Capacitance Unbalance	<160 pF/100m
6	Characteristic Impedance (ohms)	• 1-100 MHz: 100 ± 15% • 100-600 MHz: 100± 22%
7	NVP	72%
8	LCL	40-10 x log(f)dB
9	Delay Skew	≤25ns/100m
10	Operating Temperature	-20 to 75°C
11	Bend Radius (min)	≤50mm
12	Jacket Material	LSOH
13	Outer Shield	Tinned Copper Braid
14	Individual Pair Shield	Aluminium Polyester Foil Tape
15	Conductor	• ≥0.56mm • 23 AWG solid bare copper
16	Conductor Insulation	• HDPE

No.	Feature	Requirements
		• FRPE
17	Standards Compliance	• ISO/IEC 11801: Ed 2.2 • IEC 61156-5: Ed 2.0 (Category 7) • EN 50288 • EN55022 • EN 50173 • EN55024 • IEEE 802.3an • LS0H: IEC 60332-1, IEC 60754, and IEC 61034

2.9.5.5 Outdoor, Copper-Clad, ethernet twisted pair cables.

2.9.5.5.1 General Requirements

(a) The Cable shall withstand outdoor conditions over the long term, including the following:
  (i) Water ingress
  (ii) UV and sunlight exposure
  (iii) Rodent activity
  (iv) Mechanical wear and abrasion

(b) The cable shall provide high-capacity connectivity. The solutions must provide:
  (i) Crosstalk protection
  (ii) Shielding from EMI and RF interference

(c) The cable shall have the following features:
  (i) Sunlight and weather resistant polyethylene jacket
  (ii) Copper-clad armour for shielding mechanical protection and rodent resistance.
  (iii) Gel-filled for preventing water intrusion.
  (iv) 24AWG solid copper conductors

2.9.5.5.2 Minimum Specifications

No.	Feature	Requirements
1	Construction	100% Copper Clad Steel and Gel-filled
2	Conductors	24-gauge solid copper
3	Jacket	Polyethylene
4	Diameter	≥9.1 mm
5	Size	≥305m
6	Connectors	RJ-45
7	Crushing	Copper-clad steel Armor for shielding
8	Cut-through	Copper clad
9	Operating temperature	-20 to 75°C
10	Oil exposure	Polyethylene Jacket
11	UV exposure	Polyethylene Jacket
12	Water Immersion	Gel-filled and dry water block
13	Cable needs to withstand outdoor conditions over the long term, including the following.	• Water ingress • UV and sunlight exposure • Rodent activity • Mechanical wear and abrasion

2.9.5.6 Steel wire armoured Single mode Fibre optic cable.

2.9.5.6.1 General Requirements

(a) The Cable shall withstand outdoor conditions over the long term, including the following:
   (i) Water ingress
   (ii) UV and sunlight exposure
   (iii) Rodent activity
   (iv) Mechanical wear and abrasion

2.9.5.6.2 Minimum Specifications

No.	Feature	Requirements
1.	Lifetime	25 years without detriment

No.	Feature	Requirements
2.	Operation Temperature	-40 °C – +70 °C
3.	Storage Temperature	-40 °C - +70 °C
4.	Number of Fiber Optic Cores	≥12
5.	Armour	steel wire armour
6.	Static Bending Radius	15 times the cable diameter
7.	Dynamic Bending Radius	30 times the cable diameter
8.	Optical Fibres	ITU-T G.652.D (T-REC-G.652-201611)
9.	Main Mechanical and Environmental Performance	• Tension(N): 9000 • Crush(N/100mm): 3000
10.	Mechanical, Physical and Environmental Test Characteristics	• Tension: IEC 60794-1-21-E1 - Load: According to 3.5 Sample length: Not less than 50m. Duration time: 1min • Crush: IEC 60794-1-21-E3A - Load: According to 3.5 Duration of load: 1min • Impact: IEC 60794-1-21-E4 - Radius: 300 mm Impact energy: 30 J Impact number: 1 Impact points: 3 • Water Penetration: IEC 60794-1-22-F5B - Time: 24 hours Sample - Length: 3m - Water height: 1m • Temperature cycling: IEC 60794-1-22-F1 - Sample length: at least 1000m - Temperature range: -40 °C~+70 °C - Cycles: 2 Temperature cycling test dwell time: 12 hours
11.	Packaging and Drum	• Cable Sheath Marking: The cable sheath marking shall be as follows: Color: white; Contents: Manufacturer, the year of manufacture, the type of cable, cable number, length marking Interval: • Reel Length Standard reel length:

No.	Feature	Requirements
		2/3 km/reel, other length is also available • Cable Drum: The cables are packed in fumigated wooden drums. • Cable Packing Both ends of the cable will be sealed with suitable plastic caps to prevent the entry of moisture during shipping, handling, and storage. The inner end is available for testing
12.	Compliance	IEC 60794-1

2.9.6 Conduits

2.9.6.1 PVC Coated Galvanised Steel Flexible Conduit

2.9.6.1.1 General Requirements

(a) The Conduit shall withstand outdoor conditions over the long term, including the following:
  (i) UV and sunlight exposure
  (ii) Rodent activity
  (iii) Mechanical wear and abrasion

(b) Shall be used for running all communication cables along existing power plant cable routes.

2.9.6.1.2 Minimum Specifications

No.	Feature	Requirements
1	Nominal Diameter	20mm
2	Material	Galvanised Steel
3	Conduit Type	Flexible
4	Colour	Black
5	Outer Diameter	21.5mm
6	Interior Diameter	16.9mm
7	IP Rating	IP54-IP65
9	Series	SP
8	Coating Material	PVC
10	Thread Size	M20

No.	Feature	Requirements
11	Maximum Operating Temperature	+70°C
12	Minimum Operating Temperature	-15°C
13	Minimum Bend Radius	45mm

2.9.6.2 HDPE Conduits

2.9.6.2.1 General Requirements

(a) The Cable conduits shall protect communication cables from external physical and chemical damage.

(b) Shall be used for running communication cables along the walls in the plant. For cable runs along existing power plant cable trays PVC Coated Galvanised Steel Flexible Conduit shall be used

(c) Supply of HDPE pipe shall include supply and installation of all the couplers, end plugs, etc.

2.9.6.2.2 Minimum Specifications

No.	Feature	Requirements
1	Nominal Diameter	• DN25mm • DN125mm
2	Material / MRS	HDPE / 10.0Mpa
3	Pressure Rating @ 20degs	SDR 17 (PN10)
4	Colour	Black
5	Wall thickness	• ≤2.0mm • ≤7.4mm
6	Average Internal Diameter	• 20mm • 100mm
7	Applicable Standards	ISO 4427/ ISO 9001/ AS/ NZS 4130/ BS EN 12201/ SABS standards

2.10 SOFTWARE

2.10.1 Submission

2.10.1.1 One copy of each different type of Software for Devices whose Configuration and Settings is Software based and the connection Cable (Two for each type of device) shall be provided to employer when equipment is shipped to site.

2.10.1.2 Application programs developed by the contractor or his supplier or subcontractor for operation of any device supplied under this project shall be provided to employer in editable format when equipment is shipped to site.

2.10.1.3 Software used to develop Logic diagrams and application programs loaded into equipment in scope of supply and all other programs required for operation of any device supplied under this project shall be provided for installation into at least two portable computers with all necessary licences.

2.10.1.4 Intellectual property rights for application programs such as configuration files/applications, project files, IED/ controller Logic diagrams/programs, PLC application programs, HMI/SCADA application programs, document management application etc. developed by the contractor or his supplier or subcontractor specifically for operation of any device supplied under this project/contract SHALL BE CEDED to the employer after commissioning.

2.10.1.5 All the software required for configuring or programming all devices in scope of supply whether explicitly mentioned in the specifications or not shall be supplied for installation to two portable PC's. The software shall also be capable of downloading and analysing data from the devices.

2.10.1.6 It shall be possible to load the configuration/programming software into at Least two different Laptop Computers without requirement for additional licenses, to facilitate Operations. Where additional licenses are required, the cost shall be considered to have been included in the bid.

2.10.1.7 All software/programs running on any of the supplied devices which may be required for installation/reinstallation into the device at any point in the lifetime of the device e.g., after changing some parts or repairing shall be supplied.

2.10.1.8 One set of hard cover manuals for each type of software Supplied providing detailed.

2.10.2 Software Configuration Management Plan

2.10.2.1 A Software Configuration Management (CM) Plan shall be produced defining the manner in which the changes to software are controlled and logged during the lifecycle of the project.

2.10.2.2 The Contractor shall identify the CM procedures to be applied to software development.

2.10.2.3 Specifically, the Contractor shall ensure that procedures exist to identify, document, control and maintain all software design changes. The procedures shall include a method for:

(a) Program and/or module version identification, registration and updating.
(b) Obtaining approval to implement a modification.
(c) Producing build documents at baseline
(d) Ensuring that modifications are properly integrated
(e) Keeping secure masters at separate locations
(f) The provision of validated copies
(g) The proper marking, storage and handling of software media
(h) The control of the identification inspection status
(i) The control of support software
(j) Ensuring that non-conforming software is identified and segregated.

2.11 OPERATING CONDITIONS

2.11.1 Temperature and Humidity

1.1.2 The equipment shall withstand, without impairing the component function, the following ambient conditions:

(a) Temperature range: $-1^{0}C$ to $+45^{0}C$
(b) Relative humidity: 85 % at $40^{0}C$

1.1.3 The dewpoint shall not be reached. If necessary, special measures shall be taken [cooling, fanning].

2.11.2 Other environmental conditions

(a)	24-hour average temperature:	+10°C — +35°C
(b)	Relative humidity:	90 -100%
(c)	Height above sea level:	550 m — 1650m
(d)	EMC Class (IEC 61000):	Industrial environments
(e)	Seismic coefficient:	Not available
(f)	Rainfall conditions Average:	500-1200 mm/year

(g)	Indoor Pollution degree:	III
(h)	Earthquake acceleration-Horizontal acceleration:	not available
(i)	Earthquake Acceleration-Vertical acceleration:	not available
(j)	Estimated fault level main LV switchboard	20kA

3 PARTICULAR TECHNICAL SPECIFICATIONS - NETWORK AND COMMUNICATION SYSTEMS

3.1 GENERAL REQUIREMENTS & INFORMATION

3.1.1 Introduction

3.1.1.1 Procuring entity operates several power plants in the country. Wide area network is used to provide connectivity required for centralised control of the power plants, critical telephony services and business functions at the power plants.

3.1.1.2 Existing network is to be upgraded and integrated to allow sharing of network infrastructure for multiple services.

3.1.1.3 This particular specification provides requirements specific to the wide area network and network devices. All the sites in the scope of supply are covered by this specification.

3.1.1.4 The specifications are based on the current procuring entity requirements and projected requirements in the next five years. The network shall be designed to scalable to allow network growth. The equipment shall be designed for a minimum lifetime of at least ten years.

3.1.1.5 The required system shall meet the general communication requirements for power utility communications based on International Council on Large Electric Systems (CIGRE) Study Committee D2: Information Systems and Telecommunication: Utility Communication Networks and Services Specification, Deployment and Operation; IEC 61850-90-12 and other standards and documents for power utility communications. The SCADA WAN requirements given in this document have been derived from these documents and the procuring entity specific requirements.

3.1.1.6 Contractor/bidder shall note that the performance requirements given shall be met to ensure proper operation of various control functions dependent on the wide area network that are currently provided by a separate network.

3.1.1.7 Functional requirements give an overview of the system and functions required by the procuring entity, design and architectural requirements give the details of how the functional requirements are to be met while the equipment specifications provide detailed requirements of equipment and services to be supplied by the contractor.

3.1.2 Existing Systems

3.1.2.1 The existing system consist of network equipment for SCADA network, telephone network and corporate network at the power plant.

3.1.2.2 Most of the existing equipment are obsolete and require replacement.

3.1.2.3 The existing SCADA network equipment were installed between 2007 and 2010 using predominantly SDH and PDH technologies that are currently obsolete. The existing equipment have provided very reliable and dependable network for control and monitoring of the power plants which have had a sustained availability above 99.9% over all the last 12-15 years. The network to be supplied is expected to have a similar reliability and dependability like the existing network.

3.1.2.4 The existing network cabinets will be refurbished to support the new equipment or new cabinets will be supplied where the existing cabinet cannot be re used.

3.1.2.5 Various types of Cisco routers are utilised for corporate network. These vary between stations and can be checked during site visits. Details of configuration of each existing devices to be retained after the upgrade shall be provided during the design stage of the contract.

3.1.2.6 Scope of supply provides minimum equipment and accessories required for interfacing the new network systems to the existing equipment. The list is not exhaustive, any additional components required for the interfacing and installation works shall be supplied by the contractor.

3.1.2.7 Details of security appliances for SCADA can be found under the control centre specifications.

3.1.3 Scope

Scope of this specification shall include but not limited to

3.1.3.1 Requirements for a transport/backbone network supporting multiple networks/services.

3.1.3.2 Requirements for SCADA network

3.1.3.3 Requirements for operations telephone network

3.1.3.4 Specifications for network equipment and services

3.1.3.5 Specifications for telephone equipment and services

3.2 FUNCTIONAL REQUIREMENTS

3.2.1 General requirements

3.2.1.1 SCADA wide area network shall connect all the seven hydro power plants and provide facilities for connecting of all the other KenGen power plants to a common SCADA network. The network shall allow the following functions:

3.2.1.1.1 Real time Control and monitoring of all the power plants.

3.2.1.1.2 Operation of Power plants information management systems for maintenance, dispatch, and other power plant management functions

3.2.1.1.3 Provide a robust voice telephone network in all the seven forks power plants and dispatch centres for routine operations and emergency operations.

3.2.1.1.4 Provide highly reliable and deterministic network for automatic generator control and other grid automation functions.

3.2.1.1.5 Provide backup connection for corporate network provision at the power plants.

3.2.1.1.6 Sharing of common wide area network links for cost savings between industrial functions, operations telephone and business functions without degrading quality of the sensitive functions.

3.2.1.1.7 Wireless rugged telephone network on the plant floor

3.2.1.1.8 Monitoring and management/administration of the SCADA assets

3.2.1.2 The network shall be completely packet switched, TDM circuits and any other Circuit switched technologies shall not be used.

3.2.1.3 Network shall be highly scalable for future expansion to other sites, addition of new backbone links and addition of more users/devices.

3.2.1.4 Network shall be highly reliable and fault tolerant designed for operation of critical infrastructure.

3.2.1.5 Existing WAN links provided by Kenya power (KPLC/KETRACO) and other service providers shall be used to provide backbone links between various stations.

3.2.1.6 Network shall provide complete separation of various types of traffic across the WAN. Network shall provide a transport network and application networks.

3.2.1.7 Application Network shall cater for one or several applications with similar characteristics (performance, security, topology, ownership, etc.). It shall be a point-to-point connection of two sites, a group of interconnected sites or a server connecting to remote devices.

3.2.1.8 Transport network shall be the carrier network responsible for high bandwidth, low latency movement of all data between the sites while application networks shall overlay the transport network providing connections to various services in SCADA and enterprise

system. Transport network shall carry traffic from multiple application networks and shall use packet switched network PSN carrier technologies to move traffic between the various sites.

3.2.1.9 Each application network shall be a virtual private network (VPN) on the transport network. Each VPN shall be assigned a specific priority to guarantee performance of certain applications.

3.2.1.10 Network shall guarantee bandwidth and latency for critical applications such as SCADA tele control and Operations voice (telephone) within the limits of the available communication links. All measures shall be taken to ensure all critical applications such as network control, telecontrol and operations telephone are prioritised across the network and the less critical traffic such as internet traffic is assigned the lowest priority across the network to ensure that low priority traffic does not affect the high priority traffic. Contractor shall configure all network devices including routers, switches, PBX, security gateways, radios etc to ensure traffic priorities are assigned correctly and devices forward traffic according to priorities.

3.2.1.11 Contractor shall be responsible for network design to ensure the network meets all the functional, architectural and performance requirements. Network design shall be carried out by personnel with vast experience designing critical utility networks.

3.2.2 Backbone/Transport Network

3.2.2.1 Transport or backbone network shall provide the base for moving data between the main sites. It shall be highly resilient and with the highest possible availability for critical infrastructure operations. Transport network shall be a carrier class network responsible only for moving data from one site to another.

3.2.2.2 Transport network shall utilise the following infrastructure to deliver carrier services.

3.2.2.2.1 Direct fibre optic links in seven forks and Upper Tana. These links shall terminate directly to the equipment supplied by the contractor. Contractor shall be responsible for testing, configuration and re-deployment of these links.

3.2.2.2.2 Point to point ethernet radio links in seven forks and upper Tana areas. These links shall be provided by the contractor who shall be fully responsible for supply, installation and commissioning.

3.2.2.3 All transport network links to each site shall be redundant. New fibre and radio links shall be used to provide redundant links between the sites.

3.2.2.4 Contractor shall provide, configure, and commission all the fibre optic links and radio links as detailed in the architectural requirements and the scope of supply.

3.2.2.5 Network provided shall meet the performance requirements given in the architectural requirements.

3.2.2.6 There shall be at minimum eight transport network sites which shall be responsible for network switching and routing. These shall be Masinga, Kamburu, Gitaru, Kindaruma, Kiambere, Kianjiru, Matendeni and Tana, Provider edge devices shall aggregate and

isolate the application networks.

3.2.2.7 The transport network shall not rely on any single site for connectivity between the major sites. The nine major connection/routing sites shall connect to each other directly without the need for a central aggregation site. Failure of any of these major sites shall only lead to loss of services to and from that site and any other site dependent on it but it shall not lead to loss of the network. The network shall continue to function even with only two sites available. All the provider edge/aggregation devices shall have at least one direct connection to all the other aggregation devices.

3.2.2.8 Transport network shall be completely transparent to the application networks. The application networks shall be fully isolated allowing use of similar IP addressing for the different application networks without affecting the network performance.

3.2.2.9 Transport network shall provide service provider functions with very low latency and highly deterministic routing and configuration. Transport network shall for all intents and purposes be a service provider network owned and operated by the procuring entity with capability to offer services to various internal customers and possibly external customers. Contractor shall ensure all the typical Service provider network features and functions are provided to meet the functional and architectural requirements in this tender, specified standards and industry best practices

3.2.2.10 Transport network shall guarantee bandwidth- and limit latency and jitter for critical applications such as SCADA tele control and Operations voice (telephone) within the limits of the available physical links.

3.2.2.11 Transport network shall utilise traffic engineering to create deterministic routes in the network to ensure quality of service and bandwidth reservation for each application network. Traffic Engineering shall be configured by the contractor to ensure the following in the transport network

3.2.2.11.1 Utilisation of all available links to minimize network congestion, limit latency and jitter and maximise bandwidth utilisation. All available links to be utilised simultaneously and maintained stateful/persistent

3.2.2.11.2 Ensure the network is highly resilient and reliable by fast rerouting of traffic if one of the links fail without loss of high priority traffic

3.2.2.11.3 Class of service marking to ensure traffic prioritisation of traffic from each application network in order to guarantee quality of service for critical services as detailed in performance requirements. Network to provide predictable or guaranteed performance to applications, performance of critical applications such as control traffic and operations voice traffic to be guaranteed with limited network capacity.

3.2.2.11.4 Guarantee minimum bandwidth of critical services across all available links in order to ensure highest reliability and lowest latency especially for control traffic

and operations voice traffic.

3.2.3 Operations Telephone

3.2.3.1 Operations telephony shall provide very high voice quality suitable for use in very noisy environments. The operations telephony network voice encoding, and network transport bandwidth and latency shall provide for a very high background noise cancellation and very clear sound. All the telephone equipment shall support high quality wideband G. 722 voice and noise cancellation mechanisms.

3.2.3.2 Operations telephone network shall not have a central server or switch. Each IP PBX shall be able to switch/route calls independently of each other. Calls between the PBX shall use trunk lines. There shall be at least five PBX in the network, and each shall have a direct and persistent connection to all the other four PBXs and to the corporate call manager. Each PBX shall have GSM gateway to allow termination of at least two simultaneous external calls to the public network. The corporate call manager shall provide gateway to the public telephone networks.

3.2.3.3 Hybrid IP private branch exchanges, PBX, shall be provided in five sites to provide telephone switching and call routing services. The five sites with the PBX are Masinga, Kamburu, Gitaru, Kindaruma and Kiambere. The PBX shall provide session initiation protocol, SIP server for telephone nodes in these sites and remote telephone node for other sites. Hydro plaza and some Kamburu telephone nodes shall be remote telephone node to PBX in Kamburu and Gitaru.

3.2.3.4 All the PBX shall offer a minimum of the following features and functions which shall be provided and configured by the contractor.

3.2.3.4.1 VOIP phones support

3.2.3.4.2 Support for DECT wireless handsets and DECT cell network

3.2.3.4.3 SIP trunks to other PBX, Corporate Cisco call manager and other VOIP providers

3.2.3.4.4 At least 100 users

3.2.3.4.5 At least 30 simultaneous calls

3.2.3.4.6 At least 8 FXS POTS analogue terminals

3.2.3.4.7 Remote phone terminals (extensions)

3.2.3.4.8 Multiple SIP trunks at least 32 each with multiple voice channels

3.2.3.4.9 GSM gateway/module with support for at least four simultaneous calls, four SIM cards from different service providers and outdoor antenna

3.2.3.4.10 Call recording

3.2.3.4.11 DHCP server

3.2.3.4.12 Support ITU-T G.722 wideband voice encoding.

3.2.3.4.13 Store and retrieve call data records and recordings in a remote SQL database

server and file server.

3.2.3.4.14 Echo cancellation

3.2.3.4.15 Monitoring and management using SNMP

3.2.3.4.16 Firewall and intrusion detection

3.2.3.4.17 WAN connection basic routing interface to provider edge devices

3.2.3.5 Contractor shall carryout all necessary configuration in the PBX, GSM gateway and DECT bases stations to provide seamless telephone coverage. Contractor shall also configure automatic uploading of call data records and recordings to a server in the control centre. Contractor shall configure the PBX for LDAP user management and authentication using existing windows active directory domain server at each station.

3.2.3.6 Numbering scheme for the telephone nodes shall be developed for the operations telephone network during design stage. The numbering scheme shall provide easy identification of the telephone site and location and allow easy integration to the corporate call manager. It shall also meet the telephone numbering scheme as per ITU-T and communications authority of Kenya.

3.2.3.7 Robust and rugged wireless telephone network and handsets shall be provided in the power plant floors and the indoor substations. The wireless handsets shall be rugged suitable for industrial use and have excellent noise cancellation features to enable use in the very noisy power plant floors. The handsets and the whole telephone network shall support wideband voice encoding of 50Hz-7000Hz providing highest possible voice quality. All Handsets shall support and be configured for ITU-T G.722 voice encoding. Each handset shall be provided with blue tooth headsets with noise cancellation.

3.2.3.8 Contractor shall ensure all the power plant floors and indoor substation areas of the seven forks power plants have wireless telephone network coverage. Digital enhanced cordless telecommunications, DECT wireless network shall be used. DECT shall support wideband encoding for the highest possible voice quality, ITU-T G.722 voice encoding shall be supported and configured. The number of DECT base stations and base station managers shall ensure complete coverage of the power plant floors and substations. The quantity given in the scope of supply is the minimum quantity, the actual quantity shall be as per design ensuring full coverage.

3.2.3.9 Corded IP telephones shall be provided for use in main control panels and at the control desks. Corded IP telephones shall provide the highest possible voice quality. Panel mounted rugged phones shall be provided and mounted on strategic control panels at the plant. Desktop phone terminals shall be provided for control room use. ITU-T G.722 voice encoding shall be supported and configured on all IP phones. The minimum number of corded phones per site is given in the scope of supply.

3.2.3.10 Existing Plain old telephone service, POTS terminals analogue telephone sets shall be re terminated and configured the seven forks' plants using the existing telephone wiring.

They shall be used to reach remote parts of the power plant previously covered by the analogue telephones including but not limited to areas such as spillway gates, intake gates, low level gates, main gates, tunnel entrance, tailrace, draft tubes, penstock valves etc. only existing wiring shall be utilised.

3.2.3.11 Contractor shall supply and configure local area networks (LAN) at the control rooms and powerhouse areas for the telephone network equipment connections. The Local area network shall include Ethernet switches, twisted pair cabling and all other structured cable works required for the telephone network at the powerhouse and control room any other area defined in the scope of supply. The contractor shall also carry out cabling and mounting works necessary for the DECT wireless LAN.

3.2.4 SCADA Application Network

3.2.4.1 SCADA application networks shall provide very low latency and jitter suitable for automatic control functions across the WAN as per recommendations of IEC TR 61850-90-12 and as specified in the performance requirements.

3.2.4.2 The SCADA WAN shall provide connectivity to the seven hydro power plants and the central control centres in Kamburu, Gitaru and hydro plaza. All the sites given in the scope of supply shall be covered.

3.2.4.3 Security gateways shall provide connection to the transport network in all the sites. They shall be the customer edge devices in the transport network.

3.2.4.4 SCADA traffic shall be prioritised in the core network to ensure the lowest possible latency for real time control functions. Bandwidth requirements as defined in the performance requirements shall be guaranteed for the SCADA application network.

3.2.4.5 SCADA application networks shall be segmented into levels as per Purdue reference model part of ISA95 standard by using security gateways to control traffic across each level.

3.2.4.6 Existing gateways shall be configured to ensure the SCADA applications meets all requirements of performance and functionality.

3.2.4.7 SCADA application network shall meet functional, architectural, performance and security requirements as defined in the specifications and applicable standards.

3.3 NETWORK DESIGN AND ARCHITECTURE

3.3.1 General

3.3.1.1 The Architecture requirements contain the proposed implementation methodology of the required system by the procuring entity. It provides a general proposal of how the contractor shall implement the functional and supply requirements and what performance requirements the system shall meet.

3.3.1.2 Contractor shall supply goods and provide services to meet all the functional requirements and the scope of supply requirements including those not covered by the architecture requirements.

3.3.1.3 The final architecture shall be developed by the contractor during design for review and approval by the procuring entity.

3.3.1.4 Architectural requirements given in this specification shall be the basis for the contractor design. However, the architecture requirements shall not be the only considerations while creating the final design, the contractor shall also consider the OEM requirements and guidelines, optimal operating conditions, overall performance of the system, cyber security requirements, referenced IEC standards and industry best practices.

3.3.1.5 Architecture developed by the contractor shall at minimum meet the performance requirements given and implement the functions in the procuring entity architecture.

3.3.1.6 Approved architecture shall be used to implement the system at site. Contractor must design and get approval of the designs prior to site works.

3.3.2 Design and Operational Philosophy

3.3.2.1 Resiliency

3.3.2.1.1 The design philosophy of the new network shall be that failure of any single component shall not cause failure of critical function or the whole network.

3.3.2.1.2 The network shall be capable of providing a fully resilient network in which all traffic shall be automatically re-routed in the event of a trunk/node failure and/or traffic congestion occurring anywhere on the network.

3.3.2.2 Monitoring

3.3.2.2.1 Network equipment malfunction alarms and general events shall be transmitted to the network monitoring system, to alert the system operators in the control rooms of the operational status of the network.

3.3.2.2.2 Remote monitoring of network equipment operational status including alarms and performance shall be under the supervision of the monitoring system as

detailed in the control centre requirements.

3.3.2.3 Reliability

3.3.2.3.1 The design objective with respect to reliability is to ensure that no single contingency results in loss or unacceptable degradation of service, and that the incidence of failure of components/elements is consistent with achieving high availability. The system must be fault tolerant, resilient to hazards and robust in all respects.

3.3.2.3.2 The proposed design shall incorporate proven technology and address the requirements set out in this document with respect to availability and reliability.

3.3.2.3.3 The equipment shall preserve configuration data during power failure and power modules shall be capable of hot swappable and redundant for all key network equipment.

3.3.2.4 Expansion and Upgrade Capability

3.3.2.4.1 The network system supplied by the Contractor shall employ open standard concept in the design and shall offer greatest flexibility for future expansion and upgrade of the system and facilities.

3.3.2.4.2 System expansions and upgrades carried out at a later date shall be possible by means of minor modifications and/or by the addition of extra equipment modules to the network equipment.

3.3.2.4.3 All systems shall be supplied already equipped with a minimum of 25 per cent spare capacity including interface modules for each type of network interface.

3.3.2.4.4 Open topology network allowing the most flexible way of building the network shall be adopted and the network shall be able to evolve in functionality just by simply adding plug-in units or software upgrade/configuration

3.3.2.5 Electromagnetic Compatibility

3.3.2.5.1 The equipment supplied must be able to co-exist and operate within the electromagnetic environment with adequate immunity to any electromagnetic disturbances in order that operations will be free of malfunction and safe.

3.3.2.5.2 Power plants have a higher-than-average electromagnetic emission which shall be factored in the design of the equipment to be supplied.

3.3.2.5.3 Equipment and system designs proposed by the Contractor shall take into account the requirements outlined in the relevant internationally recognised Standards

and Regulations to ensure electromagnetic compatibility.

3.3.2.5.4 The design shall take account of all aspects of electromagnetic compatibility (EMC) including, for example, circuit design; equipment and cable screening; filtering; grounding and bonding.

3.3.2.5.5 The inclusion of EMC requirements in the equipment/system design shall not cause any degradation of quality, performance or loss of function.

3.3.2.5.6 Bidders shall include the following in their Tenders:

(a) A list of Standards which the proposed equipment will comply with the EMC Requirements.

(b) EMC type test certification, if any, for the proposed equipment.

3.3.2.6 Equipment Locations

3.3.2.6.1 Most of the network equipment will be located at the Control rooms and at the powerhouse. In general, new network equipment will be located adjacent to existing telecommunications & network equipment or in a location previously occupied by existing equipment.

3.3.2.6.2 The network equipment will also be co-located with existing SCADA equipment and equipment supplied by others.

3.3.2.6.3 Contractor shall visit all the sites and review the existing equipment before undertaking the design.

3.3.2.7 Environmental Compatibility

3.3.2.7.1 The equipment supplied shall be designed for operation in industrial environments with high average temperature and humidity without degradation of performance.

3.3.2.7.2 Equipment shall be designed for average max continuous temperature of over 35˚Celsius and humidity levels of over 95%. The underground powerhouse temperatures remain relatively the same during day and night hence the equipment shall be capable of operating at the maximum temperature continuously.

3.3.2.7.3 All outdoor equipment shall be designed to withstand the outdoor conditions such as direct sunlight, UV light, rainfall, high temperatures and high temperature variations, high humidity and wind loading.

3.3.2.7.4 The network equipment shall withstand the high vibration in the power plants.

3.3.2.7.5 The network cabinets shall be industrial grade providing an IP rating of at least IP54

3.3.3 Network Architecture

3.3.3.1 Overall Network Architecture

3.3.3.1.1 Procuring entity applications to be transported across the wide area network require different network topologies and quality requirements. The ownership and the management of these communicating applications is also under the responsibility of different entities in the procuring entity. Moreover, the applications shall not be deployed at the same time and cannot be enumerated exhaustively for the lifetime duration of the communication network. To enable operation of that kind of wide area network it shall be separated to Application Networks (AN) and the Transport Network (TN) as illustrated below

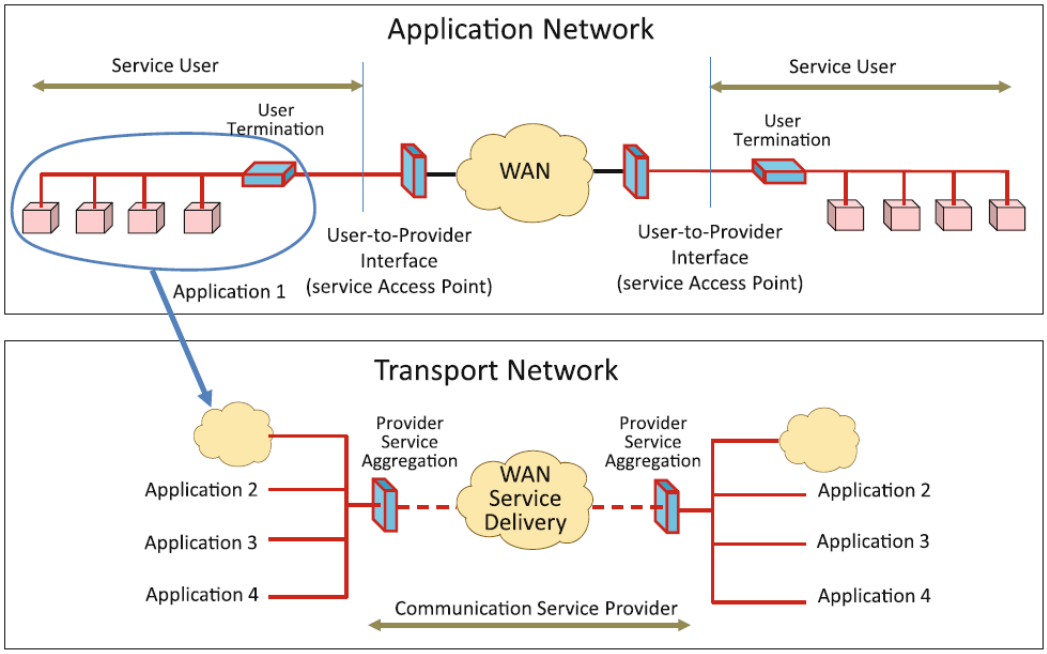

Figure 1 Application networks (AN) and transport network (TN) separation. Courtesy of CIGRE green books: Utility Communication Networks and Services

3.3.3.1.2 Each Application Network (SCADA, voice, etc.) caters one or several applications with similar characteristics (performance, security, topology, ownership, etc.). It shall be a point-to-point connection of two sites, a group of interconnected sites or a server connecting to remote devices.

3.3.3.1.3 The overall mapping between applications and Application networks is an essential part of the network design and shall allow for the future increase and growth of devices on each application network or the addition of new application networks.

3.3.3.1.4 The transport network (TN) shall be composed of network infrastructure

delivering connection services with appropriate quality to every application network at each site. The TN shall deliver a transport service to each application network through a provider edge device at a Service Access Point (SAP).

3.3.3.1.5 The quality of the delivered services shall be assured by the technical performances of the network and the way each traffic stream is treated in the aggregated data stream. This shall consist of allocating communication resources such as bandwidth and also adequate mechanisms for controlling the access to shared resources collectively called quality of service control (e.g., allocating priority in a service queue).

3.3.3.1.6 The separation of ANs from the TN shall allow distinct migration planning in the Power stations and across the network, as well as simplified network management, quality monitoring, and security management processes. The termination device for the AN/TN and SAP shall be the contractual points of service delivery, monitoring, and user/provider management.

3.3.3.1.7 As shown in Figure below, converging of data streams from different ANs into a common transport network shall require service access and aggregation devices at the sites These aggregation devices shall adapt the application interfaces to the transport requirements and manages the repartition of the AN bandwidth between different AN.

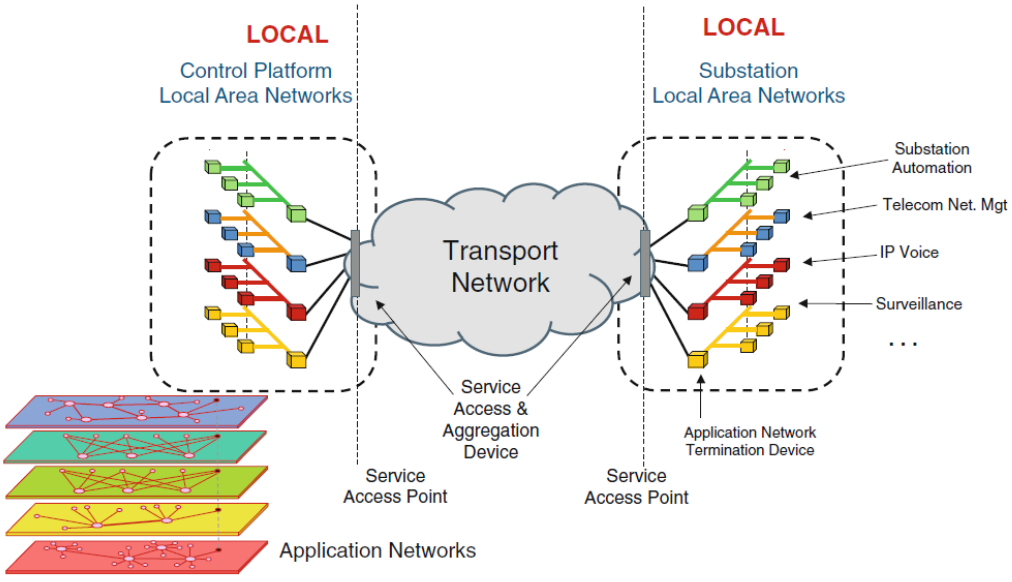

Figure 2 Architectural model for delivering operational communications services Courtesy of CIGRE green books: Utility Communication Networks and Services

3.3.3.1.8 The aggregation of application data streams shall be performed by use of established packet switched network carrier services i.e., carrier/metro Ethernet and MPLS either or both. The choice of PSN carrier service to use at the transport network shall be firmed up during design stage after factoring all requirements including performance requirements, available physical links, security

requirements, function requirements, future proofing and ease of management and administration.

3.3.3.1.9 A minimum of three application networks shall be deployed and commissioned by the contractor. These shall be.

(a) SCADA application networks
  (i) Telecontrol application network
  (ii) Plant information management network
  (iii) SCADA Asset monitoring and management network
(b) Operations telephone network
(c) Corporate services back up application networks.
  (i) Corporate telephone
  (ii) Internet
  (iii) Enterprise services

3.3.3.1.10 Network shall cover all the sites in the scope of supply.

3.3.3.1.11 Specification drawing provided shows a visual representation of the proposed network.

3.3.3.1.12 Contractor shall be responsible for reconfiguration and redeployment of existing network equipment and services not in scope of supply to ensure realisation the specified network architecture and performance.

3.3.3.2 Backbone/Transport Network

3.3.3.2.1 Transport network architecture shall cover connectivity between all the sites and shall handle differentiated services. Transport shall have to carry diverse traffic, for this purpose, carrier Ethernet or MPLS or both shall be applied to provide isolation of each class of traffic and reserve bandwidth for each class of traffic across all the available links.

3.3.3.2.2 The contractor shall install and configure MPLS or carrier ethernet on the edge routers and backbone ethernet switches/routers to provide both ethernet and IP connectivity for different services, while maintaining a complete logical separation of traffic and routing information. Each class of traffic shall be a separate VPN with each VPN having a minimum bandwidth reserved as detailed in performance requirements.

3.3.3.2.3 Contractor shall develop the transport network architecture after tender award during the design stage and submit for approval. Preliminary architecture is provided in the specification drawings. Contractor shall develop network

architecture based on the given preliminary architecture, specifications in this tender, performance requirements, standards, industry best practice and any other general requirements given during design stage by the employer.

3.3.3.2.4 Transport network Architecture shall meet the following requirements.

(a) Shall provide/meet given performance requirements.

(b) Shall provide connectivity to all the sites in the scope of this tender.

(c) Architecture shall be scalable to add more sites.

(d) Shall ensure design and operations philosophy in clause 3.3.2

3.3.3.2.5 The transport network shall be as deterministic as possible to ensure deterministic(guaranteed) latency and bandwidth for critical SCADA and operations telephone applications. Latency and bandwidth shall be guaranteed for critical applications irrespective of the amount of traffic.

3.3.3.2.6 Each of the six (6) main interconnection sites i.e., Masinga, Kamburu, Gitaru, Kindaruma, Kiambere and Tana shall have multiple WAN links as shown in the drawing and detailed in the performance requirements.

3.3.3.2.7 The transport network shall be a point-to-point network, all sites shall have at least one direct connection link to all the other eight sites without passing through another edge router.

3.3.3.2.8 All WAN links shall remain active and share traffic. All links shall be utilised simultaneously to maximise bandwidth and link availability.

3.3.3.2.9 Traffic engineering and resource reservation shall be used for network control to ensure all the WAN links remain as deterministic as possible.

3.3.3.2.10 Seven forks' sites shall have redundant routers. Router redundancy protocols shall be used to ensure services are not interrupted in case of failure of one router. The two redundant routers shall however remain active and manage assigned connections, only in case of failure shall one router handle all connections.

3.3.3.2.11 Spanning tree protocol shall not be used to control the WAN transport links for Ethernet loop management. Contractor shall configure all redundant links to ensure they remain active without creating loops in the Ethernet network. All available links shall remain active and handle traffic. Traffic engineering shall be applied to ensure all available WAN transport links remain active/stateful.

3.3.3.2.12 Transport network shall handle all routing functions for all the application networks. Routers shall be responsible for routing traffic for all the application network devices. Routers shall maintain a separate routing table (VRF) for each application network. Each application network shall maintain an independent IP address range which can be the same for multiple application networks. The routers shall thus ensure each application network has independent routing and forwarding table.

3.3.3.2.13 Contractor shall configure VRF's for each application network. Each application network shall be a VPN on the transport network. A minimum of the following application network VRF and VPN shall be configured.

(a) SCADA application network
(b) Operations telephone network
(c) Network management system (NMS) network
(d) Corporate telephone network
(e) Corporate services network

3.3.3.2.14 The transport network shall allow setting up of multiple layer 2 ethernet virtual private network i.e., L2 VPN by the procuring entity between the six main sites. It shall be possible to create a Layer 2 VPN connection across any of the six sites whenever required by the procuring entity.

3.3.3.2.15 The transport network shall allow setting up of multiple layer 3 IP virtual private network L3 VPN.by the procuring entity between the six main sites in addition to the L3 VPN already specified in this specification.

3.3.3.2.16 Contractor shall provide tools required to set up additional layer 2 and layer 3 networks by the procuring entity. The tool shall enable configuration of traffic engineering and resource reservation for the new networks set up by procuring entity.

3.3.3.3 SCADA Application Network Architecture

3.3.3.3.1 SCADA application network shall provide network to Power plant control applications and other power plant operations functions. A minimum of the following SCADA application network functions shall be provided.

(a) Telecontrol
(b) Plant information management system
(c) SCADA Asset monitoring and management

3.3.3.3.2 SCADA application network shall have a separate VPN and VRF instances on the transport network. The three network functions shall be segregated using quality of service markers and any other layer three measures to ensure the performance requirements for each function are met.

3.3.3.3.3 Telecontrol application network function shall provide connectivity to applications used for real time control commands, telemetry, and automation functions. Telecontrol function is a server client function, each power plant site shall have a client function which shall connect to servers in Gitaru and Kamburu.

3.3.3.3.4 Telecontrol application network shall operate in a hierarchical structure as follows, the five seven forks' stations (Masinga, Kamburu, Gitaru, Kindaruma and Kiambere) Local control centres, LCC to regional control centres, RCC in Gitaru and Kamburu. Each local centre shall have two connections to Gitaru RCC and Kamburu RCC.

3.3.3.3.5 Plant information management system network function shall provide connectivity for power plant dispatch, maintenance, and other management functions. Shall provide connectivity to applications that collect telemetry data, send setting & configuration data and send & receive files for plant online condition monitoring, plant assets management, maintenance management applications and other dispatch applications.

3.3.3.3.6 Plant information management system function is a server - client function, each power plant site shall have a client function which shall connect to servers in Gitaru and Kamburu.

3.3.3.3.7 SCADA Asset monitoring and management network function shall provide connectivity for SCADA equipment management and monitoring as detailed in clause 4.2.4. The SCADA assets include network devices (switches, gateways routers etc.), servers, workstations, cyber security appliances, Control devices (PLC's, PAC's, controllers etc.) and intelligent electronic devices (IED) e.g., meters, numerical protection relays, smart sensors etc. The management and monitoring functions shall include but not limited to:

(a) User management and authentication
(b) Windows operating systems and applications updates and remote management.
(c) Security appliances monitoring, updates, and remote administration.
(d) SCADA local area network devices monitoring and remote management.
(e) Control devices & IED's remote health monitoring and patch management (not in scope)

3.3.3.3.8 SCADA Asset monitoring and management function is a server client function, each power plant site shall have a client function which shall connect to servers in Gitaru and Kamburu.

3.3.3.3.9 General architecture of the SCADA application networks is provided in the specification drawings.

3.3.3.3.10 SCADA application network performance parameters (network metrics) shall be as detailed in the performance requirements.

3.3.3.3.11 The SCADA application networks shall provide connectivity to the seven hydro power plants and the central control centres in Kamburu, Gitaru and hydro plaza. All the sites given in the scope of supply shall be covered. The network shall also

be scalable to add other remaining plants in the future.

3.3.3.3.12 Security gateways shall provide connection to the transport network in all the sites. They shall be the customer edge devices in the transport network. Contractor shall configure the following network functions in the Security gateways for operation of the SCADA application networks.

(a) Differentiate the various classes of traffic as per functions described in clause 3.3.3.3.1 and any other SCADA functions by assigning priority markers that ensure correct prioritisation of traffic.

(b) Create point to point encrypted IP connection (IPsec) from source firewall to destination firewall.

(c) Multiple routing instances for traffic segregation at the CE node to enable segregation of various SCADA network functions described in clause 3.3.3.3.1 and any other SCADA functions.

3.3.3.3.13 SCADA Application networks shall have a specific VRF on the routers which will enable the transport network to reserve specific bandwidth for SCADA applications, route traffic to the destination using pre-determined multiple paths, assign high priority for the SCADA VPN traffic over the other VPN as detailed in performance requirements, prioritise the various SCADA functions based on the differentiated services header or other prioritisation method.

3.3.3.3.14 Fixed bandwidth shall be reserved on all available transport links to ensure the highest possible availability of SCADA network. Each SCADA network function shall be assigned a DSCP and CoS value suitable for the application in the following precedence telecontrol, PIMS and SCADA assets management. Network shall be designed to provide deterministic bandwidth, latency and jitter for telecontrol function similar to circuit switched network.

3.3.3.4 Operations Telephone Application Network Architecture

3.3.3.4.1 Operations telephone application network shall provide operations telephony connectivity for corded telephone sets and cordless handsets. Contractor shall provide both the wide area network and local area networks for the telephone operation.

3.3.3.4.2 Telephone application network shall consist of SIP trunk connections between private branch exchanges in five sites and remote telephone nodes SIP channels connections to Hydro Plaza and Kamburu. The eight sites with PBX shall be Masinga, Kamburu, Gitaru, Kindaruma and Kiambere.

3.3.3.4.3 The operations telephone application network shall be a distributed point to point

network without any central server or switch. Each IP PBX shall have a direct and persistent SIP trunk connection to all the other four PBXs and to the corporate call manager/server.

3.3.3.4.4 Hydro plaza and some Kamburu telephone nodes shall be remote telephone node to PBX in Kamburu and Gitaru.. Remote telephone node shall utilise the local area network provided by the new fibre network.

3.3.3.4.5 Operations telephone network shall provide low latency suitable for the best voice clarity necessary to receive calls at the noisy plant floor.

3.3.3.4.6 Each PBX shall be assigned a fixed bandwidth to all the other four PBX's and corporate call manager. The fixed bandwidth shall be provided in all the available transport links to ensure a minimum number of simultaneous calls can be transmitted irrespective of the total network traffic. One SIP channel shall be assigned a minimum full duplex bandwidth of 100Kbps i.e., aggregate bandwidth of 200kbps per channel.

3.3.3.4.7 All voice traffic shall be assigned a DSCP and CoS value suitable for real time voice service prioritisation for the best voice quality. Network shall be designed to provide voice quality similar to circuit switched network.

3.3.3.5 Corporate Services Backup Application Network Architecture

3.3.3.5.1 Corporate Services Backup Application Network shall provide connectivity for business functions such as ERP, telephone, email, internet etc. at the power plants.

3.3.3.5.2 The corporate services network shall have the highest bandwidth requirement but the lowest latency, availability, and reliability requirement, except for the corporate telephone network.

3.3.3.5.3 Bandwidth reservation shall ensure the corporate services network which has the highest users and bandwidth requirement shall not affect reliability and availability of the critical networks.

3.3.3.5.4 The network shall provide alternative corporate services connection for the main six sites i.e., Masinga, Kamburu, Gitaru, Kindaruma, Kiambere and Tana.

3.3.3.5.5 The corporate network shall have other alternative routes but the SCADA wide area network in this tender shall provide alternative paths for power plant business network services.

3.3.3.5.6 It's envisioned that the corporate network shall migrate to use software defined WAN (SD WAN) in the next two to three years to cater for the growing internet

and cloud solution requirements. The Corporate services application network shall thus be backup to the main internet-based WAN links. The transport network and other application networks shall be designed for high network availability, reliability, resiliency, and low latency not required for corporate services network. Hence, the network overall design shall be meant for critical applications and not the corporate services.

3.3.3.5.7 Currently the SCADA network and corporate networks are separate and do not share the links and network equipment.

3.3.3.5.8 Internet services shall be routed to the nearest internet gateway as per configuration to be provided during design.

3.3.3.5.9 Contractor shall be responsible for all configurations required for the corporate network to have alternative paths through the new SCADA WAN corporate services application network. This shall include reconfiguring the existing cisco corporate routers not in scope of supply of this tender.

3.3.4 Network Performance Requirements

3.3.4.1 General requirements

3.3.4.1.1 The network shall be designed to meet performance requirements given in this clause 3.3.4

3.3.4.1.2 Requirements are applicable to the transport network and application networks detailed in the architecture and the access local area networks in scope of supply.

3.3.4.1.3 Contractor shall be responsible for ensuring that the given performance parameters are met by equipment and the network. Contractor shall provide only equipment that meet given performance metrics. Contractor shall also reconfigure the existing equipment to ensure conformance of the network to the given performance parameters.

3.3.4.1.4 The performance requirements in the subsequent tables are estimates for initial design only. During design stage the performance parameters shall be examined further to arrive at the optimum configuration of the network.

3.3.4.1.5 Performance metrics considered include but not limited

(a) Bandwidth
(b) Latency
(c) Recovery delay
(d) Redundancy and reliability
(e) Availability
(f) Integrity

(g) Packet loss

(h) Dependability

(i) Jitter

3.3.4.1.6 Bandwidth

(a) Shall mean measurement indicating the maximum capacity of a network link to transmit data over a network connection in a given amount of time. Shall be expressed in Kbps, Mbps, or Gbps

(b) Bandwidth for new radio and fibre optic links shall be as defined in the architecture

(c) Bandwidth shall be defined for each application network based on available capacity of the backbone link.

(d) Bandwidth requirement given is the minimum bandwidth required for optimal function of the specific applications and number of users or connections.

3.3.4.1.7 Latency

(a) Shall mean the round-trip delay of data packets across a network link

(b) WAN Latency values given in the specification shall be the round-trip delay between the CE devices (security gateway, PBX, corporate router)

(c) Application latency shall be round trip delay between two applications or devices in a connection. Application latency shall incorporate WAN round trip delay, LAN round trip delay on both ends and both device delays.

(d) Application delays shall meet guidelines of IEC 61850

3.3.4.1.8 Recovery delay

(a) It shall mean the time the network or logical path shall take to recover after failure in the communication link.

(b) Fast Reroute shall provide link protection to WAN traffic paths. It shall enable all traffic carried along the failed path/link to be rerouted around the failure.

3.3.4.1.9 Availability, and reliability

(a) Reliability shall mean the probability of network equipment or network link failing.

(b) Availability expressed in percentage shall indicate the total uptime of a network link or equipment per year.

(c) Redundancy shall be applied to ensure failure of one equipment/component or network link does not lead to loss of network availability

(d) All transport links shall be redundant, whereas not all routers are redundant the chosen routers shall have redundant power supplies and all measures shall be applied to increase reliability of the router.

(e) Massive redundancy, in which redundant components are continuously active shall be applied for all transport network and equipment and links to ensure the lowest possible recovery delay for the critical transport links. Redundant security gateways and routers shall remain continuously active. All transport links shall also load share and remain continuously active including the lowest priority links.

(f) The routers mean time to failure and mean time between repairs shall be very high to ensure probability of router downtime is less than 0.1% per year for the initial five years and below 1% after that.

3.3.4.1.10 Integrity

(a) Integrity shall be the probability to recognize data falsified by errors as incorrect. Integrity relies on an error detection code, whose efficiency depends on the bit error ratio of the medium.

(b) The bit error ratio (BER) shall be the number of bit errors divided by the total number of transferred bits during a studied time interval. The bit error ratio requirement shall be bit error probability.

(c) The communication links and equipment shall be designed to ensure the BER probability stays below the limits given for tele control functions

(d) Integrity of communication equipment especially radio links where error correction is required due to interference shall remain high to prevent maloperation of control equipment. Integrity shall prevent wrong commands from being issued to control equipment leading to faults in the plant.

3.3.4.1.11 Quality of service

(a) Shall mean provision of different priorities to different applications, users, or data flows, to guarantee a certain level of performance to certain applications/functions.

(b) Performance metrics to be considered for quality of service shall be throughput/bandwidth, latency, availability, and packet loss

(c) Traffic prioritization shall be applied both at layer two and layer three part of the network to ensure highest performance across the network. Layer three priority markers shall be mapped to layer two markers and vice versa across devices and medium to ensure prioritisation of traffic across all links

(d) Resource reservation control mechanisms shall be applied to ensure performance of certain critical functions and application remain unchanged across the transport network irrespective of network conditions.

(e) All measures shall be taken to ensure all critical applications such as network control and telecontrol are prioritised across the network and the less critical traffic such as internet traffic is assigned the lowest priority across the

network to ensure that low priority traffic does not affect the high priority traffic

3.3.4.1.12 Jitter shall be the average variation in latency in each network connection. The jitter shall be as low as possible to support voice and SCADA auto control functions that require constant latency. The jitter shall not exceed 3ms

3.3.4.2 Overall WAN Links Bandwidth

A minimum of the following bandwidth given in the table below shall be provided for the wide area network links. Capacity given is full duplex i.e., both uplink and downlink simultaneous bandwidth. Bandwidth capacity given is maximum overall bandwidth required and not the maximum capacity of the telecom medium. Seven forks mean Masinga, Kamburu, Gitaru, Kindaruma, Kiambere sites

#	Site	Fibre optic		Radio	
		Next hop	Capacity	Next hop	Capacity
A	Masinga	Kamburu	1Gbps	Matendeni	200Mbps
B	Kamburu	All seven forks & Tana	1Gbps /10Gbps	Kianjiru	200Mbps
C	Gitaru	Kamburu, Matendeni, Hydro Plaza	1Gbps /10Gbps	Kianjiru	200Mbps
D	Kindaruma	Kamburu	1Gbps	Matendeni	200Mbps
E	Kiambere	Kamburu	1Gbps	Kianjiru	200Mbps
F	Hydro Plaza	Kamburu and Gitaru	1Gbps	N/A	N/A
G	Matendeni	Kamburu and Gitaru	1Gbps	Masinga & Kindaruma	200Mbps X 2
I	Kianjiru	N/A	N/A	Kamburu, Gitaru, Kiambere & Tana	200Mbps X 4
J1	Tana	Kamburu	1Gbps	Kianjiru	200Mbps
J2	Wanjii	Tana	1Gbps	Tana	200Mbps

N/A- Not applicable or not available TBD – to be defined later

3.3.4.3 Transport Network Performance metrics

3.3.4.3.1 Overall network convergence/recovery delay shall be less than 50ms for all redundant links

3.3.4.3.2 Fibre optic links metrics

(a) Availability shall be above 99.9 for all fibre optic links

(b) Jitter shall not exceed 1ms for all fibre optic links

(c) Bit error rate shall not exceed $1X10^{-11}$ for fibre optic links

(d) Bandwidth capacity is given in the table below is full duplex capacity i.e. both uplink and down link capacity simultaneous.

(e) Ethernet multi point to multi point ingress bandwidth is given.

(f) Bandwidth capacity given is maximum overall logical bandwidth required and not the maximum capacity of the fibre optic medium.

(g) Required Ethernet round trip latency from ingress port to the egress port is given in the table below, this includes delays of the backbone ethernet switches where applicable

#	Site	Masinga		Kamburu		Gitaru		Kindaruma		Kiambere		Tana		Wanjii	
		Bandwidth	Latency	Bandwidth	Latency	Bandwidth	Latency	Bandwidth	Latency	Bandwidth	Latency	Bandwidth	Latency	Bandwidth	Latency
A	Masinga	N/A	N/A	1Gbps	<2.5ms	1Gbps	<2.5ms	1Gbps	<2.5ms	1Gbps	<3ms	1Gbps	<4ms	N/A	N/A
B	Kamburu	1Gbps	<2.5ms	N/A	N/A	1Gbps	<2.5ms	1Gbps	<2.5ms	1Gbps	<2.5ms	1Gbps	<3.5ms	N/A	N/A
C	Gitaru	1Gbps	<2.5ms	1Gbps	<2.5ms	N/A	N/A	1Gbps	<2.5ms	1Gbps	<2.5ms	1Gbps	<3.5ms	N/A	N/A
D	Kindaruma	1Gbps	<2.5ms	1Gbps	<2.5ms	1Gbps	<2.5ms	N/A	N/A	1Gbps	<2.5ms	1Gbps	<4ms	N/A	N/A
E	Kiambere	1Gbps	<2.5ms	1Gbps	<2.5ms	1Gbps	<2.5ms	1Gbps	<2.5ms	N/A	N/A	1Gbps	<4ms	N/A	N/A
J1	Tana	1Gbps	<4ms	1Gbps	<3.5ms	1Gbps	<3.5ms	1Gbps	<4ms	1Gbps	<4ms	N/A	N/A	1Gbps	<2.5ms
J2	Wanjii	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1Gbps	<2.5ms	N/A	N/A

N/A- Not applicable or not available

3.3.4.3.3 Radio links

(a) Availability shall be above 99.9 for all radio links.

(b) Jitter shall not exceed 3ms for all radio links.

(c) Bit error rate shall not exceed $1X10^{-10}$ for all radio links.

(d) Bandwidth capacity is given in the table below is full duplex capacity i.e. both uplink and down link capacity simultaneous.

(e) Ethernet multi point to multi point ingress bandwidth is given.

(f) Bandwidth capacity given is maximum overall logical bandwidth required and not the maximum capacity of the radio medium.

(g) Required Ethernet round trip latency from ingress port to the egress port is given in the table below, this includes delays of the backbone ethernet switches where applicable. Latency is for radio-to-radio connections, links through more than one hop will have higher expected latency

#	Site	Masinga		Kamburu		Gitaru		Kindaruma		Kiambere		Tana		Wanjii	
		Bandwidth	Latency	Bandwidth	Latency	Bandwidth	Latency	Bandwidth	Latency	Bandwidth	Latency	Bandwidth	Latency	Bandwidth	Latency
A	Masinga	N/A	N/A	200Mbps	<8ms	200Mbps	<8ms	200Mbps	<8ms	200Mbps	<15ms	200Mbps	<15ms	N/A	N/A
B	Kamburu	200Mbps	<8ms	N/A	N/A	200Mbps	<15ms	200Mbps	<8ms	200Mbps	<15ms	200Mbps	<15ms	N/A	N/A
C	Gitaru	200Mbps	<8ms	200Mbps	<8ms	N/A	N/A	200Mbps	<8ms	200Mbps	<15ms	200Mbps	<15ms	N/A	N/A
D	Kindaruma	200Mbps	<15ms	200Mbps	<8ms	200Mbps	<8ms	N/A	N/A	200Mbps	<15ms	200Mbps	<15ms	N/A	N/A
E	Kiambere	200Mbps	<15ms	200Mbps	<15ms	200Mbps	<15ms	200Mbps	<15ms	N/A	N/A	200Mbps	<15ms	N/A	N/A
J1	Tana	200Mbps	<15ms	200Mbps	<15ms	200Mbps	<15ms	200Mbps	<15ms	200Mbps	<15ms	N/A	N/A	200Mbps	<8ms
J2	Wanjii	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	200Mbps	<8ms	N/A	N/A

N/A- Not applicable or not available

3.3.4.3.4 Bandwidth reservation for the application network VPN's per site

(a) The tables show the minimum capacity to be reserved on each available link for each application.

(b) Operations telephone network and SCADA network traffic bandwidth shall have the highest priority and shall be preserved as much as possible in case of reduced link bandwidth e.g., for radio links during congestion or poor weather. The lowest priority traffic bandwidth shall be dropped first in case of reduced bandwidth below the limits for high priority traffic

(c) In case the bandwidth drops below 50Mbps in any of the radio links all corporate traffic will dropped and all the remaining bandwidth dedicated to operations telephone and SCADA traffic. Corporate bandwidth shall be curtailed on the radio links whenever the capacity equals or falls below 100Mbs as per the percentage given in the table below.

(d) A minimum bandwidth shall be reserved on all the links for SCADA an operations telephone traffic that shall be sustained in case of reduced available capacity for service provider links.

(e) The ingress bandwidth to the transport network per site for each type of link is indicated.

(f) The values are not fixed and may reviewed during design.

(g) Minimum bandwidth reservation for fibre optic links shall be as follows.

#	Site	Max Capacity	SCADA	Operations telephone	NMS	Corporate telephone	Other Corporate services
A	Masinga	1Gbps	200Mbps	10Mbps	20Mbps	10Mbps	300Mbps
B	Kamburu	1Gbps	500Mbps	10Mbps	20Mbps	10Mbps	300Mbps
C	Gitaru	1Gbps	500Mbps	10Mbps	20Mbps	10Mbps	300Mbps
D	Kindaruma	1Gbps	200Mbps	10Mbps	20Mbps	10Mbps	300Mbps
E	Kiambere	1Gbps	200Mbps	10Mbps	20Mbps	10Mbps	300Mbps
J1	Tana	1Gbps	300Mbps	10Mbps	20Mbps	10Mbps	300Mbps
J2	Wanjii	1Gbps	200Mbps	10Mbps	20Mbps	10Mbps	300Mbps

(h) Minimum bandwidth reservation for radio links shall be as follows.

#	Site	Max Capacity	SCADA		Operations telephone		NMS		Corporate telephone	Other Corporate services
			Max Capacity	min % of available capacity	Max Capacity	min % of available capacity	Max Capacity	min % of available capacity	Max Capacity	Max Capacity
A	Masinga	200Mbps	40Mbps	60.0%	10Mbps	20.0%	10Mbps	5.0%	10Mbps	50Mbps
B	Kamburu	200Mbps	100Mbps	75.0%	10Mbps	20.0%	10Mbps	5.0%	10Mbps	50Mbps
C	Gitaru	200Mbps	100Mbps	75.0%	10Mbps	20.0%	10Mbps	5.0%	10Mbps	50Mbps
D	Kindaruma	200Mbps	40Mbps	60.0%	10Mbps	20.0%	10Mbps	5.0%	10Mbps	50Mbps
E	Kiambere	200Mbps	40Mbps	60.0%	10Mbps	20.0%	10Mbps	5.0%	10Mbps	50Mbps
J1	Tana	200Mbps	40Mbps	60.0%	10Mbps	20.0%	10Mbps	5.0%	10Mbps	50Mbps
J2	Wanjii	200Mbps	40Mbps	60.0%	10Mbps	20.0%	10Mbps	5.0%	10Mbps	50Mbps

3.3.4.3.5 Application network VPNs shall be prioritised as follows in the transport network.

(a) Prioritisation classes below shall apply to the full VPN traffic in the transport network links between the routers.

(b) Detailed priority classes for all traffic in the whole network is given under quality-of-service clause 3.3.4.6

Application network, VPN	Priority (802.1Q, EXP)
N/A	7
Operations telephone network	6
SCADA application network	5
Corporate telephone network	4
Network management system (NMS) network	3
N/A	2
Corporate services network	1
N/A	0

3.3.4.4 SCADA Application network Performance metrics

3.3.4.4.1 Wide area network Combined SCADA metrics for all functions

(a) Table gives minimum bandwidth and WAN latency requirement for Combined SCADA Functions

(b) The given values are for link between the security gateways at the local control centre and the security gateway at the RCC or CDC

(c) Only wide area network links are indicated. Control centre Local area network between Gitaru, Hydro Plaza and Gitaru is not included.

#	SCADA link	Bandwidth		Latency		Availability
		Nominal	Minimum	Nominal	Maximum	
A1	Masinga LCC to Kamburu RCC	100Mbps	20Mbps	5ms	10ms	99.90%
A2	Masinga LCC to Gitaru RCC	100Mbps	20Mbps	5ms	10ms	99.90%
B	Kamburu RCC to Stima Plaza CDC	20Mbps	5Mbps	20ms	40ms	99.00%
C	Gitaru RCC to Stima Plaza CDC	20Mbps	5Mbps	20ms	40ms	99.00%

#	SCADA link	Bandwidth		Latency		Availability
		Nominal	Minimum	Nominal	Maximum	
D1	Kindaruma LCC to Kamburu RCC	100Mbps	20Mbps	5ms	10ms	99.90%
D2	Kindaruma LCC to Gitaru RCC	100Mbps	20Mbps	5ms	10ms	99.90%
E1	Kiambere LCC to Kamburu RCC	100Mbps	20Mbps	6ms	12ms	99.90%
E2	Kiambere LCC to Gitaru RCC	100Mbps	20Mbps	6ms	12ms	99.90%
J1	Tana LCC to Kamburu RCC	100Mbps	20Mbps	6ms	12ms	99.90%
J2	Tana LCC to Gitaru RCC	100Mbps	20Mbps	6ms	12ms	99.90%
J3	Wanjii LCC to Kamburu RCC	20Mbps	10Mbps	12ms	24ms	99.90%
J4	Wanjii LCC to Gitaru RCC	20Mbps	10Mbps	12ms	24ms	99.90%
J5	Wanjii LCC to Tana RCC	100Mbps	20Mbps	5ms	10ms	99.90%

3.3.4.4.2 SCADA functions communication performance requirements

(a) The table below gives communication performance requirements for the specific SCADA functions from application to application i.e., application layer of client to application layer of server nodes.

(b) Latency includes the full communication round time delay time as defined in IEC61850-5

(c) The performance requirements are the minimum requirements for the effective functioning of the SCADA functions to be implemented by the procuring entity and the contractor. Network design shall ensure the application performance requirements are met

Metric	Telecontrol- Supervisory control	Telecontrol- Auto control	Plant information management system	SCADA Asset monitoring and management
Bandwidth large application	10Mbps	0.2Mbps	10Mbps	5Mbps
Bandwidth medium application	5Mbps	0.1Mbps	5Mbps	2Mbps
Bandwidth small application	3Mbps	0.1Mbps	3Mbps	1Mbps
Latency	≤ 100 ms	≤ 50 ms	≤ 300 ms	≤ 500 ms
Message rate/scan rate	5 Hz	Event driven	2 hz	1hz

Metric	Telecontrol- Supervisory control	Telecontrol- Auto control	Plant information management system	SCADA Asset monitoring and management
Packet loss	< 1%	< 0.1%	< 1%	< 1%
Recovery delay	< 1s	< 50 ms	< 1s	< 1s
Availability	99.90%	99.90%	99.00%	99.00%

3.3.4.5 Operations Telephone Performance metrics

3.3.4.5.1 Performance metrics given in this specification are for the operations telephone application. The network metrics cover the full network link from PBX to PBX or from PBX to telephone nodes and vice versa

3.3.4.5.2 Telephone WAN links/SIP trunks shall meet the following performance metrics

Metric	Value
SIP channel bandwidth full duplex capacity	100Kbps
Latency	≤ 50 ms
Jitter	≤ 5 ms
Packet loss	< 0.1%
Recovery delay	≤ 50 ms
availability	99.90%

3.3.4.5.3 SIP trunks

(a) SIP trunks shall be provisioned between all the PBX and the two corporate call mangers in Stima Plaza and Gitaru

(b) SIP trunks shall each have bandwidth for at least five simultaneous calls except SIP trunks to Gitaru, Kamburu and corporate call managers which shall have bandwidth for at least 10 simultaneous calls

(c) A bandwidth of 100kbps full duplex capacity shall be reserved for each simultaneous call

(d) Table below gives the minimum number of simultaneous calls that shall be provisioned between the various PBX, call manger and remote telephone nodes in Stima Plaza.

Masinga PBX						
10	Kamburu PBX					
10	10	Gitaru PBX				
10	10	10	Gitaru CM			
5	10	10	10	Kindaruma PBX		
5	10	10	10	5	Kiambere PBX	
10	10	10	0	10	10	Kamburu(Stima) CM

CM- corporate call manager/SIP server, RT-remote telephone nodes

(e) The following ingress/Egress bandwidth shall be reserved on the Transport network for the following telephone PBX, corporate call manager SIP trunks and Stima Plaza remote telephone nodes

#	Node	Minimum Reserved bandwidth
A	Masinga PBX	6Mbps
B1	Kamburu PBX	8.5Mbps
C1	Gitaru PBX	8.5Mbps
C2	Gitaru CM	7Mbps
D	Kindaruma PBX	6Mbps
E	Kiambere PBX	6Mbps
B2	Stima plaza CM via Kamburu	6Mbps

CM- corporate call manager/SIP server, RT-remote telephone nodes

(f) A minimum of the following bandwidth shall be reserved between the PBX's and corporate call manager in Gitaru and stima

plaza through Kamburu. Bandwidth capacity given in the table below is full duplex capacity i.e. for both uplink and down link capacity simultaneous.

Masinga PBX						
1Mbps	**Kamburu PBX**					
1Mbps	1Mbps	**Gitaru PBX**				
1Mbps	1Mbps	1Mbps	**Gitaru CM**			
500Kbps	1Mbps	1Mbps	1Mbps	**Kindaruma PBX**		
500Kbps	1Mbps	1Mbps	1Mbps	500Kbps	**Kiambere PBX**	
1Mbps	1Mbps	1Mbps	0	1Mbps	1Mbps	**Stima plaza CM through Kamburu**

CM- corporate call manager/SIP server, RT-remote telephone nodes

3.3.4.6 Quality of service

3.3.4.6.1 Quality of service markers shall be assigned to all traffic to ensure correct prioritisation of critical traffic and preventing low priority traffic from affecting the overall network performance.

3.3.4.6.2 Quality of service markers shall be assigned at the source node, security gateways, PBX, switches, routers, ethernet radios and all other network equipment. All the network devices shall be designed/configured to prioritise traffic based on the priority markers.

3.3.4.6.3 On the transport network connections between routers the VPN priorities shall be applied as given in clause 3.3.4.3.5

3.3.4.6.4 Layer three priorities shall be transferred to layer 2 where applicable.

3.3.4.6.5 The priority markers shall be assigned and prioritised as per the table below.

Traffic Class	**Applications**	**Layer 2 & MPLS QOS 802.1Q, EXP**	**Layer 3 (IP) QOS DSCP**
Network control	Network Control plane functions e.g., IS/IS, LDP, RSVP-TE, BGP, OSPF etc.	7	NC, CS7

Traffic Class	Applications	Layer 2 & MPLS QOS 802.1Q, EXP	Layer 3 (IP) QOS DSCP
Expedited	• Operations telephone • SCADA Telecontrol-auto control	6	EF, CS6
Real-Time	SCADA Telecontrol-supervisory control	5	EF, CS5
Streaming	Corporate Voice	4	AF41, AF42, AF43, CS4
Operation	SCADA PIMS	3	AF31, AF32, AF33, CS3
Support	• Network management • SCADA Asset monitoring and management	2	AF21, AF22, AF23, CS2
Business	Corporate functions Business email, file exchange, ERP	1	AF11, AF12, AF13, CS1
Internet	All internet except business email	0	Best Effort

3.3.5 Fibre Optic Links

3.3.5.1.1 Fibre optic WAN links shall be utilized in seven forks and Tana to link the sites. Dark fibre OPGW fibre links are available in Tana, Masinga, Gitaru, Kindaruma and Kiambere all linking to Kamburu. New fibre optic links shall be installed and commissioned by the contractor between Kamburu, Matendeni, Hydro Plaza and Gitaru.

3.3.5.1.2 Fibre optic shall provide Ethernet WAN links between the seven sites as detailed in the table below. Contractor shall supply equipment and materials and carry out all necessary installation and configuration for the operation of these fibre optic links

3.3.5.1.3 The fibre optic links shall be the primary links between these sites with other links as backup

3.3.5.1.4 The WAN fibre optic links are as follows

Site A	Site B	Distance	Pairs available	Type of fibre installation	Required link Capacity	Description
Wanjii	Tana	12km	1	OPGW, single mode	1G/s	To be availed from service provider
Tana	Kamburu	108km	1	OPGW, single mode	1G/s	Existing from service provider
Masinga	Kamburu	16km	1	OPGW, single mode	1G/s	Existing from service provider
Hydro Plaza	Kamburu	4km	2	Underground, single mode	1G/s	Existing by procuring entity
Hydro Plaza	Matendeni	3km	24	Underground, single mode	1G/s	To be supplied by contractor
Matendeni	Kamburu	4km	6	Underground, single mode	1G/s	To be supplied by contractor
Hydro Plaza	Gitaru	10km	6	Underground, single mode	1G/s	To be supplied by contractor
Matendeni	Gitaru	7km	4	Underground, single mode	1G/s	To be supplied by contractor
Gitaru	Gitaru CO	1km	2	Underground, single mode	1G/s	To be supplied by contractor
Gitaru	Kamburu	11km	24	Underground, single mode	10G/s	To be supplied by contractor

Site A	Site B	Distance	Pairs available	Type of fibre installation	Required link Capacity	Description
Gitaru	Kamburu	10km	1	OPGW, single mode	10G/s	Existing from service provider
Kindaruma	Kamburu	18km	1	OPGW, single mode	1G/s	Existing from service provider
Kiambere	Kamburu	42km	1	OPGW, single mode	1G/s	Existing from service provider

3.3.5.1.5 Fibre optic LAN links shall be utilised in all the sites to provide connectivity for operations telephone and local links to SCADA and to service provider terminal equipment / provider edge devices. Both single mode and multimode fibre shall be used for local area connections as detailed in the scope of supply and scope of works. All local area network fibre connections shall utilise steel wire armoured fibre or fibre shall run in flexible steel conduit.

3.3.5.1.6 Fibre optic Trans receiver modules, media converters and all other fibre optic equipment shall be designed to ensure operation to the specified performance parameters **without** use of repeaters. Use of repeaters is not acceptable unless specified.

3.3.5.1.7 The fibre optic links from the service provider shall be tested by the contractor and the optic fibre Trans receiver module shall be chosen to ensure that they provide the specified capacity and performance.

3.3.5.1.8 Fibre optic links supplied by the contractor **MUST** guarantee a minimum bandwidth of 25G/s per pair without use of special optic modules. The fibre optic installation, quality of fibre and quality of splicing shall ensure the fibre optic link properties shall guarantee a bandwidth of 25G/s per pair without use of special optic modules and without multiplexing.

3.3.5.1.9 The round-trip latency for all WAN fibre links except Tana to Kamburu shall not exceed 2.5 milliseconds, for Tana to Kamburu it shall not exceed 3.5 milliseconds. All the fibre equipment and workmanship shall ensure this metric is met.

3.3.5.1.10 All fibre optic equipment Trans receivers shall self-diagnose fault conditions and send alarms via SNMP. All failure of the fibre optic shall be alarmed by the fibre equipment and polled by the monitoring system.

3.3.5.1.11 Contractor shall provide all fibre optic equipment required for the operation of the Ethernet fibre optic links between the sites above, these shall include patch panels, patch cords, trans receiver modules, media converters etc. to ensure the fibre optic links provide the network links as per the performance requirements

3.3.6 Radio Links

3.3.6.1 General Requirements

(a) The microwave radio system shall operate in the 5-6 GHz ISM frequency band (unlicensed) and shall be designed for ethernet transmission. Other frequency bands may be acceptable should the Bidder consider there are cost benefits and improvements over the 5-6 GHz ISM frequency band. Details of benefits and justification for the proposed frequency band shall be included in the Tender. The final choice of the frequency band to be used shall be subject to approval of the Employer and/or communication authority.

(b) Microwave ethernet point to point radio shall be a wireless ethernet bridge providing an ethernet link similar to a wired ethernet connection for the specified capacity.

(c) Technical descriptions detailing the system performance including frequency plan and equipment configuration of the microwave radio system shall be provided.

(d) Radio equipment shall be rugged and robust for application in critical infrastructure. Radio equipment proposed shall provide documentation to proof its application in utility applications and application in ruggedized applications.

(e) The radio system shall be capable of providing proper performance throughout the15 year life expectancy of the system.

(f) The system shall be designed for ease of maintenance and shall include a variety of built-in alarms associated with vital operating parameters.

(g) The microwave radio system shall conform to the requirements of the communication authority regarding frequency allocation in all respects.

(h) The Contractor shall freely assist the Employer in negotiations with the radio regulatory authorities concerning the allocation of frequencies and licences for the microwave radio system should this arise.

(i) Wireless communication data shall be encrypted by at least 256bit encoding scheme to ensure no possibility of signal eavesdropping.

(j) Radio link shall provide some minimum capacity even during the most adverse weather and signal congestion by use adaptive modulation and multiplexing.

3.3.6.2 Radio Surveys

(a) The Contractor shall be responsible for carrying out radio path surveys and radio path loss calculations to confirm that the radio routes are satisfactory and to ensure that the microwave radio link system meets the given capacity and performance requirements.

(b) Existing radio towers shall be re-used. Modification of existing towers should it arise shall be detailed by the bidder in their proposal.

(c) Due consideration shall be given to fading characteristics, the radio frequencies used, the path profiles, the availability of line of sight, transmission path length and characteristics of radio transmission such as in-band dispersion, multipath, etc., and antennas used.

(d) The Contractor shall provide for each microwave link an accurate study including:

  (i) The path profiles for the determination of the exact height of antennas

  (ii) Any intrusions into the 1st Fresnel Zone to be justified.

  (iii) The reflection (from ground, water) and multipath effects.

  (iv) Availability and capacity factor

  (v) The link budget calculation for the determination of:

    - The antenna gains in transmitting and in receiving stations (dBm), and then the size of the antennas
    - The output power of the microwave equipment transmitter.

(e) The transmission performance calculations must take into account

  (i) Attenuation due to atmospheric gases as per ITU-R P.676-12, ITU-R P.835-6.

  (ii) Diffraction Loss as per ITU-R P.526-15

  (iii) Propagation loss as per ITU-R P.530-17

  (iv) Rain Rate as per ITU-R P.837-7

  (v) Refractivity Index as per ITU-R P.453-14

(f) A report detailing the results of the survey and path loss calculations shall be submitted by the Contractor for the approval of the Employer. The report should give the exact location of the radio antenna, the antenna heights, size of antenna, method of mounting the antenna, and all required civil works.

(g) A detailed Radio links path loss profile planning report using OEM software, or a reputable professional software shall be provided by the bidder showing that the proposed ethernet radio provide bandwidth and availability as detailed in the performance requirements below.

(h) Bidders are at liberty to carry out radio path surveys and field tests to assess

the radio coverage more accurately for tendering purposes if they so wish. The cost of these surveys and tests shall be borne by the Bidder.

3.3.6.3 Requirements of the Radio equipment

3.3.6.3.1 Basic features:

(a) High operational security and reliability.

(b) High quality transmission in accordance with the ITU-T/R recommendations.

(c) Economic utilisation of the frequency bands.

(d) Flexibility for adaptation to the desired transmission capacity.

(e) Simple adaptation to the available frequency.

(f) Integrated monitoring facilities.

(g) Simple operation and fault diagnosis.

(h) Direct and easy access to the transmitted base band signal.

3.3.6.3.2 Shall be a high-performance wireless bridge for Ethernet traffic with a maximum throughput of at least 450 Mbps at a channel bandwidth of up to 45 MHz

3.3.6.3.3 Shall be able to operate in line-of-sight (LOS), near-LOS and non-LOS propagation condition.

3.3.6.3.4 Shall operate in licensed and unlicensed frequency bands between 4900 MHz and 6050 MHz

3.3.6.3.5 Shall support Line of site range of at least 200KM

3.3.6.3.6 Shall provide a very high spectral efficiency of atleast10 bps/Hz and supports a channel bandwidth of up to 45 MHz.

3.3.6.3.7 Shall forward Ethernet traffic between wired Ethernet interfaces as a transparent Layer 2 bridge

3.3.6.3.8 Outdoor unit shall support power over ethernet

3.3.6.3.9 ODU unit Shall have at least three Gigabit ethernet interfaces for redundancy, with at least one Gigabit fibre optic interface and one dedicated out of band management port

3.3.6.3.10 Shall support quality of service (QoS) classification capability for MPLS and ethernet traffic

3.3.6.3.11 Shall provide 256 bit Over-the-air encryption

3.3.6.3.12 Forward error correction code to maintain high quality transmission even in the presence of interfering signals.

3.3.6.3.13 Adaptive modulation to ensure the highest throughput that can be achieved instantaneously will be obtained, taking account of propagation and interference.

3.3.6.3.14 Shall provide Online spectrum analyser and management via using HTTP or HTTPS/TLS3 and SNMP v1, v2c and v3,

3.3.6.3.15 Shall Provide specified minimum capacity even during adverse weather or congestion by use of adaptive modulation and multiplexing schemes

3.3.6.3.16 The microwave radio system shall be required to interface with the network management system for the purpose of centralised supervision and monitoring of the system performance. All necessary hardware and software interfaces to enable integration with the network management system shall be provided under this Contract

3.3.6.4 Radio Site information

3.3.6.4.1 Point to point radios shall be installed at the following sites

SITE	COORDINATES	Tower Structure	Estimated tower Height AGL (m)
MASINGA	S 00.87910, E 037.58885	Concrete Surge tank	50
KAMBURU	S 00.80648, E 037.68611	Free standing Lattice tower	40
GITARU	S 00.79651, E 037.74619	Free standing Lattice tower	20
KINDARUMA	S 00.80923, E 037.81178	Free standing Lattice tower	60
KIAMBERE	S 00.59921, E 037.88840	Triangular mast on the building roof	20
KIANJIRU	S 00.68126, E 037.61340	Free standing Lattice tower	60
MATENDENI	S 0.8147379, E 37.7071409	Free standing Lattice tower	60
TANA	S 00.78460, E 037.26250	Free standing Lattice tower	25
WANJII	S 00.74806, E 037.17241	Free standing triangular mast	15

3.3.6.5 Capacity and Performance

The radio links shall be designed installed, configured to provide the following capacity and performance. Bidder shall ensure the chosen radio equipment shall provide the given performance metrics.

Link	Mean Aggregate Data Rate	Annual Link Availability	Annual Link Unavailability	200Mb/s symmetric link capacity availability	100Mb/s symmetric link capacity availability
Masinga to Matendeni	440 Mbps	100.00%	1 secs/year	99.995%	100.00%
Kamburu to Kianjiru	440 Mbps	100.00%	1 secs/year	99.999%	100.00%
Gitaru to Kianjiru	440 Mbps	100.00%	1 secs/year	99.999%	100.00%
Kindaruma to Matendeni	440 Mbps	100.00%	1 secs/year	99.999%	100.00%
Kiambere to Kianjiru	430 Mbps	100.00%	1 secs/year	99.950%	99.9999%

Link	Mean Aggregate Data Rate	Annual Link Availability	Annual Link Unavailability	200Mb/s symmetric link capacity availability	100Mb/s symmetric link capacity availability
Tana to Kianjiru	430 Mbps	100.00%	1 secs/year	99.940%	99.9998%
Wanjii to Tana	440 Mbps	100.00%	1 secs/year	0.99999	100.00%

3.3.7 Operations Telephone System

3.3.7.1 General Requirements

3.3.7.1.1 Contractor shall provide all telephony equipment required for normal and emergency operation.

3.3.7.1.2 Telephone equipment shall include but not limited to

(a) hybrid IP PBX – switching point for the telephone calls and performing all telephone management functions.

(b) DECT base station – provide wireless connection to cordless handsets.

(c) DECT manager – to provide seamless wireless connection when moving between base station cell coverage

(d) Rugged panel mount IP telephone sets

(e) DECT rugged handsets

(f) Desk IP phones

(g) Ethernet switches

(h) Analogue telephone wiring (existing to be re-used)

3.3.7.1.3 All equipment to be provided shall robust and ruggedized as much as possible for critical infrastructure operations.

3.3.7.1.4 The telephony system shall provide the highest possible quality voice service required to serve noisy power plant floors. All the telephone equipment shall support high quality wideband G. 722 voice and noise cancellation mechanisms.

3.3.7.1.5 Telephone sets shall be rugged for utilisation at the industrial environment in the power plants

3.3.7.1.6 Robust DECT wireless network shall be set up in the powerhouse, control room areas and indoor substation areas to provide critical wireless network required during maintenance and system restoration

3.3.7.1.7 Telephony system shall meet all the functional requirements given in clause 3.2.3

3.3.7.1.8 IP corded telephone sets shall be desktop type or rugged panel mounted. Contractor shall provide all mounting accessories and mount all panel mount telephone sets as per scope of supply/drawings

3.3.7.2 Hybrid IP PBX design requirements

3.3.7.2.1 The Hybrid IP PBX shall be provided with a minimum of the following major functions integrated into one single appliance or multiple appliances. Preference is for the IP PBX to be provided as a single appliance.

(a) IP PBX for 100 users
(b) GSM gateway
(c) Analogue telephone lines (FXS)gateway at least 8 analogue telephone nodes
(d) Security gateway featuring a firewall and IPS

3.3.7.2.2 Hybrid IP PBX shall support both analogue telephone handsets and IP telephone sets.

3.3.7.2.3 The following features and functions shall be configured for all IP PBX in the five stations.

(a) IP phones connections for a minimum of the telephone sets specified in the scope of supply.
(b) DECT wireless handsets and DECT cell network connection to the PBX
(c) SIP trunks to all the other four PBX each with a minimum voice channel specified in the performance requirements.
(d) SIP trunk to Corporate Cisco call manager in Gitaru and Stima Plaza and other VOIP providers
(e) At least 100 users
(f) At least 30 simultaneous calls
(g) At least 8 FXS POTS analogue terminals
(h) Remote phone nodes (extensions or WAN) where applicable i.e., Gitaru and Kamburu.
(i) GSM gateway mapping/routing of calls two telephone extensions and termination of external GSM calls for configured extensions
(j) Call recording for all configured extensions
(k) Shall log all successful and unsuccessful call details including but limited to
    (i) Call originator
    (ii) Destination extension or number
    (iii) Call attempt or start time
    (iv) Call termination/drop time
    (v) Call duration
    (vi) Time stamp to 100ms accuracy
(l) DHCP server for automatic network configuration of all IP telephone extensions and DECT base stations and extensions
(m) ITU-T G.722 wideband voice encoding

(n) Storing and retrieval of call data records and recordings in a SQL database
(o) Echo cancellation
(p) Monitoring/management using SNMP
(q) Firewall and intrusion detection
(r) WAN connection basic routing interface to provider edge devices
(s) Time synchronisation via SNTP
(t) Integration with LDAP and active directory for role-based control

3.3.7.2.4 Hybrid PBX shall meet all the technical specifications as given in the equipment specifications

3.3.7.2.5 Contractor shall configure all the features and functions required for call set up and termination, call recording, auto setup of telephone sets and security features of the IP PBX

3.3.7.2.6 The PBX MUST support a firewall and an intrusion detection system. Contractor shall configure the firewall and IDS.

(a) To prevent termination of calls not configured in the system.
(b) Denial of service attacks
(c) Block all connections to the telephone network not originating from the telephone nodes or configured database servers.
(d) Encryption of all calls via TLS and IPsec between PBX to PBX and between PBX to remote telephone nodes
(e) support role- based access control, and integration with LDAP and active directory domain server
(f) Provide all other cyber security features as specified in the cyber security requirements.

3.3.7.2.7 Contractor shall configure the telephone numbering system for all the telephone sets as per approved numbering scheme.

3.3.7.2.8 All the IP PBXs shall be interfaced to the database servers in the DMZ host servers for archiving and retrieving of call data record, call recordings and the address book. Contractor shall carry out all necessary configurations and commission the database systems.

3.3.7.2.9 All the IP PBX shall be integrated into the active directory for role-based access and telephone directory services. Telephone directory may be offered using the database server only.

3.3.7.2.10 IP PBX shall be provided with a GSM gateway with a minimum of two GSM subscriber lines from two different GSM service providers.

(a) The GSM gateway shall be configured for setting up at least two simultaneous to public mobile telephone networks to any of the telephone sets connected to the PBX.

(b) Two PBX telephone sets shall be mapped to the two GSM lines to enable receiving calls directly from external mobile callers. External calls to the GSM lines shall be automatically routed to these two lines with option of transferring to another telephone set.

(c) GSM gateway shall be provided with an external GSM antenna to ensure the quality of GSM network reception. Siting of the GSM antenna shall be done to ensure maximum reception including during poor weather. As a minimum the GSM antenna shall be placed at least 3 meters above the control building roof.

3.3.7.2.11 IP PBX shall be integrated to the SCADA assets monitoring and management system via SNMP or as detailed in the control centre requirements.

3.3.7.2.12 Existing analogue telephone sets shall be re-terminated to the PBX. All necessary accessories and connectors (RJ11) shall be provided and wired to the existing telephone junction box.

3.3.7.3 DECT wireless telephone network

3.3.7.3.1 Robust cellular DECT wireless network shall be provided in the five power stations listed in the scope of supply. DECT wireless network shall provide wireless voice network at the critical operations areas of the power plant that is powerhouse, control room/building and indoor substation.

3.3.7.3.2 DECT wireless network shall operate within the bandwidth allocated by the communication authority of Kenya

3.3.7.3.3 DECT cellular network shall support Roaming & Handover (i.e., the call should not drop when the DECT user moves from one base station cell area to another Base station cell area)

3.3.7.3.4 DECT manager station shall be provided to enable creation of the cellular network by connecting multiple base stations. The DECT manager may be supplied as separate appliance, as part of one base station or as part of the IP PBX. If the DECT manager is not supplied as a separate appliance bidder shall provide and quote for a base station for instead of the DECT manager for all the DECT manager bill of quantity line items.

3.3.7.3.5 Contractor shall carry out RF planning using suitable OEM or other software to site the DECT base stations. Base stations shall be sited to ensure complete coverage of all the powerhouse areas, control building and indoor substation areas without blind spots. The output of the planning software giving the base station requirements and the site location drawings shall be submitted for approval as per clause 1.7. The quantity of base station given in scope supply is

the minimum requirement only. Contractor shall supply enough base stations to provide full coverage.

3.3.7.3.6 Contractor shall provide detailed drawings/maps showing the location of each base station after completion of the project as per clause 1. 7.. DECT base station location drawings shall form drawing submittals required prior to issuance of completion certificate.

3.3.7.3.7 DECT base station and managers shall be integrated to the SCADA assets monitoring and management system as detailed in the control centre requirements.

3.3.7.3.8 DECT wireless network shall support over the air encryption which shall be configured by the contractor

3.3.7.3.9 DECT managers and base stations shall support Power over Ethernet

3.3.7.3.10 DECT manager and stations shall support zero touch provisioning. Contractor shall configure ZTP to allow plug and play replacement of base stations with minimal or no configuration.

3.3.7.3.11 DECT manager and base stations shall support web configuration

3.3.8 Configuration And Management

3.3.8.1.1 Contractor shall provide tools/software and facilities for centralized configuration and administration of the transport network.

3.3.8.1.2 Contractor shall provide all necessary software tools for easy configuration and configuration management of the transport network devices. Tools shall include OEM software or third-party software that provide easy way of managing multiple devices and tracking the configuration changes.

3.3.8.1.3 The network configuration and management tool for the transport network shall meet the following requirements

(a) Shall be compatible with Microsoft windows operating systems

(b) Shall have a Graphical User Interface for central Management and network viewing

(c) Shall have a facility for Network discovery and inventory management

(d) Shall support VLAN, multicast, security, and load-balancing/fail over configuration

(e) Shall support Downloading and saving of log file from the device flash memory

(f) Shall support Centralized upgrade/backup and archiving of active devices

(g) Shall support Export of network topology to JPEG or other standard formats.

3.3.8.1.4 Within seven forks area contractor shall also provide out of band links for the

major network equipment including but not limited to: Routers, backbone ethernet switches, point to point ethernet radios, PBX, any provided multiplexers. It shall be possible to carry out of band management for this equipment from any of the stations in the seven forks area. Some bandwidths shall be reserved on the fibre optic and radio links for this function. Out of band management shall not be routed and shall only be available by direct physical connection to the routers.

3.3.8.1.5 Contractor shall integrate the new transport network devices to the existing procuring entity network access control system (Cisco Identity Services Engine (ISE)). The existing network access controller shall be used to authenticate users and devices to the transport network and provide security policies administration.

3.3.8.1.6 Contractor shall provide very detailed practical and theoretical training to procuring entity personnel for management and administration of the new network.

3.3.8.1.7 SCADA application network management shall be carried out by tools detailed in the control centre particular specifications. SCADA application network management shall be under jurisdiction of the industrial control systems section while the transport network shall be under administration of the corporate business section.

3.3.8.1.8 Contractor shall in conjunction of corporate network staff integrate the network management of the transport network devices to the existing management applications.

3.3.8.1.9 Contractor shall provide all relevant network management/monitoring tools for SCADA applications network as detailed in the control centre requirements

3.3.8.1.10 Network configuration shall ensure the network always meet the tabulated performance parameters for both core and application networks. Configuration tools shall indicate where incorrect/poor configuration is causing network poor performance

3.4 EQUIPMENT SPECIFICATIONS

3.4.1 Industrial Grade Routers

3.4.1.1 General Requirements

3.4.1.1.1 The contractor shall install and configure routers to meet the functional and architectural requirements.

3.4.1.1.2 The device shall be temperature-hardened and suitable for areas with constant temperature above 35 degrees Celsius.

3.4.1.1.3 The router shall operate reliably in harsh industrial environments and provide a high level of immunity to electromagnetic interference and heavy electrical surges typical of environments found in electric utility substations as detailed in clause. 2.6.10.1.1

3.4.1.1.4 The router shall have modular dual 110V DC – 240VAC and 48V DC power supplies. For power plant sites one power supply shall be connected to station UPS 240V AC power supply and the other to station 110V DC power supply. They shall also allow for power supply options of 48V DC which shall be connected to existing 48V DC supplies at sites that are not power stations.

3.4.1.1.5 The device offered shall be complete with all hardware components, accessories, features, and devices necessary for a complete functional site deployment irrespective of whether these features have been specified in these specifications or not.

3.4.1.2 Hardware minimum specifications

No.	Feature	Requirement
1.	Interfaces (Ports)	≥ 8x 1GE SFP/RJ45
2.	Switching capacity	≥ 10 Gbps
3.	L3 Forwarding Rate (64-byte packets)	≥7.4 Mpps
4.	Power Supplies	Hot-swappable, modular dual power supplies modules rated for wide range 110VDC – 240V AC voltage input and 48V DC rated power supply units.

No.	Feature	Requirement
5.	Cooling	Passive cooling – **fanless**
6.	Operating Temperature Range	-40°C to +85°C
7.	Non-operating (Storage) Temperature	–40°C to +85°C
8.	Operating Humidity Range	5-95% RH, noncondensing
9.	Power supply types	• 110VDC – 240V AC- high voltage type • 48V DC low voltage type
10.	Power supply input range	(i) 45VDC to 57VDC for 48V DC low voltage type (ii) 100 – 240 VAC and 100 – 300 VDC for high voltage 110VDC-240V AC type
11.	Power supply insulation rating	2000 V for 1 minute
12.	Enclosure	(a) Full metal enclosure (b) Heavy duty mounting (c) Industrial terminal blocks
13.	Ruggedness	(a) Immunity to EMI and heavy electrical surges (b) Meets IEEE 1613 Class 2 (electric utility substations) (c) Exceeds IEC 61850-3 (electric utility substations) (d) Exceeds IEC 61000-6-2 (generic industrial) (e) -40° C to +85°C operating temperature (f) **Fan less operation** (g) Zero packet loss technology
14.	Mounting	19" Rackmount
15.	Mounting Options	Rack Mount 1U, Inclusive of all mounting accessories.
16.	Management Interfaces	Serial console port, USB memory port, RJ45 console
17.	Alarm Output Contact	≥One (1) Form-C failsafe contact relay
18.	Alarm Output Contact wiring	Terminal blocks

No.	Feature	Requirement
19.	Warranty	Five (5) years Hardware and Software Support by OEM (parts, labour & patches)

3.4.1.3 Software and configuration minimum Requirements

No.	Feature	Requirement
1.	Layer 2 Protocols and features provided	(a). QoS (Quality of Service)- CoS (b). RSTP, eRSTP, MSTP, MRP (c). SNTP (d). L2TPv2, L2TPv3, GRE (e). Port rate limiting (f). Link backup (g). Link aggregation (h). Port mirroring (i). Broadcast storm filtering (j). Jumbo frame (9 kb)
2.	Layer 3 Protocols and features provided	(a). MPLS (b). DHCP (c). VRRPv2 and VRRPv3 (d). PIM SM, PIM-SSM, IGMPv3 (e). OSPF (f). BGP (g). Traffic prioritization (h). IS-IS (i). Virtual routing and forwarding (VRF) (j). Dynamic L2TPv3 and GRE (k). DMVPN (l). R-GOOSE (m).NetFlow
3.	MPLS Protocols and features provided	(a). Label switching (LER, LSR) (b). Label Distribution Protocol (LDP) (c). L3 VPN (VRF) (d). Static Label Binding

No.	Feature	Requirement
4.	Multicast functions provided	(a). IPv4 and IPv6 multicast routing (b). PIM-SM, (c). PIM-SSM (d). R-GOOSE
5.	Quality of Service (QoS) functions provided	(a). Classes of Service (CoS) (b). IEEE 802.1p (c). IEEE 802.1p priority-to-CoS mapping (d). DSCP-to-CoS Mapping (e). Traffic control – Bandwidth management (f). Port Rate Limiting
6.	Security Protocols and features provided	(a). Integrated firewall (b). IPsec (c). VPN (d). HTTPS (e). VLANs (f). SNMPv3 (g). Port-based access control (h). MAC-based port security (i). RADIUS, TACACS+ (j). Brute Force Attack prevention (k). Dead peer detection (l). IPv6 tunnelling. (m).IPv6 firewall (n). Secure Shell (SSH) (o). Network Address Translation (p). Port forwarding
7.	Manageability features provided	(a). Web UI (b). HTTPS (c). SSH (d). RMON (e). SNMP (f). CLI (g). NETCONF (XML etc.) (h). Secure remote syslog (i). Real-time line traces (j). USB mass-storage

No.	Feature	Requirement
		(k). Serial console

3.4.1.4 Type tests

Router shall have been type tested and passed the following type tests. Type test report/certificate to be attached with the bid offer.

3.4.1.4.1 IEC61850-3: EMI and Environmental Type Tests

No.	Test	Description	Test Levels
1	IEC 61000-4-2	ESD – Enclosure Contact	+/- 8 kV
		ESD - Enclosure Air	+/- 15 kV
2	IEC 61000-4-3	Radiated RFI	20V/m
3	IEC 61000-4-4	Burst (Fast Transient) – Signal Ports	+/- 4kV @ 2.5kHz
		Burst (Fast Transient) – DC Power Ports	+/- 4kV
		Burst (Fast Transient) – AC Power Ports	+/- 4kV
		Burst (Fast Transient) – Earth ground Ports	+/- 4kV
4	IEC 61000-4-5	Surge – Signal Ports	• +/- 4kV line to Earth • +/- 2kV line to line
		Surge – DC Power Ports	• +/- 2kV line to Earth • +/- 1kV line to line
		Surge – AC Power Ports	• +/- 4kV line to Earth • +/- 2kV line to line
5	IEC 61000-4-8	Magnetic Field – Enclosure Ports	• 40A/m, Continuous, 1000A/m for 1s • 1000A/m for 1s
6	IEC 61000-4-29	Voltage Dips and Interrupts – DC Power Ports	• 30% for 0.1 s • 60% for 0.1 s • 100% for 0.05 s
7	IEC 61000-4-	Voltage Dips and	• 30% for 1 period

No.	Test	Description	Test Levels
	11	Interrupts – AC Power Ports	• 60% for 50 periods
8	IEC 61000-4-12	Damped Oscillatory – Signal Ports	2.5 kV common, 1 kV differential mode@1 MHz
		Damped Oscillatory – DC Power Ports	2.5 kV common, 1 kV differential mode@1 MHz
		Damped Oscillatory – AC Power Ports	2.5 kV common, 1 kV differential mode@1 MHz
9	IEC 61000-4-16	Mains Frequency Voltage – Signal Ports	30 V Continuous, 300 V for 1s
		Mains Frequency Voltage – DC Power Ports	30 V Continuous, 300 V for 1s
10	IEC 61000-4-17	Ripple on D.C. Power Supply – DC Power Ports	10%
11	IEC 60255-5	Dielectric Strength – Signal Ports	2 kVAC (Fail-Safe Relay output)
		Dielectric Strength – DC Power Ports	1.5kVDC
		Dielectric Strength – AC Power Ports	2 kVAC
12	IEC 60255-27	H.V. Impulse – Signal Ports	5 kV (Fail-Safe Relay output)
		H.V. Impulse – DC Power Ports	5 kV
		H.V. Impulse – AC Power Ports	5 kV

3.4.1.4.2 IEEE 1613 (C37.90.x) EMI Immunity Type Tests

No.	Test	Description	Test Levels
1	IEEE C37.90.3	ESD – Enclosure Contact	• +/-2 kV • +/-4 kV • +/-8 kV
		ESD - Enclosure Air	• +/-4 kV • +/-8 kV • +/-15 kV
2	IEEE C37.90.2	Radiated RFI – Enclosure Ports	35V/m

No.	Test	Description	Test Levels
3	IEEE C37.90.1	Fast Transient – Signal Ports	+/- 4 kV @ 2.5 kHz
		Fast Transient – DC Power Ports	+/- 4 kV
		Fast Transient – AC Power Ports	+/- 4 kV
		Fast Transient – Earth ground Ports	+/- 4 kV
4	IEEE C37.90.1	Oscillatory - Signal Ports	2.5 kV common mode @1MHz
		Oscillatory - DC Power Ports	• 2.5 kV common • 1 kV differential mode @ 1 MHz
		Oscillatory - AC Power Ports	• 2.5 kV common • 1 kV differential mode @ 1 MHz
5	IEEE C37.90	H.V. Impulse - Signal Ports	5 kV (Fail-Safe Relay Output)
		H.V. Impulse- DC Power Ports	5 kV
		H.V. Impulse- AC Power Ports	5 kV
6	IEEE C37.90	Dielectric Strength- Signal Ports	2 kVAC
		Dielectric Strength - DC Power Ports	1.5kVDC
		Dielectric Strength - AC Power Ports	2 kVAC

3.4.1.4.3 Environmental Conditions Type Tests

No.	Test	Description	Test Levels
1	IEC 60068-2-1	Cold Temperature – Test	-40 °C (-40 °F), 16

No.	Test	Description	Test Levels
		Ad	Hours
2	IEC 60068-2-2	Dry Heat – Test Bd	85 °C (185 °F), 16 Hours
3	IEC 60068-2-30	Humidity (Damp Heat, Cyclic) – Test Db	95% (non-condensing), 55 °C (131 °F), 6 cycles
4	IEC 60255-21-1	Vibration	2 g @ 10-150 Hz
5	IEC 60255-21-2	Shock	30 g @ 11 mS
		Bump	10 g @ 16 ms
6	IEC 60255-21-3	Seismic	Method A
7	IEC 60529	Ingress Protection	IP4x
8	MIL-STD-810G	Altitude	12192 m (40000 ft) @ 40 °C, 90 minutes

3.4.1.5 Product Standards

The router shall be designed and tested/certified as per the following standards. Product certification from an EU or USA or Canada reputable firm MUST be provided along with the bid.

3.4.1.5.1 Agency Approvals

No.	Agency	Standards	Comments
1.	TUV	• UL 62368-1 • CAN/CSA-C22.2 No. 62368-1 (R2014)	Approved
2.	CE	• EN 60950-1 • EN 61000-6-2 • EN 55022 • EN 60825-1 • EN 50581	CE Compliance is claimed via Declaration of Self Conformity Route
3.	FCC	FCC Part 15, Class A	Approved
4.	FDA/CDRH	21 CFR Chapter I, Sub-chapter J	Laser Eye Safety
5.	ISO	ISO9001:2015	Designed and manufactured using an ISO9001: 2015 certified quality program

No.	Agency	Standards	Comments
6.	ACTA	FCC Part 68	TC1, TC2 and TC4 line modules
7.	Industry Canada	IC CS-03 Part II, Issue 9	TC1, TC2 and TC4 line modules
8.	EU	Directive 2014/30/EU	Electromagnetic compatibility
		Directive 2014/35/EU	Equipment design for use within certain voltage limits
		Directive 2011/65/EU	Restriction on the use of certain hazardous substances in equipment
		Directive 2014/53/EU	
		EN 62368-1	Information Technology Equipment – Safety – Part 1: General Requirements
		EN 61000-3-2	Electromagnetic compatibility (EMC) – Part 3-2: Limits – Limits for harmonic current emissions (equipment input current ≤ 16 A per phase)
		EN 61000-3-3	Electromagnetic compatibility (EMC) – Part 3-3: Limits – Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤16 A per phase and not subject to conditional connection
		EN 61000-6-2	Electromagnetic Compatibility (EMC) – Part 6-2: Generic Standards – Immunity for Industrial Environments
		EN 60825-1	Safety of Laser Products – Equipment Classification and Requirements
		EN 50581	Technical Documentation for the Assessment of Electrical and Electronic Products with Respect to the Restriction of Hazardous Substances
		EN 55032	Information Technology Equipment – Radio

No.	Agency	Standards	Comments
			Disturbance Characteristics – Limits and Methods of Measurement
9.	NEMA	NEMA TS-2	Traffic Controller with NTCIP Requirements

3.4.1.5.2 FCC Compliance

(i) The device shall have been tested and fully compliant within the limits for a Class A digital device pursuant to Part 15 of the FCC Rules.

3.4.1.5.3 Industry Canada Compliance

(i) CAN ICES-3 (A) / NMB-3 (A)

3.4.1.5.4 EMI and Environmental Type Test

(i) IEC61850-3 EMI Type Tests

(ii) IEEE 1613 EMI Immunity Type Tests

3.4.1.6 Product Certifications

3.4.1.6.1 Device must be tested and approved for use in the EU or USA or Canada. Proof of testing and certification MUST be provided.

3.4.1.6.2 Product certification from an EU or USA or Canada reputable firm MUST be provided along with the bid.

3.4.2 Point to Point Ethernet Radios

3.4.2.1 General Requirements

3.4.2.1.1 **Multi band flexibility.** The device shall operate in channel sizes from 5 to 45 MHz

3.4.2.1.2 **Channel Selection.** The device shall constantly optimize the channel of operation to maximize link reliability and performance.

3.4.2.1.3 **99.999% availability in virtually any environment.** The device shall operate over long-distance line-of-sight, high interference, over water, desert and through extreme weather conditions.

3.4.2.1.4 **RF Bands.** The device shall have a Wide-band operation.

3.4.2.1.5 **Spectral Efficiency.** The device shall provide channel encoding method to utilize

bandwidth efficiently.

3.4.2.1.6 **Modulation / Error Correction.** The device shall have Fast Pre-emptive Adaptive Modulation.

3.4.2.1.7 **Duplex Scheme**. The device shall have Adaptive or fixed transmit/receive duty cycles and Split frequency operation allows separate transmit and receive frequencies where allowed by regulation.

3.4.2.1.8 **Range.** The device shall operate over long-distance line-of-sight

3.4.2.1.9 **Security.** The device shall provide for secure authentication, logs, disaster recovery and vulnerability management.

3.4.2.1.10 **Ethernet Protocols.** The device shall comply with IEEE 802.3

3.4.2.1.11 **Ethernet Ports.** The device shall include standard Ethernet ports with atleast Two (2) Gigabit Ethernet copper ports and at least one (1) Gigabit ethernet SFP port.

3.4.2.1.12 **Quality of Service (QOS).** The device shall support extensive QOS

3.4.2.1.13 **Layer 2 Traffic Prioritization.** The device shall support IEEE 802.1Q-2005 VLAN and Priority Tagging CoS traffic prioritization.

3.4.2.1.14 **Layer 3 Traffic Prioritization.** The device shall support DiffServ DSCP traffic prioritization.

3.4.2.1.15 **Network Management.** The device shall have In-band and out-of-band management.

3.4.2.1.16 **System Management.** The device shall support IPv6/IPv4 dual-stack management support, Web access and PTP MIB Online spectrum analyzer.

3.4.2.1.17 **Installation.** The device shall have a Built-in audio and graphical assistance for link optimization

3.4.2.1.18 The device offered shall be complete with all hardware components, accessories, features and devices necessary for a complete functional site deployment irrespective of whether these features have been specified in these specifications or not.

3.4.2.1.19 **Dual Power Supplies.** The device shall have dual redundant power supply

3.4.2.1.20 **Suitable for Harsh Environments.** The device shall operate within a temperature range of –40° to +60°C, , including solar radiation

3.4.2.1.21 **Reliability**. The vendor shall supply the actual measured Mean Time Between Failures (MTBF) for the device upon request.

3.4.2.1.22 **Service.** The device shall include no-cost technical support for the life of the product.

3.4.2.1.23 **Conformal Coating.** The device shall have conformal coating to protect the circuit boards from harsh environments.

3.4.2.1.24 **Warranty.** The device shall include a five-year warranty for all material and workmanship defects.

3.4.2.2 Minimum specifications

No.	Feature	Requirements
1.	Architecture	• ODU: Outdoor Unit with point-to-point Parabolic Antenna • IDU: Indoor Unit PoE Device
2.	RF Bands	Sub-6 GHz, 4.9 to 6.05 GHz
3.	Channel Sizes	5 — 45 MHz channels
4.	Spectral Efficiency	≥ 10 bps/Hz
5.	Aggregate throughput	≥450Mbps
6.	Channel Selection	• Automatic selection on start-up • Continual self-optimization to avoid interference
7.	Maximum Transmit Power	≥27 dBm
8.	System Gain	≥164 dB
9.	Modulation	Adaptive Modulation
10.	Duplex Scheme	Time Division Duplex (TDD)
11.	Antenna	Dual polarity antennas
12.	Range	≥ 200Km LOS
13.	Security	• AES Symmetric encryption algorithm FIPS-197 compliant 128/256-bit Encryption • HTTPS and SNMPv3. • Identity-based user accounts Configurable password rules • User authentication and RADIUS support • Event logging and management. • logging via syslog • Disaster recovery and vulnerability management

No.	Feature	Requirements
14.	Ethernet Protocol	IEEE802.3 packet based physical communication
15.	Latency	≤ 3 milliseconds one direction
16.	Quality of Service (QOS)	8 classes
17.	Packet Classification	• Layer 2 and Layer 3 IEEE 802.1p • IP MPLS • Ethernet priority
18.	Packet Performance/ Line rate	>850K packets per second
19.	Timing Transport	Synchronous Ethernet; IEEE 1588v2
20.	Frame Support	Jumbo frame up to 9600 bytes
21.	ODU Ethernet Ports	• 2x Gigabit Ethernet copper ports: o Data + PoE power input o 802.3at PoE output port • 1 x SFP port
22.	Time Division Multiplexing	• T1/E1support • G.823 compliant • DC power input (compatible with AC+DC Power Injector output)
23.	Network Management	In-band and out-of-band management
24.	System Management	• Web access via browser using HTTP or HTTPS/TLS3 • SNMP v1, v2c and v3, MIB-II • IPv6/IPv4 dual-stack management support. • Online spectrum analyser (no impact on payload traffic or network operation)
25.	Installation	Built-in audio and graphical assistance for link optimization
26.	Power Supply Unit (PSU)	AC + DC power injector: • 240 VAC 50 Hz (-40° to +60° C) • 48VDC

No.	Feature	Requirements
27.	Enclosure type	Steel or metallic equivalent
28.	Minimum Ethernet connections to ODU	≥ Three (3) ≥ One (1) Gigabit Base-LX/SX SFP port ≥ One (1) Gigabit Base-T: Data + PoE power input ≥ One (1) Gigabit Base-T: Data
29.	Outdoor CAT5E/6A cable	• Outside plant (OSP) type • copper-clad steel armour • waterproof jacket • Sunlight and abrasion resistant • ≤ 328 ft (100 m)
30.	Cable Connector (Per ODU)	• ≥ 2 N-type Connector • ≥ 1 Bend insensitive multimode fibre optic cable with LC-LC connectors • ≥ 10 RJ45 connectors provided for ODUs, LPUs, PSUs and other devices.
31.	Flexible Conduit (optional)	• PVC Coated Galvanized Steel core • 10-20mm internal diameter for fibre optic cable
32.	Lightening Protection and Grounding kit (per ODU)	≥ One (1)
33.	Coaxial Cable with grounding kit for antenna	≥ One (1)
34.	Mounting	Supply with all mounting accessories required
35.	Ingress Protection	IP66 and IP67
36.	Device Cooling	heat sink
37.	Grounding	Coaxial Cable Kits for Cable
38.	Surge protector and lightening protection unit	To be provided
39.	Continuous ambient operating temperature	–40° to +60°C
40.	Device Cooling	Natural, heat sink or solid state

No.	Feature	Requirements
41.	Wind Speed Survival	≥322 Kph
42.	Manufacturer Warranty	5 years
43.	Country/Region of Origin	USA, European Union, Canada or Japan (Provide documentary evidence)
44.	Approval	Type approved by Communications Authority of Kenya (CA).

3.4.2.3 Antenna specifications

No.	Feature	Requirements
1	Antenna Type	Parabolic
2	Dish size	≥ 0.9 m (3 ft) for Wanji-Tana ≥ 1.2 m (4 ft) for all other
3	Gain	≥ 34.7dBi
4	Operating Frequency	4.9-6.05 GHz
5	3 dB Beamwidth	≥ 3°
6	Polarization	Dual
7	Front to Back Ratio (F/B)	≥ 49dB
8	Voltage Standing Wave Ratio (VSWR)	1.5:1

3.4.2.4 Product Standards

The device shall be designed and tested/certified as per the following standards. Product certification from an EU or USA or Canada reputable firm MUST be provided along with the bid.

3.4.2.4.1 Human exposure to radio frequency energy

(i) ANSI IEEE C95.1-1991, IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz.

(ii) Council recommendation of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz) (1999/519/EC) and respective national regulations.

(iii) EN 50383:2002 to 2010 Basic standard for the calculation and measurement of electromagnetic field strength and SAR related to human exposure from radio base stations and fixed terminal stations

for wireless telecommunication systems (110 MHz - 40 GHz).

(iv) BS EN 50385:2017 Product standard to demonstrate the compliances of radio base stations and fixed terminal stations for wireless telecommunication systems with the basic restrictions or the reference levels related to human exposure to radio frequency electromagnetic fields (110 MHz – 40 GHz) – general public.

(v) ICNIRP (International Commission on Non-Ionizing Radiation Protection) guidelines for the general public

3.4.2.4.2 Electrical safety compliance

(i) USA, UL 60950-1, 2nd Edition; UL60950-22

(ii) Canada, CSA-C22.2 NO. 60950-1-07 (R2012), CSA-C22.2 NO. 60950-22:17

(iii) EU, EN 60950-1:2006 + Amendment 12:2011, EN 60950-22

(iv) RoW, IEC 60950-1, IEC60950-22, IEC 60079-0:2011, IEC 60079-11:2011

3.4.2.4.3 Electromagnetic compatibility (EMC) compliance

(i) Europe, ETSI EN301 489-17, FCC Part 15B, CSA C22.2 No

3.4.2.4.4 Radio certifications (4.9 GHz)

(i) USA, FCC 47 CFR Part 90

(ii) Canada, ISEDC RSS-111, Issue 5

3.4.2.4.5 Radio certifications (5.1 GHz)

(i) USA, FCC 47 CFR Part 15E

(ii) Canada, SMSE-013-17

3.4.2.4.6 Radio certifications (5.2 GHz)

(i) USA, FCC 47 CFR Part 15E

(ii) Canada, ISEDC RSS-247 Issue 1

3.4.2.4.7 Radio certifications (5.4 GHz)

(i) USA, FCC 47 CFR Part 15E

(ii) Canada, ISEDC RSS-247 Issue 1

3.4.2.4.8 Radio certifications (5.8 GHz)

(i) USA, FCC 47 CFR Part 15E

3.4.3 Industrial Ethernet switches

3.4.3.1 General Requirements

3.4.3.1.1 The contractor shall supply three models of switches:

(i) With at least eight (8) 100M Power Over Ethernet (POE) and with at

least two (2) SFP ports, total of at least **10 ports**

(ii) With at least four (4) 1G SFP ports and at least six (6) RJ45 ethernet ports, total of at least **10, 1G ports**

(iii) With at least four (4) 10G SFP+ ports and at least twelve (12) RJ45 ethernet ports, total of at least **16 ports**

3.4.3.1.2 The ethernet switch shall meet requirements in clause 2.6.10.

3.4.3.1.3 The switch shall be fully managed Ethernet switch.

3.4.3.1.4 The switch shall operate reliably in harsh industrial environments and provide a high level of immunity to electromagnetic interference and heavy electrical surges typical of environments found in electric utility substations as detailed in clause. 2.6.10.1.1

3.4.3.1.5 The switch shall support industry standard fibre optic connectors: LC, SC, ST and SFP pluggable optics.

3.4.3.1.6 The device offered shall be complete with all hardware components, accessories, features, and devices necessary for a complete functional site deployment irrespective of whether these features have been specified in these schedules.

3.4.3.2 Minimum specifications

No.	Feature	Requirements
1.	Switch type	Managed Ethernet Switch
2.	Switching Method:	Store and forward
3.	Switching Latency:	<7 µs
4.	Switch Throughput:	≥5.6 Gbps for 10 port POE option ≥20 Gbps for 10 port option ≥68 Gbps for 16 port option
5.	Maximum VLANs:	≥255
6.	MAC Address Table Size:	≥8192 addresses
7.	Power Over Ethernet (PoE)	(i)≥ Eight (8) 10/100BaseTx 802.3af / 802.3at compliant ports (ii)Data and power over a single Ethernet cable (iii)Auto-sensing ports that provide power only to PoE end devices
8.	Network Management	(i) Web-based, SSH, CLI management interfaces

No.	Feature	Requirements
		(ii) SNMP v1/v2/v3 (56-bit encryption) (iii) Remote Monitoring (RMON) (iv) Rich set of diagnostics with logging and alarms.
9.	Key Protocol and functions provided	(i) Compliant with IEC 61850-9-2 Sampled Values and IEC 61850-8-1 GOOSE Message (ii) Compliant with IEEE 802.3, 802.3u, 802.3x, 802.3ab, 802.1d, 802.1p, 802.1Q, 802.1Q-2005, 802.1w', Link Aggregation (iii) Bridge Protocol Data Unit (BPDU) Guard. (v) Port-Based MAC Security. (vi) Simple plug-and-play operation – automatic learning, negotiation, and crossover detection (vii) MSTP 802.1Q-2005 (viii) RSTP (802.1w) and Enhanced Rapid Spanning Tree (ix) eRSTP network fault recovery (x) Quality of service (802.1p) for real-time traffic (xi) Port rate limiting (xii) IEEE 802.1Q-2005 VLAN and Priority Tagging Class of Service (CoS)
10.	Enabled and supported security functions	(i) Multilevel user passwords (ii) Secure File Transfer Protocol (SFTP) using SSH (iii) Web-based management using SSL (iv) RADIUS-Authentication service for device management (v) 1024-bit RSA encryption for key management and key exchange

No.	Feature	Requirements
		(vi) Enable/disable ports, (vii) MAC-based port security. (viii) Port-based network access control (802.1x); (ix) VLAN (802.1Q) to segregate and secure network traffic. (x) SNMPv3 encrypted authentication
11.	Ruggedness	(a) Immunity to EMI and heavy electrical surges (b) Meets IEEE 1613 Class 2 (electric utility substations) (c) Exceeds IEC 61850-3 (electric utility substations) (d) Exceeds IEC 61000-6-2 (generic industrial) (e) -40° C to +85°C operating temperature (f) Fan less operation
12.	Total number 1GB Base-T Ethernet ports (RJ45)	≥Six (6) for 10 port option ≥Twelve (12) for 16 port option
13.	Total number 1Gb SFP Ethernet ports	≥Two (2) for POE option ≥Four (4) for 10 port option
14.	Total number of 10G SFP+ Ethernet ports	≥Four (4) for 16 port option
15.	Total number POE ports 100MB base-Tx or higher	≥Eight (8) for POE option
16.	Fibre connector types	SFP Pluggable Optics
17.	Bi-directional single strand fiber	Supported
18.	Supported Long haul gigabit optics	≥ 70Km for 10 port PoE Option ≥ 115Km for other
19.	Management Console port	≥One (1)
20.	Front side LED's	(i) Power supply status LED's (ii) Device status LED (iii) Alarm status LED

No.	Feature	Requirements
21.	Alarm Output Contact	≥One (1) Form-C failsafe contact relay
22.	Alarm Output Contact wiring	Terminal blocks
23.	Power supply type	(i) 110VDC – 240V AC- high voltage type (ii) 48V DC low voltage type
24.	Power supply input range	(i) 45VDC to 57VDC for 48V DC option (ii) 100 – 240 VAC / 100 – 300 VDC for 110VDC-240V AC option
25.	Power supply units' options	(i) Dual supplies for 16 port and 10 port options. Combinations to be as given in the scope of supply. (ii) 48V DC option for the POE switch
26.	Maximum Combined Power Output at PoE Ports	≥273 W
27.	Power supply connections	Terminal blocks
28.	Enclosure type	Rugged Construction Cast aluminium/steel Enclosure.
29.	Ingress Protection	≥IP30
30.	Mounting Option	DIN rail Panel mount Rackmount
31.	Device Cooling	Natural, heat sink or solid state. **Fanless**
32.	Continuous ambient operating temperature	–40° C to +85°C
33.	Operating Relative Humidity (non-condensing)	0 to 95%
34.	Manufacturer Warranty	5 Years

3.4.3.3 Type tests

The device shall have been type tested and passed the following type tests. Type test report/certificate to be attached with the bid offer.

3.4.3.3.1 EMI and Environmental Type Tests

(i) IEC 61000-4-2 ESD

- Enclosure contact +/- 8kV
- Enclosure air +/- 15kV

(ii) IEC 61000-4-3

- Radiated RFI Enclosure ports 20 V/m

(iii) IEC 61000-4-4 Burst (fast transient)

- Signal ports +/- 2kV @ 2.5kHz
- D.C. power ports +/- 2kV
- Earth ground ports +/- 2kV

(iv) IEC 61000-4-5

- Surge Signal ports +/- 2kV line-to-earth, +/- 1.5kV line-to-line
- D.C. power ports +/- 1.5V line-to-earth, +/- 1kV line-to-line

(v) IEC 61000-4-6 Induced (conducted) RFI

- Signal ports 10V
- D.C power ports 10V
- Earth ground ports 10V

(vi) IEC 61000-4-8 Magnetic field

- Enclosure ports 40 A/m continuous,
  - 1000 A/m for 1 s

(vii) IEC 61000-4-29 Voltage dips and interrupts

- D.C. power ports
  - 30% for 0.1s, 60% for 0.1s, 100% for 0.05s

(viii) IEC 61000-4-12 Damped oscillatory.

- Signal ports 2.5kV common, 1kV diff. mode@1MHz
- D.C. power ports 2.5kV common, 1kV diff. mode@1MHz

(ix) IEC 61000-4-16 Mains frequency voltage

- Signal ports 30V Continuous, 300V for 1s
- D.C. power ports 30V Continuous, 300V for 1s

(x) IEC 61000-4-17 Ripple on D.C. power supply

- D.C. power ports 10%

(xi) IEC 60255-5 Dielectric strength Signal ports 1.5k V AC (Fail-safe relay output)

(xii) D.C. power ports 1.5V DC

(xiii) IEC 60255-5 H.V. impulse

- Signal ports 5kV (Fail-safe relay output)

- D.C. Power ports 5Kv

(xiv) IEC 60068-2-6 Vibration Testing

(xv) IEC 60068-2-27 Shock Testing

(xvi) CISPR 22 & FCC Part 15 Class A

3.4.3.3.2 IEEE 1613 (C37.90.x) EMI Immunity Type Tests

(i) C37.90.3 ESD

- Enclosure contact +/- 8kV
- Enclosure air +/-12kV

(ii) IEEE C37.90.2 Radiated RFI

- Enclosure ports 35 V/m

(iii) IEEE C37.90.1 Fast transient

- Signal ports +/- 2kV @ 2.5kHz
- D.C. power ports +/-2kV
- Earth ground ports +/- 2kV

(iv) IEEE C37.90.1 Oscillatory

- Signal ports 2.5kV common mode@1MHz
- D.C. power ports 2.5kV common, 1kV diff. mode@1MHz

(v) IEEE C37.90 H.V. impulse

- Signal ports 5kV (Fail-safe relay output)
- D.C. power ports 5kV

3.4.3.3.3 Environmental Type Tests

(i) IEC 60068-2-1 Cold temperature

- Test Ad -40°C, 16 hours N/A

(ii) IEC 60068-2-2 Dry heat

- Test Bd +85°C, 16 hours N/A

(iii) IEC 60068-2-30 Humidity (damp heat, cyclic)

- Test Db 95% (non-condensing), 55°C, 6 cycles N/A

(iv) IEC 60255-21-1 Vibration

- Test Fc 2g @ (10 - 150) Hz Class 2 2

(v) IEC 60255-21-2 Shock

- Test Ea 30g @ 11mS Class 2 2

(vi) IEEE 1613

(vii) IEC 61850-3 Section 6.7

3.4.3.4 Product Standards

The device shall be designed and tested/certified as per the following standards. Product

certification from an EU or USA or Canada reputable firm MUST be provided along with the bid.

3.4.3.4.1 Regulatory Approvals

(i) ISO: Designed and manufactured using ISO9001: 2000 certified quality program
(ii) CE marking
(iii) Emissions: FCC Part 15 (Class A), EN55022 (CISPR22 Class A)
(iv) Safety: cCSAus (Compliant with CSA C22.2 No. 60950, UL 60950, EN60950)
(v) Laser eye safety (FDA/CDRH): Complies with 21 CFR Chapter 1, Subchapter J

3.4.3.4.2 EMI Immunity and Environmental Compliance

(i) IEC 61000-6-2 Industrial (Generic)
(ii) IEC 61800-3 Industrial (Variable Speed Drive Systems)
(iii) IEC 61850-3 Electric Utility Substations
(iv) IEEE 1613 Electric Utility Substations
(v) NEMA TS 2 Traffic Control Equipment
(vi) EN 50121-4 Railway Applications
(vii) Hazardous Locations: Class 1, Division 2

3.4.3.4.3 IEEE Compliance

(i) 802.3-10BaseT
(ii) 802.3af / 802.3at
(iii) 802.3u-100BaseTX, 100BaseFX
(iv) 802.3x-Flow Control
(v) 802.3z-1000BaseLX
(vi) 802.3ab-1000BaseTX
(vii) 802.3ad-Link Aggregation
(viii) 802.1d-MAC Bridges
(ix) 802.1d-Spanning Tree Protocol
(x) 802.1p-Class of Service
(xi) 802.1Q-VLAN Tagging
(xii) 802.1w-Rapid Spanning Tree Protocol
(xiii) 802.1x-Port Based Network Access Control
(xiv) 802.1Q-2005 (formerly 802.1s) MSTP

3.4.3.4.4 IETF RFC Compliance

(i) RFC768-UDP
(ii) RFC783-TFTP

(iii) RFC791-IP
(iv) RFC792-ICMP
(v) RFC793-TCP
(vi) RFC826-ARP
(vii) RFC854-Telnet
(viii) FC894-IP over Ethernet
(ix) RFC1112-IGMP v1
(x) RFC1519-CIDR
(xi) RFC1541-DHCP (client)
(xii) RFC2030-SNTP
(xiii) RFC2068-HTTP
(xiv) RFC2236-IGMP v2
(xv) RFC2284-EAP
(xvi) RFC2475-Differentiated Services
(xvii) RFC2865-RADIUS
(xviii) RFC3414-SNMPv3-USM
(xix) RFC3415-SNMPv3-VACM

3.4.3.4.5 IETF SNMP MIBS

(i) RFC1493-BRIDGE-MIB
(ii) RFC1907-SNMPv2-MIB
(iii) RFC2012-TCP-MIB
(iv) RFC2013-UDP-MIB
(v) RFC2578-SNMPv2-SMI
(vi) RFC2579-SNMPv2-TC
(vii) RFC2819-RMON-MIB
(viii) RFC2863-IF-MIB
(ix) draft-ietf-bridge-rstpmib-03-BRIDGE-MIB
(x) draft-ietf-bridge-bridgemib-smiv2-03-RSTP-MIB
(xi) IANAifType-MIB

3.4.4 Fibre Optic Media Converter/Repeater

3.4.4.1 General Requirements

3.4.4.1.1 Shall be used to interface two fibre connections either to extend the link or to convert the media type. They shall have two SFP ports supporting SFP modules for long haul optics, single mode or multimode or copper and any other

3.4.4.1.2 A pair of these devices shall support a fibre optic link extending to 120Km. It shall support 1000Base-X fiber interfaces preferably compliant with IEEE standards for

long haul optics.

3.4.4.1.3 The devices shall support Smart Link Pass-Through mode, when the Link Mode switch is placed into the 1000BASE-X link on one port will reflect the state of the other 1000Base-X media converter port.

3.4.4.1.4 The devices shall support Fiber Fault Alert when the state of the 1000Base-X receiver is passed to the 1000Base-X transmitter.

3.4.4.1.5 The device shall support interconnection of multiple fiber types and wavelengths across the SFPs by converting Multimode to Multimode, Multimode to Single Mode, Single Mode to Single Mode and Duplex to Simplex BiDi.

3.4.4.1.6 The device shall provide wavelength conversion for CWDM and DWDM transponder applications.

3.4.4.1.7 The device shall be transparent to the traffic.

3.4.4.1.8 The devices shall support signal regeneration maintain signal integrity and allows for maximum fiber to fiber connections without degradation.

3.4.4.1.9 The devices can be cascaded. Two or more media converters can be chained in a link to achieve even greater distances.

3.4.4.1.10 The device shall support Pause signalling an IEEE feature that suspends data transmission between two devices if one of the devices becomes overwhelmed. The media converter shall be transparent to Pause frames.

3.4.4.1.11 The device shall support Full and half duplex operation.

3.4.4.1.12 The device shall be Transparent to jumbo packets up to 10KB.

3.4.4.1.13 The device shall perform a loopback on each 1000Base-X fiber interface.

3.4.4.1.14 The device shall support SFP data rates greater than or equal to 4.25Gbps.

3.4.4.1.15 The device shall support SFPs compliant with SFP MSA for 1000Base-X.

3.4.4.2 Minimum specifications

No.	Feature	Requirements
1.	SFP ports	2
2.	SFP data rates	≥ 4.25 Gbps
3.	Chassis	Metal with IP20 Rating
4.	Operating Temperature	0° C to 50° C
5.	Storage Temperature	minimum range of -25° C to 70° C
6.	Operating Humidity	5% to 90% non-condensing

No.	Feature	Requirements
7.	Storage Humidity	5% to 95% non-condensing
8.	Operating Altitude	Up to 3,048 meters (10,000 feet)
9.	MTBF	≥416,965 Hours
10.	Mounting Kits	• DIN rail Kit • Panel/ Wall mount Kit • Rack mount Kits
11.	Emissions	Compliant with: • FCC part 15 Class A, EN55022 Class A • CISPR 22 Class A • CISPR 32:2015/EN 55032 (Class A) • CISPR 24:2010/EN 55024:2010 • EN61000-3-2
12.	Immunity	Compliant with: • EN55024
13.	Electrical Safety	• CE • UL/EN/IEC 62368-1 • CAN/CSA C22.2 No. 62368-1 • UL 60950-1 • IEC 60950-1(ed 2); am1, am2 • EN 60950-1:2006+A11:2009+A1:2010+A12:2011+A2:2013
14.	Environmental	Complaint with: • Reach • RoHS • WEEE
15.	Warranty	Lifetime Warranty

3.4.4.3 Product Certifications

3.4.4.3.1 Device must be tested and approved for use in the EU or USA or Canada. Proof of testing and certification MUST be provided.

3.4.4.3.2 Product certification from an EU or USA or Canada reputable firm MUST be

provided along with the bid.

3.4.5 Hybrid IP PBX

3.4.5.1 General Requirements

3.4.5.1.1 The device shall support IP-PBX, and IP-Gateway in a single structure.

3.4.5.1.2 The device shall support unified communication.

3.4.5.1.3 The device shall have open software architecture.

3.4.5.1.4 The device shall be modular allowing for system expansion by simply plugging in additional cards or connecting modules to existing ports.

3.4.5.1.5 The device shall support mobility to allow for communication over extension numbers independent of their location.

3.4.5.1.6 The device shall support Digital Enhanced Cordless Telecommunications (DECT) base stations for reliable cordless communication.

3.4.5.1.7 The device shall have a DHCP server for IP assignment to all IP telephone extensions and DECT base stations and extensions.

3.4.5.1.8 The device IP communication systems shall operate interactively with other Session Initiation Protocol (SIP) and H.323 compliant devices.

3.4.5.1.9 The device shall be ITU-T G.722 compliant.

3.4.5.1.10 The device shall support Out of Band management. IP communication systems can be accessed remotely over an IP based network for management.

3.4.5.1.11 The device shall be grounded and have surge protection.

3.4.5.1.12 The device shall have a firewall and IPS integrated, where packets other than the specified IPs, MAC addresses or ports may be blocked.

3.4.5.1.13 The device shall support several systems at the same location or at different location may be remotely managed and updated from a single point and over a single interface.

3.4.5.1.14 This device shall support zero touch configuration / deployment.

3.4.5.1.15 The device shall support Call recording facilities to enable call recording of desired ports without need for additional equipment.

3.4.5.1.16 The device shall have an integrated alarm and failure management system which lets system administrators to monitor (real time), report (real time) or log the possible system faults or link/port failures.

3.4.5.1.17 The device shall have a log system that captures all activities including but not limited to

(i) Call originator
(ii) Destination extension or number
(iii) Call attempt or start time.
(iv) Call termination/drop time.
(v) Call duration
(vi) Time stamp to 100ms accuracy

3.4.5.1.18 The device shall have a database for storing and retrieval of call data records and recordings.

3.4.5.1.19 The device shall support time synchronisation via SNTP.

3.4.5.1.20 The device shall support integration with other systems.

3.4.5.1.21 The device shall support auto attendant and voice mail applications.

3.4.5.1.22 The device shall support web-based management.

3.4.5.1.23 The device shall support Incoming call distribution.

3.4.5.1.24 The device shall support connection to SQL database servers for call data records, directory and call recording storage and retrieval.

3.4.5.1.25 The device offered shall be complete with all hardware components, accessories, features, and devices necessary for a complete functional site deployment irrespective of whether these features have been specified in these schedules or not.

3.4.5.2 Minimum specifications

No.	Feature	Requirements
1.	Equipment Type	Digital Hybrid IP-PBX System Switching (ANALOG & IP)
2.	Equipment Design	Modular and server-based IP communication platform
3.	Supported User Extension	≥ Hundred (100)
4.	Concurrent Calls	≥ Thirty (30)
5.	Foreign Exchange Subscriber (FXS) nodes	≥ Eight (8)
6.	Storage	≥ 2 TB SSD
7.	SIP trunks	≥ Thirty-two (32)

No.	Feature	Requirements
8.	Operating principle	• Stored program control • Distributed processor architecture • High system reliability
9.	WAN ethernet ports interface	≥ One (1) 1G Base T
10.	LAN Interface	≥ One (1) 1G Base T
11.	IP Protocol	• H. 323 (for trunks) • SIP (for trunks and extensions)
12.	GSM module/gateway	Support 2G/3G/4G networks with a high gain outdoor antenna
13.	GSM Module/gateway Subscriber lines/channels	≥ Four (4)
14.	GSM Gateway Ethernet Interfaces (if applicable)	≥ One (1), 10/100 Mbps
15.	GSM Outdoor antenna	• Surge protection • Grounding and Lightning protection • Mounting accessories • 700-2700MHz wide band frequency range • ≥12dBi gain • IP67 • Sunlight/UV and weatherproof • Fibre glass or heavy-duty plastic material housing
16.	E1/T1/J1 Ports	≥ One (1)
17.	USB:	≥ 1
18.	Mounting	Rackmount
19.	NFC	Supported- Read and write
20.	Power Supply	48 VDC or 110 VDC internal or external power supply

No.	Feature	Requirements
21.	Connectors	• RJ45 (Ethernet, Lines / Extensions) • RJ11 (RS232) • Pin type-2 pin (External Devices)
22.	Peripherals	• Standard Telephones • Alarm • Paging • DECT base stations
23.	Operating environment:	• Temperature: 0°C to +40°C • Humidity: 10% to 90% non-condensing • Storage Range: -20°C to +65°C
24.	Mobility	IP DECT Manager, Base Stations and IP DECT handsets that support SIP
25.	WAN	Static routing or dynamic routing
26.	Time synchronisation	SNTP
27.	Monitoring/management	• Web UI, HTTPS • SNMP • syslog
28.	User management and role-based access	• LDAP and RADIUS user authentication and management • Active directory integration • LDAP server for extensions
29.	VoIP functions	• Standard SIP protocols • IP extension/trunk support • IETF Session Initiation Protocol (SIP), RFC3261 • Realtime Transport Protocol (RTP), RFC 3550 • Realtime Transport Control Protocol (RTCP) • Session Description Protocol (SDP) RFC 2327 • DTMF/Tone support while using media gateway. • RFC 2833, SIP INFO or in-band DTMF

No.	Feature	Requirements
		detection, generation • Media gateway configuration over network
30.	Audio Codecs and Algorithms	• **G722** • G711 A-law, µ-law • G729A/B • G723.1 • iLBC • Encryption with SRTP/TLS* • T.38 fax-over-IP* • Advanced dynamic jitter buffer • Packet loss compensation (PLC) • Central collection and querying of QoS statistics. • Echo prevention, G.168 compliant • Audio activity detection • Noise suppression, RFC3389 • Automatic gain control
31.	Audio recording	• File compression • Online audio recording to NFS server • Automatic uploading of recordings to a file server
32.	PBX Services	• AutoCLIP • Call routing • Call Forwarding • Call Monitoring (Listen/Whisper/Barge-in) • Call Parking • Call Recording • Call Flip • Call Switch • Call Transfer (Attended and Blind) • Call Waiting • Caller ID • Conference Rooms

No.	Feature	Requirements
		• Speed dial • Dial by Name • DNIS • DID (Direct Inward Dialling) • DND (Do not Disturb) • DOD (Direct Outward Dialing) • CID-based and DID-Based Call • Allowed/Blocked Number • Concurrent Registration for IP Phones • Web-based Management Portal • Graphical Dashboard • Auto Provisioning • Bulk Import and Export • Extension Directory • Group and Organisation • User Role and Permissions • Operation logs • Event logs and Notifications • Backup and Restore • Troubleshooting • Built-in SMTP Server • Network Drive • AMI • Remote Management • Hot Standby
33.	IP PBX Security	• Firewall • Intrusion Prevention System (IPS) • Encryption, TLS and SRTP • Password Policy Enforcement • Auto and Static Defence • IP Blocklist • Country Allow/Block List • Outbound Call Frequency Restriction

No.	Feature	Requirements
34.	GSM Functions	• Mobile Ports Grouping • VoIP Trunk Group • Incoming/ Outgoing Routing Rules • Call Blocklist • Hotline • AutoCLIP • Call Duration Limitation • Call Transfer • Call Back • Call Detail Record • Call Status Display • NTP • IP Blocklist • Network Attack Alert • Packet Capture • System logs
35.	GSM Gateway/module Voice Processing Functions	• Protocol: SIP, IAX2 • Transport: UDP, TCP, TLS, SRTP • Voice Codec: G.711 (a-law/μ-Law), G.722, G.726, G.729A, GSM, ADPCM, Speex • Echo Cancellation: ITU-T G.168 LEC • DTMF Mode: RFC2833, SIP INFO, In-band • SIP Server for IP Phones • SIP Response Code Switch • Call Progress Tone Generation • 1 Stage/2 Stage Dial
36.	GSM Gateway/module Mobile Features	• GSM Frequency: 850/900/1800/1900MHz • WCDMA Frequency: 850/1900MHz, 850/2100MHz, 900/2100MHz • 4G LTE Band

No.	Feature	Requirements
		• VoLTE • SMS Sending and Receiving • Send Bulk SMS • SMS Center • Gain Adjustment • USSD • PIN Modify • Carrier Selection: Auto/Manual • Talk Time Alarm • Caller ID/CLIR • Open API for SMS and USSD
37.	GSM Gateway/module Network Functions	• Network Protocol: FTP, TFTP, HTTP, SSH • NAT Traversal: Static NAT, STUN • Static Route • OpenVPN • Firewall • VLAN • QoS/ToS • DDNS • Configure Backup/Restore • Firmware Upgrade by HTTP/TFTP • Web based Configuration
38.	GSM Gateway/module Environmental Conditions	• Operation Range: 0°C to 40°C (32°F to 104°F) • Storage Range: -20°C to 65°C (-4°F to 149°F) • Humidity: 10-90%, non-condensing
39.	Certificates	ITU-T G.722
40.	Manufacturer Warranty	≥3 years

3.4.6 Rugged Panel Mount IP telephone set

3.4.6.1 General Requirements

3.4.6.1.1 They shall be Standard IP phone with rugged construction for use in industrial environments.

3.4.6.1.2 They shall have Robust housing, constructed of cold rolled steel with powder coat. shall have Full metal keypad with LCD Display

3.4.6.1.3 The telephones sets shall be suitable for Wall mounting and panel mounting All necessary mounting accessories to be provided.

3.4.6.1.4 The device shall be Weatherproof protection to IP54~IP65

3.4.6.1.5 The device shall have a power supply and PoE.

3.4.6.1.6 They shall be mounted on the plant control panels. They shall be yellow in colour for easy identification during an emergency.

3.4.6.2 Minimum Specifications

No.	Feature	Requirements
1.	Casing Material	Cold rolled steel body Colour: YELLOW
2.	Handset Material	ABS material handset with stainless steel spiral cord
3.	Keypad	Weather sealed tactile digital keypad. Chrome key and frame made of zinc alloy.
4.	Temperature Operating	-30°C to +65°C
5.	Temperature Storing:	-40°C to +75°C
6.	Weather Resistance	IP54~IP65
7.	Ringing Tone typical	Shrill warble tone 80 dBA @ 1 metre
8.	Hook switch	Electronic / magnetic with no visible moving parts
9.	M.T.B.F.	Calculated to have an M.T.B.F. in excess. of 50,000 hours
10.	Power Input:	12~24V DC, PoE
11.	Ethernet Port:	10/100Base~ T RJ~45, POE
12.	Power Usage	≤3W

No.	Feature	Requirements
13.	SIP 2.0 (RFC3261)	Yes
14.	Codec:	G.711A/u, G.7231 high/low, G.729, G.722
15.	Echo cancellation:	Support G.168 and hand-free headphones
16.	Full duplex	Yes
17.	SIP Support	domain, SIP support authentication (none, basic, MD5), DNS name of server
18.	DTMF	SIP info, DTMF Relay, RFC2833
19.	Static IP address	Yes
20.	DHCP get IP	Yes
21.	VLAN	Yes
22.	Web config	Yes
23.	Approvals CE	Radio & Telecommunications Terminal Equipment Directive 2004/108/EC
24.	Approval FCC	Part 15 Subpart B Class B

3.4.7 Cordless IP DECT Multi-Cell System (Base station and DECT Manager)

3.4.7.1 General Requirements

3.4.7.1.1 The DECT IP Multi-Cell System shall consists of the DECT Managers and base stations.

3.4.7.1.2 The devices shall support scalability and increased mobility providing a seamless handover and roaming solution, stable communication experience, and simple deployment service covering large spaces.

3.4.7.1.3 The device shall support up to 30 base stations and 100 handsets.

3.4.7.1.4 This device shall support the registration of up to 100 multiple terminal devices and up to 100 parallel calls.

3.4.7.1.5 The device shall have easy access to multiple phone books including compatibility to with PBX contacts.

3.4.7.1.6 The device shall support DECT radio coverage up to 50m indoors and 300m outdoors.

3.4.7.1.7 The device shall support ECT technology based on CAT-iq2.0, which focuses on high quality Audio VoIP (wideband), as well as low bit - rate data applications.

3.4.7.1.8 The device shall support Opus audio codec.

3.4.7.1.9 The device shall support power over ethernet (POE)

3.4.7.1.10 The device shall have TLS and SRTP security.

3.4.7.1.11 The device shall be compatibility with several PBX platforms.

3.4.7.1.12 The device shall support configuration and management of the entire multi-cell system on the DECT Manager web portal, making the deployment, maintenance, and upgrade trouble-free as well as saving time.

3.4.7.1.13 The device shall support zero touch provisioning.

3.4.7.2 Minimum Specifications

No.	Feature	Requirements
1	Call Technology	Seamless handover and roaming
2	Simultaneous calls	≥100
3	Base stations	≥30
4	handsets	≥100
5	VoIP accounts	≥100
6	Simultaneous calls per base station	≥ 8
7	Handover	Within group
8	Roaming	Supported
9	Air Synchronization	Supported
10	Over-The-Air (OTA)encryption	Supported
11	Call Functions	Call hold, call transfer, 3-way conference
12	Switching between calls	Supported
13	Management	• Auto-provision via TFTP/FTP/HTTP/HTTPS/RPS • Auto-provision with PnP • Handset upgrade: OTA (Over-The-Air) • Configuration: browser/phone/auto-provision • Trace package and system log

No.	Feature	Requirements
		export
14	Audio Features	• Full-duplex speakerphone • Hearing Aid Compatibility (HAC) compliant • DTMF • Wideband codec: Opus, AMR-WB (optional), G.722 • Narrowband codec: AMR-NB (optional), PCMU, PCMA, G.726, G.729, iLBC • VAD, CNG, AGC, PLC, AJB
15	Network Features	• SIP v1 (RFC2543), v2 (RFC3261) • SNTP/NTP • VLAN (802.1Q and 802.1P) • 802.1x, LLDP • STUN Client (NAT Traversal) • UDP/TCP/TLS • IP assignment: static/DHCP • Support outbound proxy server backup
16	Security	• Open VPN • Transport Layer Security (TLS) • HTTPS (server/client), SRTP • Digest authentication • Secure configuration file via AES encryption • Support SHA256/SHA512/SHA384
17	DECT Frequency bands	• 1880 – 1900 MHz (Europe) • 1920 – 1930 MHz (US)
18	DECT Standards:	CAT-iq2.0
19	Interface	• 1 x RJ45 10/100M Ethernet port • Power over Ethernet (IEEE 802.3af), Class 1
20	Indoor Range:	20m~50m

No.	Feature	Requirements
21	Outdoor Range:	≥300m
22	Wall mountable	Compliant
23	Ingress Protection rating	IP67
24	Outdoor Installation	UV & weatherproof
25	External AC adapter :	• AC 100-240V Input • DC 5V/1.2A Output
26	Operating humidity:	10~95%
27	Operating temperature:	0~+40°C

3.4.8 Ruggedized DECT Handset

3.4.8.1 General Requirements

3.4.8.1.1 The device shall resist dust, splash, and water, making it ideal for dusty, humid, or harsh environments.

3.4.8.1.2 The device shall be Certified to Ingress Protection rating of IP67.

3.4.8.1.3 The device shall be shock resistant with a tough rubberized surface protects the handset from dropping, slipping, and scratching.

3.4.8.1.4 The device can secure itself from a fall of up to 2.5 meters, an immersion in water up to 1 meter in depth for 30 minutes at most.

3.4.8.1.5 The device shall be Scratch resistant, disinfectant resistant.

3.4.8.1.6 The device shall have Keypad backlight and keypad lock.

3.4.8.1.7 The device shall support SIP cordless phone system.

3.4.8.1.8 The device shall support up to 2 simultaneous calls.

3.4.8.1.9 The device shall support Opus audio codec.

3.4.8.1.10 The device shall have a Noise Reduction System and Flexible Noise Reduction for noise cancellation.

3.4.8.1.11 The device shall support up to 28 hours of talk time and 360-hour standby time.

3.4.8.1.12 The device shall support Quick charging function.

3.4.8.1.13 The device shall support Transport Layer Security (TLS) and Secure Real-time Transport Protocol (SRTP) security encryption.

3.4.8.1.14 The device shall have an Alarm function.

3.4.8.1.15 The device shall have Vibration function.

3.4.8.1.16 The device shall support Headset connection via Bluetooth. It hand set shall be

supplied with a set of noise cancellation headphones

3.4.8.1.17 The device shall have a wall mountable Charger.

3.4.8.1.18 The device offered shall be complete with all hardware components, accessories, features, and devices necessary for a complete functional site deployment irrespective of whether these features have been specified in these schedules or not.

3.4.8.2 Minimum specifications:

No.	Feature	Requirements
1.	Indoor range	≥50m
2.	Outdoor range	≥300m
3.	Standby time	≥360 hours
4.	Talk time	≥28 hours
5.	Display	• ≥1.8" TFT color display • Intuitive user interface with icons and soft keys • Caller ID with name and number • Notification Light: voice mail, missed call • Date & time (manual/auto synchronization) • Keypad backlight
6.	Simultaneous calls per handset	≥2
7.	3-way conference	Yes
8.	Audio Features	• Full-duplex speakerphone • Hearing Aid Compatibility (HAC) compliant • FNR (Flexible Noise Reduction) • Acoustic warning for low battery status • DTMF
9.	DECT Frequency bands	• 1880 – 1900 MHz (Europe) • 1920 – 1930 MHz (US)
10.	DECT Standards:	CAT-iq2.0
11.	Battery	1460 mAh, Lithium-ion, 3.7 V, 5.4 WH
12.	Charger	DC 5V/0.6A Output

No.	Feature	Requirements
13.	Ruggedness	• Scratch resistant, • disinfectant resistant. • Ingress Protection rating of IP67 • shock resistant
14.	Noise cancellation headsets	• To be provided, one pair for each handset
15.	Power Adapter	• Input 240 V, 50 Hz, 0.2 A • Output: 5 V, 0.6 A
16.	Packaging contents	• Belt Clip • Charging Cradle • Rechargeable Battery • Power Adapter • Quick Start Guide

3.4.9 Desktop phone telephone set

3.4.1.3 General Requirements

3.4.9.1.1 The device shall be a Desktop IP Phone with integrated Noise Filtering Technology delivering excellent sound quality for fluent conversations.

3.4.9.1.2 The device offered shall be complete with all hardware components, accessories, features, and devices necessary for a complete functional site deployment irrespective of whether these features have been specified in these schedules or not.

3.4.1.4 Minimum Specifications

No.	Feature	Requirements
1	Colour	Yellow
2	Voice	HD handset and HD Speaker
3	Supported Codecs	Wideband – Opus, G.722

No.	Feature	Requirements
		Narrowband – G.711(A/μ), G.723.1, G.729, G.729A, G.726, iLBC
4	Dual Tone Multi Frequency (DTMF)	In-band, Out-of-band (RFC 2833) and SIP INFO
5	Speakerphone	Full-duplex hands-free speakerphone with AEC
6	VoIP Accounts	≥ Two (2)
7	Phone Features	• One-touch speed dial • Call forward • Call waiting • Call transfer • Group listening • SMS • Emergency call, • Redial • Call return • Auto answer • ≥ 5-way conferencing • Direct IP call without SIP proxy • Ringtone selection, import and delete • Set date time manually or automatically • XML Browser, action URL and URI • Integrated screenshots • Enhanced DSS Keys
8	Directory	• Local phonebook entries ≥ 1000 • Blacklist • XML/LDAP remote phonebook • Smart dialing • Phonebook search, import and export • Call history – dialed, received,

No.	Feature	Requirements
		missed and forwarded
9	IP-PBX Features	• Busy Lamp Field (BLF) • Bridged Line Appearance (BLA) • Anonymous call and anonymous call rejection • Hot-desking • Voicemail • Flexible seating • Call Park • Call Pickup • Centralised Call recording • Visual Voice Mail • Call recording
10	Display and Indicator	• ≥ 2.3" Graphical LCD with backlight • LED for call and message waiting indication • ≥ 2 colour illuminated LEDs for line status information • Caller ID with name and number
11	Interface	• ≥ Two (2) RJ45 10/100M Ethernet Ports • PoE (IEEE 802.3af), class 2 • ≥ One (1) RJ9 (4P4C) headset port • ≥ One (1) RJ9 (4P4C) handset port
12	Security	• SIP v1 (RFC2543) and v2 (RFC3261) • Call server redundancy supported. • NAT traversal: STUN mode • Proxy mode and peer-to-peer SIP link mode • IP assignment: static/DHCP • HTTP/HTTPS web server

No.	Feature	Requirements
		• Time and date synchronization using SNTP • UDP/TCP/DNS-SRV (RFC 3263) • QoS: 802.1p/Q tagging (VLAN), Layer 3 ToS DSCP • SRTP for voice • Transport Layer Security (TLS) • HTTPS certificate manager • AES encryption for configuration file • Digest authentication • OpenVPN, IEEE802.1X • IPv6 • LLDP/CDP/DHCP VLAN • ICE
13	Management	• Configuration: browser/phone/auto-provision • Auto provision via FTP/TFTP/HTTP/HTTPS for mass deploy • Auto-provision with PnP • Zero-sp-touch, TR-069 • Phone lock for personal privacy protection • Reset to factory, reboot • Package tracing export, system log
	Conferencing	• ≥ Five (5) Conferencing
14	Accessories	• Handset with handset cord • Ethernet Cable (1.5m CAT5E UTP Cable) • Stand • Quick Start Guide • Power Adapter
15	Environmental Conditions	• Operating humidity: 10~95%

No.	Feature	Requirements
		• Operating temperature: -10~50°C

3.4.10 Network And Communication Cabinets

3.4.10.1 General Requirements

3.4.1.4.1 Existing network and SCADA cabinets shall be used to install the new communication equipment as much as possible but where this is not possible contractor shall supply install and commission the following types of cabinet.

(a) 42U Rack type free standing cabinet

(b) 9U wall mounted.

(c) 9U with Ground supports

3.4.1.4.2 Where existing panels are to be re-used contractor shall dismantle existing equipment carry out modifications and wiring to meet requirements in clause 3.4.10.2 and clause 2.7.1

3.4.1.4.3 All panel mounted equipment shall be labelled using Aluminium anodized plate or engraved plastic castings as detailed in clause 2.2 and 2.7

3.4.1.4.4 All Panels shall meet requirements in clause 2.7.1

3.4.10.2 Panel design and Wiring

3.4.10.2.1 Electrical wiring and networking of the panel shall be carried out as per approved drawings.

3.4.10.2.2 Bidder shall design panel electrical schematic drawing based on the tender specifications, OEM requirements and any other requirements necessary for optimal operation of the cabinet and cabinet mounted equipment. The drawing shall be submitted for review and approval as detailed in clause 1.7.

3.4.10.2.3 During design, contractor shall ensure all requirements of the OEM for optimal operation of the equipment have been met. All components and accessories proscribed by the OEM for optimal operation of the mounted equipment shall be provided for and installed by the contractor irrespective of whether such devices have been included in the tender specifications.

3.4.10.2.4 Panel structural drawing and panel layout drawings showing device placement shall carried out by the contractor and submitted for approval as detailed in clause 1.7.

3.4.10.2.5 Sizing of electrical protection devices such as MCB's shall be carried out as per

requirements in clause 2.5 and OEM requirements.

3.4.10.2.6 Electrical equipment shall utilise nominal auxiliary supply of 110V DC -125VDC or 220V AC-240 VAC as detailed in clause 2.5. power supply units meeting requirements in clause 2.5.8 shall be installed in the cabinet for supply of power to devices requiring any other auxiliary power supply other than the one specified above, irrespective of whether such devices are listed in the scope of supply.

3.4.10.2.7 Electrical wiring cables and conductors shall meet OEM requirements and requirements in clause 2.7.1 and 2.8.

3.4.10.2.8 Cubicle shall be installed in an environment with average temperature of 40°C. The equipment in the cabinet shall be designed for continuous operation at this temperature without derating and external forced cooling.

3.4.10.2.9 Two redundant (1+1) fans rated for a minimum of 750m^3/hour air flow rate shall be installed at roof of the cabinets to improve panel cooling and extend the life of the installed equipment. However, the panel shall be designed for operation without the fans.

3.4.10.2.10 Panel materials shall meet the requirements of clause 2.2. panel design shall meet the requirements of clause 2.7.1

3.4.10.2.11 All external cables shall terminate to a terminal block or a patch panel. All cabinet devices ports and terminals shall be wired/connected to patch panels or terminal blocks for connection to external cables.

3.4.10.2.12 All ethernet ports of equipment mounted in the cabinets shall be connected to the patch panels. Ethernet connections between devices on the cabinets shall be via patch panel ports but not directly between device to device except for fibre optic patch cords which may be connected directly between devices.

3.4.10.2.13 Ethernet twisted pair patch panels shall be rack mounted on the front or rear side of the cabinets.

3.4.10.2.14 The cabinet wiring shall be very neat and shall allow easy access and aeration of the internal equipment. Spaghetti wiring shall NOT be accepted. All wiring shall neatly run in the cable managers, conduits and cable trays and neatly tied for cable guiding.

3.4.10.2.15 All networking cables MUST be guided around the panel using cable trunks.

3.4.10.2.16 Cable ties shall not be used to support cables to frames or to mounting rails. When used, cable ties shall only be used to guide and arrange cables in the cable managers.

3.4.10.3 Wall Mount 9U Panel Minimum Specifications

3.4.10.3.1 In addition to requirements in clause 2.7.1 the panel shall meet the following minimum specifications

No.	Feature	Minimum Requirements
1	Design & Description	(a). Wall-mounted enclosure with optimum accessibility due to hinged part. (b). With three parts, glass door, hinged swing type mounting rack and wall fixed mounting part (c). with punched rails and mounting angles, depth-variable (d). To comply with tender requirements clause 2.7.1
2	Material Wall and hinged part	Sheet steel, 1.5 mm
3	Material Viewing window	Single-pane safety glass, 3 mm
4	Surface finish	Powder-coated
5	Coat thickness outdoor type	>200micron
6	Coat thickness indoor type	>90microns
7	Colour	RAL 7035
8	Enclosure parts	(a). **Wall section** with solid gland plate, top and bottom, two vertical mounting rails and C rails, horizontal, for cable clamping (b). **Hinged part** with 25 mm pitch pattern of holes in the front and rear frame, and two 482.6 mm (19") mounting angles at the front, infinitely depth-variable (c). 4 wall mounting brackets, (d). 10mm Glazed door (e). double-kit key (f). Mini-comfort handle for lock inserts or equivalent (g). Security lock with at least two keys

No.	Feature	Minimum Requirements
9	Size	9 U
10	Dimensions	Width: 600 mm, Height: 478 mm, Depth: 473 mm or equivalent
11	Internal Installation depth	≥420 mm
12	Depth hinged part	≥316 mm
13	Depth of wall section	≥135 mm
14	IK Code	IK08
15	Load capacity of hinged part (static)	450 N
16	Basic material	Sheet steel
17	Protection category acc. to IEC 60 529	IP 55
18	Wiring and workmanship	As per tender clause 2.7.1

3.4.10.3.2 Ground mounting supports shall be provided for free standing 9U cabinets meeting the following minimum requirements.

No.	Feature	Minimum Requirements
1	General description	Support brackets with angled roof and ground mounting concrete plinths
2	Supports type	At least three (3) angle brackets or hollow sections
3	Supports Material	Sheet steel, ≥2mm
4	Roof material	Galvanised iron, ≥0.5 mm
5	Surface treatment	400micron powder paint with at least three coats
6.	Colour	RAL 9006
7.	Concrete plinth	Class 25 concrete with a depth of at least 500mm
8.	Dimensions	Overall Width: 700 mm, height: 2000mm, Roof Depth: 700 mm
9.	Anchor	At least four anchor bolts

3.4.10.4 42U Panel Minimum Specifications

3.4.10.4.1 In addition to requirements in clause 2.7.1 the panel shall meet the following minimum specifications

No.	Feature	Requirements
1	Overall requirements, wiring and workmanship	As per tender clause 2.7.1
2	Material	Sheet steel, ≥2mm
3	Surface treatment	Powder coats At least three coats, ≥90-micron thickness
4	Glazed front door	Single-pane safety glass, 3 mm
5	Colour	RAL 7035
6	Load capacity	≥8,000 N
7	IK Code	IK08
8	Panel Size	42U
9	Dimensions	Width: 800 mm Height: 2,000 mm Depth: 800 mm
10	Rack mount size	482.6 mm (19")
11	Protection category according to IEC 60 529	IP 54
	Enclosure components and parts	
12	enclosure frame with doors and roof plate	lot
13	Sheet steel side panels	Two (2)
14	Glazed aluminum door at the front, 180° hinges	One (1)
15	Lock front and rear: Comfort handle for profile half-cylinders and security lock each with at least two keys	Two (2)
16	Mounting angles, 482.6 mm (19") with variable depth and width	Four (4)
17	Spacers, height 50 mm, to raise a cover plate above the fan cut-out in the roof plate,	lot
18	482.6 mm (19") fastener, 1 U, conductive	≥12
19	Multi-tooth screws, conductive	≥25

No.	Feature	Requirements
20	IPPC wooden pallet	lot
21	Roof plate, solid multi-piece, with fan cut outs	lot
22	Sheet steel rear door, solid, vertically divided, 180° hinges	lot
23	100mm base plate (plinth)	Lot
24	Cable ducts horizontal 60mm x 80mm and 100mmX80mm, quantity as per design	Lot, as per design
25	Sheet steel horizontal Punched section with mounting flange for device mounting	≥8
26	DIN rails	Lot, as per design
27	Sheet steel Side Pieces between 19-inch mounting rail side wall	Two (2)
28	1U sheet steel blanking plates	Lot, as per design
29	Solid sheet steel glanding plate with factory punched cable glanding holes	Two (2)
30	Electrical and other accessories	As per the scope of supply

3.5 INSPECTION AND TESTING

3.5.1 General Requirements

3.5.1.1.1 All components and panel/cabinet assemblies shall be tested in accordance with the relevant IEC, ITU and IEEE Standards to verify compliance with the requirements of the Standards and this specification.

3.5.1.1.2 Contractor shall provide a detailed testing and commissioning procedure including the standards its derived from for all supplied network equipment.

3.5.1.1.3 Type test certificates shall be provided for all major equipment as detailed in the equipment specifications.

3.5.1.1.4 The Contractor shall be responsible for carrying out all necessary inspections and tests on the radio links and fibre optic links, including leased fibres from Kenya Power, to verify that the communication links are suitable for use by the proposed communication equipment.

3.5.1.1.5 A test plan shall be submitted for approval by the Employer and shall include a description of the proposed link tests and test procedures.

3.5.1.1.6 Contractor shall also develop a commissioning procedure for procedures for operating the system during the commissioning period and during the switchover from the old system to the new network system. Interruption of SCADA system

shall not be allowed for periods of more than four hours. Planning shall be carried out to limit required down time on the SCADA links.

3.5.1.1.7 All equipment shall be inspected and tested at the factory prior to delivery to site. No equipment shall be accepted at site without prior inspection by the procuring entity at the factory, contractor premises or OEM/supplier premises.

3.5.2 Type Test

3.4.1.4.5 Type test Reports/certificate Requirements

(a) Type tests shall be certified by an EU/USA/Canadian National Standards and Testing Authority (NSTA) or by a third-party Reputable Testing Authority accredited by an EU/USA/Canadian National Standards and Testing Authority (NSTA).

(b) Where a body other than NSTA stated above is used to certify the type-test reports, a copy of the certificate of accreditation shall be attached.

(c) Results of type test shall have been conducted at least 6 months and not more than fifteen years prior to the date of tender submission. The contractor shall submit contact details (Title, email, and fax) of certifying laboratory during design.

(d) Testing materials and equipment in Type Test Reports shall have the same code/ country / manufacturer and technical parameters as offered materials and equipment. Type tests of non-conforming materials/equipment shall not be accepted.

(e) Type Test Reports shall include all items tested and results confirming that they meet the requirements of applied standards as stipulated in Tender Documents.

(f) Type Test reports shall have Report Numbers for authentication.

(g) Current contact information of the testing and certification authority shall be provided during design.

3.4.1.4.6 Product certifications approved through testing by from the following bodies will be accepted: UL, CE, FCC, RoHS, TUV GS where stated.

3.4.1.4.7 Type test reports and product certificates shall be provided during design or at bidding stage in accordance as detailed in the tender.

3.5.3 Factory Acceptance Tests

3.4.1.4.8 The procuring entity personnel shall witness the factory tests in person.

3.4.1.4.9 All equipment in scope of supply shall be subject to testing and inspection prior

to delivery to site.

3.4.1.4.10 Contractor shall prepare a test plan as per detailed in clause 1.9 for approval as detailed in clause 1.7

3.5.4 General Equipment Tests

3.4.1.4.11 These tests shall be carried out on all equipment in scope of supply.

3.4.1.4.12 Visual Checks: General Check of the panels/cabinets in respect of dimension, finishing, construction, wiring & ferules verification lay out equipment on the panel, make and rating of instrument etc.

3.4.1.4.13 Operational tests: Operation tests on all equipment to prove correctness of wiring of various circuits as per the approved design.

3.4.1.4.14 Setting range and Functional tests

3.4.1.4.15 Power on checks

3.4.1.4.16 Insulation/dielectric tests

3.4.1.4.17 Network/communication checks

3.4.1.4.18 For moving parts e.g., slide rails, a minimum of ten consecutive mechanical operations shall be carried out in quick succession to confirm the healthiness of the cubicle assembly.

3.5.5 Specific Equipment Tests

3.4.1.4.19 All routine tests as per specified standard shall be carried out in the factory or site

3.4.1.4.20 During design the contractor shall prepare a detailed test plan for factory tests and site tests for approval as detailed in clause 1.7

3.4.1.4.21 Functional testing shall be carried out for all components and systems to verify that the system meets requirements.

3.5.6 Functional & Performance Tests

3.4.1.4.22 Functional tests shall be carried out to confirm the whole system meets the given requirement.

3.4.1.4.23 Testing shall be carried out to ensure all the systems meets performance requirements as detailed in the performance requirements.

3.4.1.4.24 Applications developed under this contract shall be tested to ensure all specified requirements have been met. Software functional testing shall be carried as per ISO/IEC/IEEE 29119. Procedure shall be developed.

3.4.1.4.25 Contractor shall prepare a detailed test plan for approval incorporating all tests to be carried.

4 PARTICULAR TECHNICAL SPECIFICATIONS – CONTROL CENTERS HARDWARE

4.1 GENERAL REQUIREMENTS & INFORMATION

4.1.1 Introduction

4.1.1.1 Procuring entity operates several power plants in the country. SCADA system is used to control and monitor the power plant systems. It also provides data required for maintenance, dispatch, and expansion/upgrade planning of the power plants.

4.1.1.2 SCADA systems are used to run all the power plants which are sites in this tender. The SCADA systems in some stations are not interconnected.

4.1.1.3 Each power plant has a local control centre (central control room) that provide SCADA functionality for each station.

4.1.1.4 With all the stations interconnected, central control centre is required for data gathering and to provide interfaces for common monitoring of all the power plants. The contractor shall provide infrastructure required to achieve this functionality.

4.1.1.5 This particular specification provides requirements specific to the control centres. The main sites to be covered by this scope are Kamburu, Gitaru and hydro plaza.

4.1.1.6 In this contract, contractor shall provide infrastructure for Gitaru and hydro plaza to create backup control centre. Modifications and reconfiguration shall also be carried out in Kamburu.

4.1.1.7 The specification does not cover the specific SCADA applications/functions, but the infrastructure required to run the SCADA related applications. Provision and commissioning of SCADA applications/functions **is not** in scope of this contract.

4.1.2 Existing Systems

4.1.2.1 Existing systems include local control centre equipment in all the power stations and Kamburu regional control centre equipment. Gitaru DMZ server cabinet is also to be supplied under an ongoing project.

4.1.2.2 Local control centre equipment in Masinga, Kamburu, Gitaru, Kindaruma, Kiambere and Turkwel include.

4.1.2.2.1 Local control centre panel with the following equipment

(i) Two (2) Rack mount industrial PC, SEL 3355-2, complete with licensed pre-installed software

(ii) One (1) Thin client PC, HP T640, complete with licensed pre-installed software

(iii) Four (4) Rack mount industrial Ethernet Switches, SEL-2730M, complete with licensed pre-installed software

(iv) One (1) Rack mount PTP grandmaster clock and time server with GNSS receiver, SEL-2488, complete with licensed pre-installed software

(v) Four (4) Checkpoint Industrial cyber security appliance, checkpoint 1200R/1570R with licensed pre-installed software

(vi) One (1) industrial grade LCD touch monitor

(vii) One (1) 4port KVM switch

(viii) One (1) Cyber sciences DCF77 Time code converter

(ix) Electrical and networking accessories

4.1.2.2.2 Process LAN panels at the powerhouse with the following equipment

(i) Two (2) Rack mount industrial Ethernet Switches, SEL-2730M, complete with licensed pre-installed software

(ii) Electrical and networking accessories

4.1.2.2.3 Workstation terminal with the following equipment

(i) Two (2) 27.0 Inch LED backlit LCD monitor, HP Z27q, for each workstation terminal

(ii) Two (2) Thin client PC's, HP T640, complete with licensed pre-installed software for each workstation terminal

(iii) One (1) two-port dual display KVM Switch for each workstation terminal

(iv) Operators' workstation terminal accessories

4.1.2.3 Kamburu regional control centre equipment include

4.1.2.3.1 One (1) fully configured and assembled SCADA DMZ server cabinet, housing the following major equipment

(i) Three (3) Rack mount VM Host Servers, PowerEdge R740 Server, complete with licensed pre-installed software

(ii) Two (2) Rack mount Network Attached Storage, PowerEdge R740XD Server, complete with licensed pre-installed software and two LTO external tape drives

(iii) One (1) Rack mount Workstations, Dell Precision 7920, complete with licensed pre-installed software

(iv) Two (2) Rack mount enterprise cyber security appliance, Checkpoint 6200/5100, with licensed pre-installed software

(v) Two (2) Cisco C9300-24UX-A Ethernet Switches complete with licensed pre-installed software

(vi) One (1) Rack mount Integrated console LCD monitor, keyboard & 8 port KVM switch, ATEN KL1508AIN-AXA-AG

(vii) Electrical and networking accessories

4.1.2.3.2 One (1) fully configured and assembled SCADA Operations server cabinet, housing the following major equipment

(i) Three (3) Rack mount VM Host Servers, PowerEdge R740 Server, complete with licensed pre-installed software

(ii) One (1) Rack mount Workstations, Dell Precision 7920, complete with licensed pre-installed software

(iii) Four (4) Rack mount enterprise cyber security appliance, Checkpoint 6200/5100, with licensed pre-installed software

(iv) Two (2) Cisco C9300-24UX-A Ethernet Switches complete with licensed pre-installed software

(v) One (1) Rack mount Integrated console LCD monitor, keyboard & 8 port KVM switch, ATEN KL1508AIN-AXA-AG

(vi) Electrical and networking accessories

4.1.2.3.3 The following software are installed into the Kamburu RCC equipment

(i) Two (2) VMware vSphere essential plus licenses for the six servers

(ii) Twenty (20) Microsoft windows 2022 server virtual machines

(iii) One (1) Solar Winds Orion Network Performance monitoring for 2000 elements (SL 2000) server

(iv) One (1) Solar Winds Orion Server & Application Monitor (SAM) for 300 monitors (AL 300)

4.1.2.3.4 Four (4) Workstation terminals **each** with the following equipment

(i) Two (2) 27.0 Inch LED backlit LCD monitor, HP Z27q, for each workstation terminal (total of 8)

(ii) Two (2) Thin client PC's, HP T640, complete with licensed pre-installed software for each workstation terminal (total of 8)

(iii) One (1) two-port dual display KVM Switch for each workstation terminal (total of 4)

(iv) Operators' workstation terminal accessories

4.1.2.4 Gitaru control centre equipment which are being supplied under Gitaru rehabilitation project and PIMS project include

4.1.2.4.1 One (1) fully configured and assembled SCADA DMZ server cabinet, housing the following major equipment

(i) Two (2) Rack mount VM Host Servers, PowerEdge R740 Server, complete with licensed pre-installed software

(ii) One (1) Rack mount Cisco fire power FPR1120-NGFW-K9 cyber security appliance with licensed pre-installed software

(iii) Two (2) C9300-24U-A Ethernet Switches complete with licensed pre-installed software

(iv) One (1) Rack mount inverter power supply, EPC INV 110/220-3KVA

(v) Electrical and networking accessories

4.1.2.5 All power stations have a GPS time receiver which will be used for time synchronisation of equipment in each station. GPS clock, time receivers support NTP and PTP.

4.1.2.6 More detailed information of existing systems required for design, installation and commissioning of the new systems shall be provided to the winning bidder after contract signing. All relevant information required for bidding have been provided. If bidders require further information for bidding purposes, they shall write to the procuring entity

as detailed in ITT clauses

4.1.3 Scope

4.1.3.1 Contractor shall carry out design and submit for approval to meet functional and architectural requirements for the following.

(i) Server Virtualisation architecture

(ii) Network, Servers, virtualisation, and applications monitoring architecture.

4.1.3.2 Contractor shall develop configuration, settings and applications/programs/scripts required to meet the functional and architectural requirements.

4.1.3.3 Contractor shall supply install and commission Gitaru Operations server cabinet complete with all specified equipment and as detailed in the scope of supply, functional requirements, and architectural requirements.

4.1.3.4 Contractor shall carry out modifications on the existing Gitaru DMZ servers to meet all the functional and architectural requirements and as detailed in the scope of supply.

4.1.3.5 Contractor shall carry out modifications on the existing Kamburu servers and workstations to meet all the functional and architectural requirements and as detailed in the scope of supply.

4.1.3.6 Contractor shall supply, install, and commission workstations in Hydro Plaza to meet all the functional and architectural requirements and as detailed in the scope of supply.

4.1.3.7 Contractor shall supply, install, and commission all software applications required to meet the functional requirements and as detailed in the scope of supply and architecture.

4.1.3.8 Contractor shall monitor and test all deployed applications and servers to ensure optimal performance, user satisfaction and conformance to performance requirements.

4.2 FUNCTIONAL REQUIREMENTS

4.2.1 General requirements

4.2.1.1 Control centre hardware shall be used to run a minimum of the following applications.

(a) Power Plants Supervisory control and monitoring by Operations servers and workstations (not in scope)

(b) Power Plants Information management system by DMZ servers (not in scope)

(c) Power Plant data archives (time series databases) & systems data storage using NAS server in DMZ and automatic backups.

(d) SCADA system Administration and Management systems such as active directory services, Windows update service (WSUS), DNS etc. in management servers

(e) Sever Virtualization system management.
(f) SCADA system Cyber Security management
(g) SCADA assets monitoring system.
(h) Other services

4.2.1.1.1 Control Centre servers shall provide services to operator and management workstation clients in the SCADA network and remote clients in the corporate network.

4.2.1.1.2 All servers shall at minimum provide the following features/functions.

(a) Hypervisor software for installation of virtual machines, all server operating systems shall be virtual machines except storage server.
(b) Server replication and high availability to allow back up and transfer of all server software and data to another hardware host machine in case of hardware failure with minimal or no changes to the applications.
(c) Shall provide multiple network interfaces as described in the architecture. All servers shall be connected to at least two independent local area networks and have more than one network interface modules.
(d) Redundant high availability data storage. All servers shall have redundant drives in RAID 1 or 5 configuration.

4.2.1.1.3 Operator Workstations shall provide interfaces for plant operators and maintenance personnel to access the SCADA system for supervisory control and monitoring of the power plants. Management workstations shall be used by engineers and system administrators for SCADA system monitoring and administration. Workstation equipment shall include thin clients, dual displays, KVM switches, keyboard etc.

4.2.1.1.4 Operator workstations shall provide the following features and functions.

(a) Windows operating system for installation of applications with windows endpoint security application
(b) Applications for remote desktop services
(c) Dual displays for all SCADA operator workstations
(d) 4K display resolutions for SCADA operator workstations.

4.2.1.1.5 All services/applications shall have redundancies across Kamburu and Gitaru sites. Virtualisation high availability shall ensure server remain available in every cluster even after failure of one host or part of the network. Server replication shall be used to provide redundancy of some servers across the Gitaru and Kamburu. Virtual machines shall be provided in both sites hosting the same service/applications which shall implement application-level redundancy.

4.2.1.1.6 Application-level redundancy will depend on the type of application. SCADA applications and PIMS applications, application-level redundancies shall be

configured by the procuring entity. Contractor shall be responsible for application redundancies for all applications in scope of supply. For monitoring and security management servers which may not have application-level redundancy, redundancy across sites shall be ensured by server replication. Contractor shall provide a licenses management mechanism to ensure the replicated servers remain licensed after replication to a different site

4.2.2 Server Virtualisation requirements

4.2.2.1 General requirements

4.2.2.1.1 All the servers supplied under this project shall be a virtual machine container, to host the employers' power plants control and management applications and other applications.

4.2.2.1.2 Virtual machines shall be hardware independent, i.e., in case of Hypervisor machine hardware change, the virtual machines shall have to work with the same base features, with no specialist support for the substitution.

4.2.2.1.3 Virtualisation and installation of VM's in all the servers, setting up of the virtualisation management client and the associated virtualisation set up shall be carried out by the contractor as per the architectural requirements and other specifications.

4.2.2.1.4 Data stores shall be configured on the network attached storage for running the virtual machines and storing all virtual machines data

4.2.2.1.5 Virtualisation servers and hosts in Gitaru and Kamburu shall provide all the functions/features given in the virtualisation requirements.

4.2.2.2 Bare metal hypervisor

4.2.2.2.1 Contractor shall supply install and deploy VMware hypervisor on the Gitaru operations servers and carry out reconfiguration on the existing Gitaru and Kamburu servers. Each server shall contain latest Enterprise VMware vSphere (ESXi) native (bare metal) Hypervisor operating system installed. The VMware hypervisor shall support all Microsoft windows operating systems from windows server 2022 to windows 1995.

4.2.2.2.2 Each host server shall contain Virtual Machines of Standard Windows server 22 installed on the VMware Hypervisor as detailed in the architecture, windows licenses shall be provided by the procuring entity. Other virtual machines and virtual appliances of non-windows operating systems will be installed by the contractor where applicable.

4.2.2.2.3 Hypervisor shall enable remote control, management and configuration capability of the hardware machine and all its virtual machines without mouse,

keyboard and monitor direct connections (hypervisor remote control)

4.2.2.2.4 Contractor shall set up NTP time synchronization of the hypervisor which transfer the time synchronization to its own virtual machines.

4.2.2.2.5 Hypervisor shall be configured for RAID management capability. The SSD's installed on the hardware shall be configured for RAID 1

4.2.2.2.6 Hypervisor shall be configured to allow network interfaces to be connected directly to one of its virtual machines with no virtual driver interposition ("hardware pass-through").

4.2.2.2.7 Contractor shall also configure virtual network for each of the physical interfaces and creation of virtual network interfaces on the virtual machines.

4.2.2.3 Virtualisation management

4.2.2.3.1 Virtualisation Server

(a) vCenter server shall be installed in the host servers for virtual machines monitoring and management.

(b) vCenter Server shall provide centralized management of virtualized hosts and virtual machines from a single console.

(c) Each of the four virtual environments in Kamburu and Gitaru shall have a separate vCenter server.

(d) Contractor shall carry out all necessary configuration of the vCenter server for management of the virtualisation environment.

(e) Contractor shall configure data store volumes in the network attached storage for running the virtual machines.

(f) vCenter server shall be configured to allow scheduled creation of snapshots of all running virtual machines and storing them in the storage servers for restoration if required.

4.2.2.3.2 High Availability (HA)

(i) Contractor shall provide and configure vSphere High Availability for automated restart within minutes for all applications in the event of hardware or OS failures.

(ii) Contractor shall create clusters for each of the virtualisation environments in Kamburu and Gitaru

(iii) Clusters across the sites may also be configured.

4.2.2.3.3 Live Migration of Virtual Machines

(i) Contractor shall provide and configure vSphere vMotion to enable live migration 0f virtual machines across servers with no disruption to users or service loss, eliminating the need to schedule application

downtime for server maintenance.

(ii) Live migration shall be possible within one site or between sites

4.2.2.3.4 Host based Replication of Virtual machines & appliances.

(i) Contractor shall provide and configure vSphere Replication for replication of virtual machines between Gitaru and Kamburu sites. Also, replication for manual backup of the operations servers in the DMZ storage servers.

(ii) During design, Virtual machines to be replicated automatically between the sites shall be agreed upon. As a minimum however, virtual machines running applications without high availability across the two sites shall be replicated in the other site. Automatic replication shall also be set for automatic back up of critical virtual machines even with high availability.

(iii) Recovery point objective (RPO) shall be set to enable retention of instances from multiple points in time.

4.2.2.3.5 Virtualisation Client

(i) Web based client shall be provided for administration and management of the virtualisation intrastate through the vCenter server.

(ii) A workstation computer or thin client shall be used with standard web browser as virtualisation client. The client software shall allow all administration and configuration functions of the virtual environment such as manual copying of Vm's and moving of vm's, adjusting VM parameters, creation of new Vm's in the servers etc.

(iii) Vsphere client shall be provided and installed in one management workstation in Hydro Plaza, stima plaza and Kamburu for continuous monitoring of the virtualisation including alarms and alerts

4.2.3 Operating systems for SCADA and Other Applications

4.2.3.1 Contractor shall supply and install all operating systems as virtual machines as detailed in the architecture. The virtual machines shall be installed, configured and tested prior to factory acceptance tests by the procuring entity.

4.2.3.2 Windows operating systems licenses are not in the scope of supply, they shall be provided by the procuring entity.

4.2.3.3 The operating systems/ virtual machines shall run SCADA applications for operation of critical power systems. Contractor shall when configuring the servers ensure the highest

reliability of the systems configured for this purpose.

4.2.3.4 Windows software installed into the production servers shall be configured with the optimal settings and services for an industrial control system use.

4.2.3.5 Virtual hardware resources i.e., CPU, RAM, storage etc provision to the virtual machines and appliances shall be discussed with the employer and agreed upon during design and commissioning. The resources shall be within the host server capability.

4.2.3.6 Contractor shall install at least two windows operating systems in the management hosts for installation of vCenter server and provision of domain control services. All virtual machines and virtual appliances required to provide virtualisation management functions shall be installed in the management host server.

4.2.3.7 Contractor shall train the procuring entity extensively on virtualisation, operating systems installation and configuration, Windows server services and applications configuration and all other items as detailed in this tender.

4.2.4 SCADA system Administration and Management requirements

4.2.4.1 General requirements

4.2.4.1.1 Under the SCADA project/s applications required for administration and management of the SCADA assets shall be provided and configured by the contractor/s. The SCADA assets include network devices (switches, gateways routers etc.), servers, workstations, cyber security appliances, Control devices (PLC's, PAC's, controllers etc.) and intelligent electronic devices (IED) e.g., meters, numerical protection relays, smart sensors etc.). The administration and management services required include.

(a) User management and authentication
(b) Windows operating systems and applications updates and remote management
(c) Security appliances monitoring, updates, and remote administration
(d) Network devices monitoring and remote management.
(e) Control devices & IED's remote health monitoring and patch management (not in scope)

4.2.4.1.2 SCADA applications for plant control and plant information management system applications are not scope of this project. The infrastructure (servers, network, operating systems and database management system) required to run these applications are in scope of the project.

4.2.4.1.3 The following servers and applications shall be configured for SCADA assets

administration and management.

(a) Systems management- Windows server for active directory, update services, DNS, DHCP etc. (windows servers), vCenter server & vSphere client for virtualization management

(b) System monitoring server- centralised monitoring of servers to include.

(i) Virtualisation system monitoring (SolarWinds VIM/VMAN)

(ii) Servers, and applications monitoring (Solar winds SAM-existing)

(iii) Logs manager- for viewing, analysing and archiving syslog from operating systems, applications and devices supporting syslog. (Solar winds log analyser)

(iv) Network monitoring and performance analysis (Existing) for monitoring of the network

4.2.4.2 Systems Management servers

4.2.4.2.1 Contractor shall supply install and commission windows servers to provide a minimum of the following administration and management services of the SCADA network.

(a) Domain controller

(b) Windows Server Update Services

(c) DNS

(d) DHCP

4.2.4.2.2 The services shall be configured in a hierarchical architecture where servers in the corporate network will be the top-level providing authentication and internet related services. DMZ servers (L3.5) will derive services and authentication from corporate, RCC/CDC operations servers (L3) from DMZ servers and Local control servers (L2) from RCC Operations servers. The hierarchy will be governed by the cyber security architecture and the need to limit ports and services through each network segment.

4.2.4.2.3 Contractor shall configure windows licenses management server in the management hosts to enable moving of windows virtual machines across the hosts without losing the license compliance. All cores in each server MUST be licensed as per Microsoft requirements.

4.2.4.2.4 vCenter servers shall be configured to monitor and administer the four virtual environments in Kamburu and Gitaru. vCenter server shall be configured to allow monitoring of the resources consumed by VMs and their health status.

4.2.4.2.5 Contractor shall in conjunction with the procuring entity configure/reconfigure domain controllers and windows update servers in each level of the network. Each domain controller & WSUS shall be redundant and shall have all the inbound ports Blocked in the firewalls to prevent access from users outside the

level of network the domain is responsible for. Domain controllers and WSUS shall be configured to meet the procuring entity ICS cyber security standards.

4.2.4.2.6 DNS servers and DHCP servers shall also be configured for management of networks requests in the level the server is responsible for. DNS requests shall also follow the hierarchical structure of the security architecture.

4.2.4.3 System Monitoring server.

4.2.4.3.1 Contractor shall supply install, configure, and deploy systems to monitor the SCADA assets (devices, servers, workstations, and application) for the following.

(a) Get notification of failures and alarms in the assets
(b) Allow quick troubleshooting of problems.
(c) Enable performance monitoring.
(d) Provide a situational awareness of each asset's status.

4.2.4.3.2 The monitoring system shall enable quick overview of the whole system to enable system administrators to manage the system but **shall not** be used for configuration (to modify or manipulate the systems). Configuration shall be carried out using the native software. The system shall however be used to monitor and archive configuration changes of each system.

4.2.4.3.3 SolarWinds Orion Platform for network performance and server and applications management is to be supplied under the SCADA hardware project. Under this project contractor shall modify and enhance the existing Orion system to provide functionalities required and to enable monitoring of new assets. The SolarWinds Orion platform system under procurement has the following licenses NPM SL2000 and SAM AL300

4.2.4.3.4 The Existing Solar winds monitoring shall be enhanced to provide the following.

(a) Virtualisation system monitoring - SolarWinds VIM/VMAN. License for at least 32 CPU sockets to be provided.
(b) Logs manager- for viewing, analysing, and archiving syslog from operating systems, applications and devices supporting syslog to be added for at least 250 nodes.
(c) Network performance monitor existing license of SL2000 is considered sufficient but will be upgraded by the contractor if found not to be sufficient. Network performance monitor shall be configured to monitor all network devices and interfaces in level 2,3 and 3.5 and all the network and telephony devices supplied under the project.
(d) Additional polling engine shall be provided and installed at network level

three (operations servers) for polling SCADA level 3 & level 2 devices.

4.2.4.3.5 Orion platform server shall be supplied and installed as a minimum of four servers as follows

(a) Orion platform server and main polling engine – to run in windows server in the DMZ network (level 3.5)

(b) Orion platform SQL database – to run in windows server in the DMZ network (level 3.5). Database redundancy to be provided on a server in a separate site.

(c) Orion platform additional polling engine – to run in windows server in the operations network (level 3)

4.2.4.3.6 Contractor shall also configure/reconfigure Orion platform for monitoring of new applications, servers and devices supplied under this project and all existing servers, devices and applications supplied under the SCADA hardware project.

4.2.4.3.7 The software support for solar winds shall be extended to at least three years from the date of deployment.

4.2.4.3.8 Contractor shall configure all features of Solar winds for in-depth monitoring of all servers and applications running in the ten power stations local control centres and the four virtualised server clusters in Kamburu and Gitaru.

(a) Contractor shall configure monitoring of server and workstation hardware in all the sites (thirteen),

(b) Configure monitoring of vMware Esxi and Hyper-V hypervisors in all the visualised sites (eight).

(c) Configure comprehensive virtual environment monitoring of performance, capacity, configuration, and usage of hosts, VMs, clusters, and datastores for all the virtualised clusters in the network (12 clusters)

(d) Agents and collectors shall be provided and installed into the hypervisors, operating systems and hardware to ensure visibility of all the general computer systems in the SCADA system.

(e) Contractor shall carry out all configurations necessary to enable detailed monitoring of applications in the ten sites. Contractor shall configure Deep Monitoring of Microsoft Active Directory, Exchange, IIS, and SQL Servers across all the ten sites. SQL database clusters shall also be monitored. Monitoring shall also provide visibility to the storage and back up applications showing capacity and performance of the storage servers and the backup application.

(f) Contractor shall configure monitoring of server and workstation hardware devices including but not limited to All storage devices (SSD & HDD), CPU, RAM, NIC etc. and provide performance metrics and alerts.

4.2.4.3.9 Contractor shall configure network performance monitor for network monitoring of all network devices in level 2 and above and the telephony network.

Contractor shall configure all features of the SolarWinds NPM for

(a) Fault, performance, and availability monitoring
(b) Hop-by-hop analysis along critical paths.
(c) Cross-stack network data correlation
(d) Customizable topology- and dependency-aware intelligent alerts
(e) Dynamic network discovery and mapping
(f) Automated capacity forecasting, alerting, and reporting.
(g) Logical and physical network monitoring in one tool
(h) Intelligent maps
(i) Comprehensive monitoring for advanced network devices
(j) Dynamic statistical network performance baselines
(k) Hardware health monitoring
(l) Customizable performance and availability reports

4.2.4.3.10 Contractor shall create and configure monitoring dashboards for Performance and Availability Reports and Alerts.

(a) Events and alerts shall be arranged and categorised to highlight the critical issues with ease.
(b) Contractor shall configure the system to provide SMS and email alerts for the most critical events in the system.
(c) Monitored events and logs shall be highlighted based on the severity of the even.
(d) Configuration changes on monitored systems shall create notifications and logs that shall be archived in the system.
(e) Intelligent maps shall be configured to provide NOC view showing the overall network view and each network view. NOC view shall show all critical network events and performance metrics
(f) Contractor shall also create intelligent maps for monitoring the virtualisation, applications, and databases. Maps shall provide at a glance view of all the systems requiring attention and provide a broad view of the system performance.
(g) Retrieve historical events and values for trouble shooting and other maintenance and planning activities. It shall be possible to retrieve historical events as old as ten years

4.2.4.3.11 Application shall be configured to archive all events and logs including log files in an SQL server with capability to store data archives for over ten years. Archive can be shared for all Orion products. The database shall be redundant with a database mirror in Gitaru or Kamburu depending on where the main server will be running.

4.2.4.3.12 Contractor shall configure system for management of logs from devices and applications. Logs shall be captured from syslog and SNMP traps and from any other method. Agent to be used to capture logs from operating systems and applications without native support for syslog.

4.2.4.3.13 Contractor shall create dashboard to monitor security events and logs. Dashboard shall highlight detected anomalies and all critical security events from the security appliances and endpoint security agents in the servers and workstations. This shall include windows and vsphere endpoint security applications

4.2.4.3.14 Monitoring system shall have user management to give rights to what various users can view or change. User authentication shall be via the domain controller in the DMZ

4.2.4.3.15 Contractor shall supply remote collectors and agents to enable monitoring of all systems in the ten sites that are across the various network segments. A minimum of twenty agents or collectors shall be installed in the ten power plants local control centre servers (industrial PC's) for monitoring of these systems. The remote collectors/agents shall be light weight capable of running in industrial PC environment with limited resources (2GHZ processor and 4GB RAM)

4.2.4.3.16 Contractor shall supply an additional polling engine with the perpetual license in the operations server in Kamburu or Gitaru for polling the RCC/BCC/CDC operations servers in the four sites and at least 20 LCC servers in the ten power stations through firewalls. The existing main polling engine in the DMZ shall poll the DMZ directly and the transport network and telephony devices through a firewall

4.2.4.4 System management workstations

4.2.4.5 Whereas the operator workstations shall be used to monitor and control the power plants, management workstations shall be used to monitor and administer/manage the SCADA assets (servers, network devices, control, and protection devices)

4.2.4.6 There shall be management workstations terminals in Kamburu and hydro plaza. Each workstation terminal shall consist of at least two thin clients and a visual display unit. The management workstations shall be used following

(a) Network operations centre, Monitoring and configuring the network and network devices

(b) Security operations centre, Monitoring and configuring the cyber security appliances, threat and anomalies monitoring (check point or any other additional system)

(c) System monitoring of Virtualisation, servers, hardware, operating systems,

and applications running on the servers. User interface for all the monitoring services described in clause 4.2.4.3

(d) Configuration of applications, servers and client stations in the SCADA system

(e) Administrative services such as Users' configuration and support, device updates etc.

(f) Monitoring of control devices (not in scope)

4.2.4.6.2 One host server in each cluster shall have a configuration server which shall be a windows virtual machine configured as remote clients for all the management & administration of servers (virtualisation, windows, security management server, system servers, database servers, etc.). The management workstation terminals in Kamburu and Hydro Plaza shall be used to log in to the configuration server through remote desktop sessions.

4.2.4.6.3 The management workstation shall provide a platform for the following in all the management servers:

(i) Event & Log Management- Searching logs, viewing events, filtering logs, sequence of events

(ii) Creating reports, creation and viewing of dashboards.

(iii) Viewing situational maps

(iv) Configuration interface for all server & applications (SCADA, PIMS, Windows, Virtualisation, network, security, systems(hardware) etc. and workstations

4.2.4.6.4 Webserver shall be provisioned in the DMZ network to provide interface to the monitoring servers (Orion platform) from the corporate network and mobile clients.

(a) The monitoring interface client interface for all the monitoring services described in clause 4.2.4.3

(b) The monitoring web server shall not allow configuration or administration of the servers.

(c) Contractor shall configure the monitoring system for the following

(i) control the number of allowed users

(ii) manage information available for external view

(iii) provide a central website for accessing monitoring services, home page

(iv) Shall handle authentication of users instead of the management servers themselves

(d) During design the contractor shall provide details of the configuration and design of the management monitoring interface

4.2.5 Data Storage and Backup requirements

4.2.5.1 Network attached storage requirements

4.2.5.1.1 Contractor shall make any required modifications on the existing Kamburu NAS to suit the new architecture.

4.2.5.1.2 Each NAS server shall contain Microsoft Windows storage server standard edition with a minimum of the following:

(i) Shall host the data store for the DMZ virtual environment and data store for other functions especially archive/historical servers.

(ii) Shall be supplied, installed, and configured by the contractor

(iii) Each NAS to have eight arrays of RAID 5 disks with each array having three 2.4TB 10K HDD

4.2.5.1.3 All the DMZ virtual machines and data shall be stored in the network storage servers except specific management virtual machines that might require to be installed in the host server's storage. This shall be designed for the effective operation of the virtual system. This shall ensure most of the data in the DMZ is stored in the NAS.

4.2.5.1.4 All the DMZ host servers shall be connected to the NAS via 10Gb/s ethernet connection. Contractor shall ensure a 10Gb ethernet link shall be maintained between each host servers and NAS. There shall be 10Gb ethernet links to the ethernet switch in each site and 10Gb link between the two sites. This shall ensure a high bandwidth low latency link shall exist between the storage and the host servers in one site and between sites in the DMZ.

4.2.5.2 NAS high availability failover and replication

4.2.5.2.1 Contractor shall configure the two NAS to be dual redundant (high availability) with failover.

4.2.5.2.2 The two NAS servers shall operate in a duty standby configuration.

4.2.5.2.3 Data in the two NAS shall be replicated automatically and failure of duty NAS server shall lead to automatic take over by the standby NAS. The transfer shall be seamless without data loss.

4.2.5.2.4 Failures leading to failover shall include but limited to

(a) Disk failure, if the number of failed disks exceed what is covered by RAID 5 configuration or if the failure will lead to loss of data.

(b) Failure in 10Gb network connection to one of the host servers

(c) Failure of the NAS hardware or operating system

4.2.5.2.5 On resumption from failure, the NAS shall transfer all the missing data from the duty NAS before becoming available in standby.

4.2.5.2.6 Only one NAS server shall be visible to storage client applications.

4.2.5.2.7 Contractor shall supply, install, configure, and test all applications required for the NAS server redundancy and failover.

4.2.5.2.8 Failed NAS server shall not be available in standby, and alarm shall be generated to notify that NAS is no longer on standby. These events shall be captured by the management servers.

4.2.5.2.9 Failover application shall also be designed to failover to the most suitable NAS if both NAS have failures.

4.2.5.3 Storage and data backup

4.2.5.3.1 Contractor shall re-configure the duty NAS for automatic daily incremental backup and fully automatic weekly backup of the full NAS storage array to the external tape drive. Scheduled data dumps shall also be scheduled in the NAS applications.

4.2.5.3.2 Contractor shall provide any necessary additional applications/software for the tape backup and restoration for Kamburu and Gitaru.

4.2.5.3.3 Backup application shall also be configured for specific application backup to the tape drives including but not limited to dataset server tables and archives, critical server applications etc.

4.2.5.3.4 Contractor shall also re-configure host-based replication of virtual machines in the operations network to the NAS in the DMZ network. Host based replication shall also be configured between sites for the DMZ servers.

4.3 DESIGN & ARCHITECTURE REQUIREMENTS

4.3.1 General Requirements

4.3.1.1 The Architecture requirements shall contain the proposed implementation methodology of the required system by the procuring entity. Provides a general proposal of how the contractor shall implement the functional and supply requirements.

4.3.1.2 Contractor shall supply goods and provide services to meet all the functional requirements and the scope of works requirements including those not covered by the architecture requirements.

4.3.1.3 The final architecture shall be developed by the contractor during design for review and approval by the procuring entity.

4.3.1.4 Architectural requirements given in this specification shall be the basis for the contractor design. However, the architecture requirements shall not be the only considerations while creating the final design, the contractor shall also consider the OEM requirements and guidelines, optimal operating conditions, overall performance of the system and

industry best practices.

4.3.1.5 Approved architecture shall be used to implement the system at site. Contractor must design and get approval of the designs prior to site works.

4.3.2 Overall Architecture

4.3.2.1 The overall system architecture of the Control and dispatch centres shall consist of servers and workstations spread out in ten power plants plus hydro plaza. The SCADA WAN shall interconnect these control centres and dispatch centres. The overall proposed architecture drawing of the SCADA system is provided in the specification drawings.

4.3.2.2 Gitaru and Kamburu shall host the main servers providing services to users in the whole SCADA system and corporate.

4.3.2.2.1 There shall be two sets of servers in each site. One set of servers shall host the SCADA control applications and shall be used for operating the power plants these are referred to as the operations or control servers.

4.3.2.2.2 The other set of servers shall host applications for Power plant information management system used for dispatch, maintenance, and other power plant management activities. These shall be the DMZ servers; the DMZ servers shall also host applications for SCADA assets administration and management detailed in the functional requirements.

4.3.2.2.3 DMZ servers shall be connected to the SCADA network and to the corporate (business) network providing services to users in the corporate network and the internet and obtaining data from the SCADA network

4.3.2.2.4 Corporate network, DMZ servers and operations servers shall be separated by security gateways (firewalls) which will limit what services, users or nodes can connect between the two networks

4.3.2.3 The local control centres consist of two physical servers of industrial PC type (three sites have HP ProLiant servers) with virtualisation running control servers and workstation virtual machines. Supply of local control servers and workstation is not in scope of this project. The contractor shall however carry out configurations/modifications required for monitoring of these servers for SCADA system management and administration.

4.3.2.4 SCADA system shall also consist of operator workstations and management workstations. Operator workstations shall be used for control and monitoring of the power plants while management workstations shall be used for administration and management of SCADA assets. There are workstations in all the ten power stations and are not in scope of this tender. There shall be three major workstation sites at Kamburu, Hydro Plaza and Stima Plaza. Kamburu workstations are supplied under the SCADA hardware upgrade project. Contractor shall however carry out all necessary configurations in all workstations

including those supplied under SCADA hardware upgrade project to meet functional and architectural requirements given in this tender.

4.3.2.5 Workstations shall consist of thin clients and Visual display units at the operator desk and workstation servers running in the host servers. Thin clients shall establish a remote desktop connection to the workstation servers via RDP or any other suitable open protocol to be agreed during design phase. One workstation server shall serve multiple thin clients each with an independent remote session in the server.

4.3.2.6 Stima plaza shall host the central dispatch centre (CDC) that shall have workstations for operating all the power plants and management workstations for management and administration of the whole SCADA system. Stima plaza CDC servers shall provide remote access to the main servers in Kamburu and Gitaru. The servers in Stima Plaza shall provide client interfaces to thin clients in the dispatch office and other users. In Stima Plaza CDC, two configuration servers shall be installed in each host server to serve CDC workstations. Configuration servers shall connect to administration& management servers in Kamburu and Gitaru. Each CDC host servers shall host the SCADA remote client server that shall connect to the process servers in Kamburu and Gitaru and the other and shall be used for power plant operations. Existing servers shall be used for Stima plaza CDC.

4.3.2.7 Remote users in the corporate network and mobile users shall have access to servers in the DMZ for access to PIMS web servers, system monitoring web server as described in the functional requirements

4.3.2.8 SCADA application network shall be used to connect the servers and workstations.

4.3.3 Gitaru & Kamburu Control Centres Architecture

4.3.3.1 Kamburu and Gitaru RCC/BCC control centres hardware equipment shall each consist of two server cabinets. One server cabinet shall be operations side servers while the other shall be for DMZ servers.

4.3.3.2 Operations servers shall provide services required for real time control the power plants while DMZ servers shall provide services required for power plant management and for SCADA assets management.

4.3.3.3 The servers shall be organised in clusters for high availability. There shall be one cluster of operations servers in Kamburu and another in Gitaru. There shall also be one DMZ cluster in Kamburu and another in Gitaru.

4.3.3.4 The two operations clusters shall be similar in the two sites and shall provide the same services. One site shall be the primary site while the other shall be back up. The same

shall apply for the two DMZ clusters. Some services shall be balanced between the two sites while some shall be provided by one site while the other is on standby. One site may be primary for some services while the other it's on standby for some services. The services/applications are further described in the software architecture.

4.3.3.5 There shall be at least two host servers for each cluster, DMZ clusters shall also include an additional storage server and tape back up

4.3.3.6 The two control centres shall ensure high availability of services for SCADA related services. As part of this project contractor shall supply network equipment to ensure multiple redundant links between the two sites for high availability.

4.3.3.7 The workstation terminals shall be situated in Kamburu and Hydro Plaza. Each workstation terminal shall be connected to both Gitaru and Kamburu servers. Workstation terminals shall each have two thin clients, one thin client shall establish a remote desktop session with a server in Kamburu while the other shall establish a connection to Gitaru servers.

4.3.3.8 Kamburu servers & workstations and Gitaru DMZ production host servers are supplied under a different project. However, the contractor shall be responsible for modifications and reconfigurations to ensure the new architecture meets all requirements.

4.3.4 Hardware Architecture

4.3.4.1 General requirements

4.3.4.1.1 Gitaru and Kamburu sites shall have two server cabinets one for operations side servers and another for the DMZ side servers. Both server cabinets in Kamburu are supplied under another project. Contractor shall however carry out modifications to conform to the new architecture.

4.3.4.1.2 Gitaru DMZ server cabinet is also supplied under a separate project. Contractor shall however carry out modifications at site install all other devices as detailed in the scope of supply. During site works contractor shall migrate new host servers to Kamburu DMZ cluster and replace them with the existing host servers. One storage server shall also be migrated from Kamburu to Gitaru Contractor shall also carry out all other necessary modifications to conform to the new architecture. This shall include installation of the new host servers and all wiring and network connections to meet all requirements in clause 2.7 and 2.9.

4.3.4.1.3 Contractor shall supply a new server cabinet with all the equipment as detailed in the scope of supply installed and configured for Gitaru operations server cabinet. All cubicle, electrical and networking accessories shall be provided for and installed as detailed in clause 4.4.2 and 2.7.

4.3.4.1.4 The contractor shall supply, assemble, configure, and test all the equipment prior to factory acceptance testing witnessed by the procuring entity.

4.3.4.1.5 Kamburu and Gitaru Servers shall be supplied installed and configured as four clusters. Each site shall have two clusters and each network shall have two clusters as detailled below and as illustrated in the specification drawing. Contractor shall revise the architecture to ensure it meets all requirements in the tender and submit for approval during design stage.

4.3.4.2 Revised Kamburu & Gitaru RCC/BCC Hardware (Clusters) architecture

4.3.4.2.1 Kamburu operations (L3) virtualisation cluster

(a) Two (2) hosts

(i) Servers existing

(ii) Two hosts each with 1CPU,18cores 256GB RAM each

(iii) Network interfaces to be upgraded to 10G.

4.3.4.2.2 Gitaru operations (L3) virtualisation cluster

(a) Two (2) hosts

(i) Two hosts each with 1CPU,18cores 256GB RAM each

(ii) Existing Servers to be moved from Kamburu.

(iii) Network interfaces to be upgraded to 10G.

4.3.4.2.3 Kamburu DMZ (L3.5) virtualisation cluster

(a) Two (2) n hosts

(i) One hosts with 2CPU,18cores 256GB RAM - new.

(ii) One host with 2CPU,20cores 256GB RAM -existing

(iii) One server is in scope of supply the other is existing.

(iv) Existing server network interface to be upgraded to 10G.

(v) Existing server RAM to be upgraded to 256GB.

(b) One (1) Storage hosts

(i) One (1) host with 1CPU,10cores 64GB RAM each

(ii) Server existing

(iii) One host is a mirror of the other in Gitaru.

(iv) Server network interface to be upgraded to 10G.

(v) HDD capacity to be upgraded from 24TB to 48TB.

4.3.4.2.4 Gitaru DMZ (L3.5) virtualisation cluster

(a) Two (2) Production hosts

(i) One host with 2CPU,18cores 256GB RAM - new.

(ii) One host with 2CPU,20cores 256GB RAM -existing

(iii) One server is in scope of supply the other is existing.

(iv) Existing server network interface to be upgraded to 10G.

(v) Existing server RAM to be upgraded to 256GB.

(b) One (1) Storage hosts

(i) One (1) host with 1CPU,10cores 64GB RAM each

(ii) Server existing in Kamburu

(iii) One host is a mirror of the other in Kamburu.

(iv) Server network interface to be upgraded to 10G.

(v) HDD capacity to be upgraded from 24TB to 48TB.

4.3.4.3 Server Cabinet design

4.3.4.3.1 There shall be four server cabinets two in each station. Three server cabinets are supplied under hardware upgrade project while one cabinet shall be supplied under this contract. Server cabinets shall meet all requirements in clause 4.4.2

4.3.4.3.2 Electrical wiring and networking of the panel shall be carried out as per approved drawings.

4.3.4.3.3 Contractor shall design panel electrical schematic drawing based on the tender specifications, OEM requirements and any other requirements necessary for optimal operation of the cabinet and cabinet mounted equipment. The drawing shall be submitted for review and approval as detailed in clause1.7

4.3.4.3.4 During design, contractor shall ensure all requirements of the OEM for optimal operation of the equipment have been met. All components and accessories proscribed by the OEM for optimal operation of the mounted equipment shall be provided for and installed by the contractor irrespective of whether such devices have been included in the tender specifications.

4.3.4.3.5 Panel structural drawing and panel layout drawings showing device placement shall carried out by the contractor and submitted for approval as detailed in clause 1.7.

4.3.4.3.6 All electrical equipment shall be protected from electrical faults such as short circuits as per the OEM specifications. Devices such as fuses, MCB's etc shall be included for device protection.

4.3.4.3.7 Sizing of electrical protection devices such as MCB's shall be carried out as per requirements in clause 2.5 and OEM requirements.

4.3.4.3.8 Electrical equipment shall utilise nominal auxiliary supply of 110V DC -125VDC or 220V AC-240 VAC as detailed in clause 2.5. power supply units meeting requirements in clause 2.5.7 shall be installed in the cabinet for supply of power to devices requiring any other auxiliary power supply other than the one specified above, irrespective of whether such devices are included in scope of supply or not

4.3.4.3.9 Electrical wiring cables and conductors shall meet OEM requirements and requirements in clause 2.7.1 and 2.8

4.3.4.3.10 Cubicle shall be installed in an environment with average temperature of 35°C.

The equipment in the cabinet shall be designed for continuous operation at this temperature without derating and external forced cooling.

4.3.4.3.11 Two redundant (1+1) fans rated for a minimum of 750m^3/hour air flow rate shall be installed at roof of the cabinets to improve cabinet cooling and extend the life of the installed equipment. However, the panel shall be designed for operation without the fans.

4.3.4.3.12 All cabinets shall have redundant power supplies. Server cabinets shall be supplied with at least two power distribution units. Servers, Ethernet switches and workstations shall all be supplied with redundant power supplies. Each power supply for devices with redundant power supply shall be connected to a separated power distribution unit.

4.3.4.3.13 Cabinet materials shall meet the requirements of clause 2.3. Cabinet design shall meet the requirements of clause 2.5

4.3.4.3.14 All external cables shall terminate to a terminal block or a patch panel. All cabinet devices ports and terminals shall be wired/connected to patch panels or terminal blocks for connection to external cables during installation by the procuring entity.

4.3.4.3.15 All equipment in the cabinet electrical wiring terminals shall all be wired to terminal blocks

4.3.4.3.16 All ethernet ports of all equipment mounted in the cabinets shall be connected to the patch panels. Ethernet connections between devices on the cabinets shall be via patch panel ports but not directly between device to device except for fibre optic patch cords which may be connected directly between devices.

4.3.4.3.17 Ethernet twisted pair patch panels shall be rack mounted on the front/rear side of the cabinets and panel mounted or DIN rail mounted at the rear side of the panel. The cabinet wiring shall be very neat and shall allow easy access of the internal equipment.

4.3.4.3.18 All networking cables shall be guided around the cabinet using cable managers (cable trunks)

4.3.4.3.19 All the servers and workstation/thin clients in each cabinet shall be connected to the console KVM switch for local administration.

4.3.4.4 Gitaru Operations Server Cabinet

4.3.4.4.1 Contractor shall supply server cabinet meeting all the requirements in clause 4.4.2 for installation in Gitaru.

4.3.4.4.2 The cabinet shall contain all components detailed in the scope of supply.

4.3.4.4.3 Cabinet shall be factory wired and tested prior to delivery to site. Contractor shall carry out all installations and configurations at their premises prior to factory

acceptance tests, modifications shall NOT be carried out at site unless there is change in design

4.3.4.4.4 Cabinet shall be as similar as possible to the operations server cabinet in Kamburu.

4.3.4.4.5 To ensure quality and workmanship is adhered to panel enclosure shall be obtained from renown manufacturers such as Rittal.

4.3.4.5 Workstations

4.3.4.5.1 Each Workstation terminal shall consist of the following

(a) Two thin client computer terminals for remote desktop connection to a different server for redundancy of connections to the terminal.

(b) Display with the following options.

(i) Two desktop displays 27" size.

(ii) Two large video walls display 75"/84" size.

(iii) One large video wall displays 75"/84" size.

(c) Dual display KVM switch

(d) Keyboard and mouse

4.3.4.5.2 There shall be the following workstation terminals in Kamburu.

(a) Four operator workstation terminals each with two client connection to SCADA remote desktop servers in Kamburu and Gitaru and each with dual desktop displays. Thin clients and displays to be supplied under SCADA hardware upgrade project and not in scope of this project.

(b) One operator workstation terminal with two client connection to SCADA remote desktop servers in Kamburu and Gitaru and with large video wall display. To utilise KVM extender. Video wall existing

(c) One management workstation terminal with connections to configuration servers in Kamburu and Gitaru and with desktop displays

4.3.4.5.3 There shall be the following workstation terminals in Hydro Plaza

(a) Four operator workstation terminals each with two client connection to SCADA remote desktop servers in Kamburu and Gitaru and each with dual desktop displays.

(b) One operator workstation terminal with two client connection to SCADA remote desktop servers in Kamburu and Gitaru and with large video wall displays. One large video display existing

(c) Two operator workstation terminals with two client connection to SCADA web servers in Kamburu and Gitaru and with large video wall displays.

(d) One management workstation terminal with connections to configuration servers in Kamburu and Gitaru and with desktop displays.

(e) One management workstation terminal with client connection to monitoring server with large video wall display shall be connected to the monitoring server.

4.3.5 Local Area Network Architecture

4.3.5.1 Physical network architecture

4.3.5.1.1 Dual redundant ethernet LAN shall be provided for the four clusters. Each server shall be connected to two LAN's while every workstation terminal shall also be connected to two LAN's.

4.3.5.1.2 DMZ cabinets in Kamburu and Gitaru and operations cabinet in Kamburu contain two Cisco 9300U Ethernet Switches which are supplied under SCADA hardware upgrade project. Each device in each cabinet shall be connected to both switches. The switches shall create the network interfaces between the cabinet devices and the external network.

4.3.5.1.3 Gitaru operations cabinet shall contain at least two ethernet switches similar to existing and meeting all requirements in clause 4.4.9

4.3.5.1.4 Each DMZ cabinet shall also contain at least one check point security gateway appliance for external connections to the corporate network. Appliance is supplied under a different project. One of the security gateways in Kamburu supplied under hardware project shall be shifted to Gitaru DMZ

4.3.5.1.5 Operations server cabinet shall also contain two checkpoint security gateway appliances supplied under different project. Contractor shift two gateways from Kamburu to Gitaru and reconfigure the appliance to ensure compliance to the new architecture and requirements.

4.3.5.1.6 Contractor shall carry out configurations and connections for all the ethernet switches and firewall to ensure they conform to the new architecture to be approved during design.

4.3.5.1.7 The two DMZ LAN's in Kamburu and Gitaru shall have 10Gb/s redundant fibre optic link connecting the four ethernet switch to form one network. The DMZ LAN shall be configured to enable implementation of all the functions given in this tender and as per approved designs.

4.3.5.1.8 Operations clusters shall be isolated by fire wall separating the two operations side clusters and the Hydro Plaza control centre workstation LAN. Logical operation and connection of the LAN in Kamburu RCC/BCC operations, Gitaru RCC/BCC operations and Hydro Plaza RCC/BCC shall be designed to ensure redundancies, function requirements and security requirements given in this tender. Contractor network expert and OT cyber security expert shall review the initial requirements given in this tender and provide a design meeting all requirements and providing the most secure, safe, and reliable network for the

given functions.

4.3.5.1.9 All cluster hosts shall have at least two 10Gb/s physical network connection to each LAN with a total of at least four 10Gb/s physical links to the local network.

4.3.5.1.10 To ensure high availability, low latency, and high bandwidth for virtualisation clusters a management network shall be created between the servers in each cluster in Gitaru and Kamburu as detailed in the clauses below.

4.3.5.1.11 VLANs shall be configured in the ethernet switches and security gateways to enable sharing of physical appliances and ethernet switches by devices and services in different network segments across the WAN and within the LAN's. Network virtualisation shall meet cyber security requirements and provide all required functional requirements.

4.3.5.1.12 Connections shall be made in such a manner to allow very deterministic network failover redundancy management.

4.2.2.3.5 Contractor shall supply and install new quad port 10Gb/s ethernet module on each server to enable 10Gb/s connections between the cluster hosts.

4.3.5.2 Logical network architecture

4.2.2.3.6 Contractor shall develop a detailed network architecture for the RCC/BCC control/dispatch centres. The local networks shall be designed to ensure the servers are able to provide all the services given in the functional requirements and clients are able to access the servers while meeting the minimum performance requirements. The network design shall also include the requirements in the following clauses below.

4.2.2.3.7 Network shall allow seamless connection between the two operations server clusters in Gitaru and the operator workstations in Kamburu and Hydro Plaza with redundant links of at least 1Gb/s capacity. Workstations shall be connected to a server in Gitaru and a server in Kamburu.

4.2.2.3.8 Network shall ensure the clusters in Kamburu and Gitaru have dual redundant 10Gb/s link across the new fibre and the existing Kenya power fibre. Network configuration shall ensure there is persistent stateful parallel dual 10Gb/s links between Gitaru and Kamburu without being blocked by spanning tree. The network shall be configured to ensure the two links remain stateful without creating loops between the networks. Each link shall connect one switch to the other ensuring that the two clusters are always connected to at least one 10Gb/link.

4.2.2.3.9 The four 10Gb links between Kamburu and Gitaru clusters shall be encrypted.

4.2.2.3.10 The workstations shall be connected to an operator workstation network and

management workstation network. Operator Workstation network shall limit connections only to relevant servers and prevent any connections to servers that are not be accessed from the operator workstation. Operator Workstation network shall also ensure that connections from the workstations pass through a security gateway before connecting to the server. VLAN's shall be configured to segregate the operator workstation network from the servers.

4.2.2.3.11 Virtual network shall be configured on the host servers to ensure the virtual machines have access to all resources and clients required for a specific function. Network connections shall ensure that each virtual machine shall have at least a dual 1Gb/s connection to the other servers and clients and has at least 10Gb/s link to the storage.

4.3.6 Software Architecture

4.3.6.1 General Requirements

4.3.6.1.1 The host server shall be a virtual machine container, to host the employers' SCADA servers and other applications. The fundamental aim of the virtualization shall be to allow back up and transfer of all server software and data to another hardware host machine in case of hardware failure with minimal or no changes to the applications.

4.3.6.1.2 All windows licenses shall be provided by the procuring entity.

4.3.6.1.3 All server operating systems except NAS shall be virtual machines running on a bare metal hypervisor. VMware shall be utilised.

4.3.6.1.4 Windows license manager shall be configured if necessary to enable moving and replication of servers across the host servers in operations or DMZ clusters.

4.3.6.2 Operations Production host servers (RCC/BCC Operations Clusters)

4.3.6.2.1 Operations production host server in **each** cluster shall contain a minimum of the following virtual machines:

(a) SCADA RCC control gateway server: Shall be a Windows 2022 server virtual machine with the following features (existing)

(i) Ten (10) Windows User CALS (license not in scope)

(ii) Main application- SCADA gateway control server (not in scope)

(iii) There shall be application-level redundancy between application in Kamburu and Gitaru (application implementation by Procuring

entity)

(b) SCADA RCC control remote client's server: Shall be a Windows 2022 server virtual machine with the following features (existing)

(i) Ten (10) Windows User CALS (license not in scope)

(ii) Ten (10) remote desktop CALS (license not in scope)

(iii) Main application- SCADA client's server (not in scope)

(iv) Thin clients shall connect to this server via remote desktop.

(v) Server shall be a client to the gateway server. The two servers in Gitaru and Kamburu shall have continuous connection with the duty gateway server.

(c) SCADA CDC control gateway server: Shall be a Windows 2022 server virtual machine with the following features (to be installed- license not in scope)

(i) Ten (10) Windows User CALS (license not in scope)

(ii) Main application- SCADA gateway control server (not in scope)

(iii) There shall be application-level redundancy between application in Kamburu and Gitaru (application implementation by Procuring entity)

(d) Plant information management proxy server: Shall be a Windows 2022 server virtual machine with the following features (license not in scope)

(i) Five (5) Windows User CALS (license not in scope)

(ii) Main application- PIMS proxy server (not in scope)

(iii) There shall be application-level redundancy between application in Kamburu and Gitaru (application implementation by Procuring entity)

(e) Database server: Shall be a Windows 2022 server virtual machine with the following features (existing)

(i) Five (5) Windows User CALS (license not in scope)

(ii) Microsoft SQL server standard edition with ten (10) user CALS (license not in scope)

(iii) Main application- Oracle DBMS (not in scope) and SQL server

(iv) Database redundancy clustering to be implemented by the contractor between Gitaru and Kamburu servers.

(f) Virtualisation server: Shall be a Windows 2022 server virtual machine with the following features (license not in scope).

(i) Five (5) Windows User CALS (license not in scope)

(ii) Main application-

- vSphere vCenter server
- vSphere replication server
- All other vSphere components required for cluster management.

(g) Domain controller: Shall be a Windows 2022 server virtual machine with the following features(license not in scope).

(i) Fifty (50) Windows User CALS (license not in scope)

(ii) Main applications

- Windows active directory
- DNS
- Windows update server (WSUS)
- Windows license manager.
- RADIUS server

(h) Configuration server: Shall be a Windows 2022 server virtual machine with the following features.

(i) Five (5) Windows User CALS (license not in scope)

(ii) Five (5) remote desktop CALS (license not in scope)

(iii) Main application- configuration clients

4.3.6.2.2 The following virtual machines shall operate in one Operations production host server cluster with replication in the other cluster. One instance of the server shall be licenced and operate at any one time. Contractor shall carry out installation and configurations to ensure theses servers can be replicated across the sites without losing the licenses.

(a) SCADA assets monitoring server (SolarWinds Orion) additional polling engine: Shall be a Windows 2019/2022 server virtual machine for polling monitored devices in network segment 3 and 2 with the following features.

(i) five (5) Windows User CALS (license not in scope)

(ii) Main applications: Solar winds Orion additional polling engine for NPM, SAM, VMAN, LA etc.

4.3.6.2.3 VMware vSphere Host virtualisation software to be used.

(a) vSphere essential plus licenses is existing for virtualisation of Kamburu servers.

(b) Contractor shall supply one (1) VMware vSphere essential plus kit with perpetual licenses for virtualisation of the new servers.

4.3.6.3 DMZ Production host servers (RCC/BCC DMZ Clusters)

4.3.6.3.1 Operations production host server in **each** cluster shall contain a minimum of the following virtual machines:

(a) SCADA Time series data Historical server: Shall be a Windows 2022 server

virtual machine with the following features (existing)

(i) Ten (10) Windows User CALS (license not in scope)
(ii) Microsoft SQL server standard edition with ten (10) user CALS (license not in scope).
(iii) Main application- SCADA historical server (not in scope)

(b) SCADA Events Historical server: Shall be a Windows 2022 server virtual machine with the following features (existing)

(i) Ten (10) Windows User CALS (license not in scope)
(ii) Microsoft SQL server standard edition with ten (10) user CALS (license not in scope).
(iii) Main application- SCADA historical server (not in scope)

(c) SCADA web server: Shall be a Windows 2022 server virtual machine with the following features (existing)

(i) Fifty (50) Windows User CALS (license not in scope)
(ii) Main application- SCADA web server, IIS (not in scope)

(d) Plant information management Visualisation web server: Shall be a Windows 2022 server virtual machine with the following features (license not in scope)

(i) Two hundred (200) Windows User CALS (license not in scope)
(ii) Main application- PIMS visualisation web server, IIS (not in scope)

(e) Plant information management archive server: Shall be a Windows 2022 server virtual machine with the following features (license not in scope)

(i) Ten (10) Windows User CALS (license not in scope)
(ii) Microsoft SQL server standard edition with ten (10) user CALS (license not in scope).
(iii) Main application- PIMS historical server (not in scope)

(f) SCADA assets monitoring server (SolarWinds Orion) database server: Shall be a Windows 2022 server virtual machine with the following features.

(i) Ten (10) Windows User CALS (license not in scope)
(ii) Microsoft SQL server standard edition with ten (10) user CALS.
(iii) Main application- Microsoft SQL server

(g) Virtualisation server: Shall be a Windows 2022server virtual machine with the following features.

(i) Five (5) Windows User CALS (license not in scope)
(ii) Main application-

- vSphere vCenter server

- vSphere replication server
- All other vSphere components required for cluster management.

(h) Domain controller: Shall be a Windows 2022 server virtual machine with the following features.

(i) Fifty (50) Windows User CALS (license not in scope)

(ii) Main applications

- Windows active directory
- DNS
- Windows update server (WSUS)
- Windows license manager.
- RADIUS server

(i) Configuration server: Shall be a Windows 2022 server virtual machine with the following features.

(i) Five (5) Windows User CALS (license not in scope)

(ii) Five (5) remote desktop CALS (license not in scope)

(iii) Main application- configuration clients

4.3.6.3.2 The following virtual machines shall operate in one DMZ production host server cluster with replication in the other cluster. One instance of the server shall be licenced and operate at any one time. Contractor shall carry out installation and configurations to ensure theses servers can be replicated across the sites without losing the licenses.

(a) SCADA assets monitoring server (SolarWinds Orion): Shall be a Windows 2019/2022 server virtual machine with the following features.

(i) Ten (10) Windows User CALS (license not in scope)

(ii) Main applications

- Solar winds Orion platform server - existing
- Network performance monitor (SL2000)-existing
- Server and applications monitor (AL300)-existing.
- Virtualisation monitor (VMS32)-new
- Log analyser (LA250)-new
- All other monitoring applications

4.3.6.3.3 VMware vSphere Host virtualisation software to be used.

(a) vSphere essential plus licenses is existing for virtualisation of existing servers.

(b) Contractor shall supply one (1) VMware vSphere essential plus kit with perpetual licenses for virtualisation of the new servers.

4.3.6.4 DMZ Storage host servers (RCC/BCC DMZ Clusters)

4.3.6.4.1 There shall be network attached storage servers in each DMZ cluster.

(a) One NAS servers in each cluster. Both servers are existing.

(b) Storage backup solution to be supplied or upgraded to suit the revised architecture.

4.3.6.4.2 Contractor shall provision data stores (NFS or other) for the servers running in the DMZ cluster. All the VM's in the DMZ shall run from the storage servers.

4.3.6.4.3 Contractor shall configure and modify all the NAS in Kamburu and Gitaru to create storage clusters meeting functional and architectural requirements in this tender.

4.3.6.5 Workstations

4.3.6.5.1 Workstation terminals shall consist of two thin clients and two display units for 27" screens. Thin clients shall establish remote desktop sessions with the process, monitoring, or configuration servers.

4.3.6.5.2 Operator workstations shall be connected to the SCADA remote clients' servers as follows.

(a) Five workstation terminals in Kamburu. One workstation thin client shall be connected to Kamburu servers and the other to Gitaru servers. One terminal shall have one large display.

(b) Five workstation terminals in Hydro Plaza. One workstation thin client shall be connected to Kamburu servers and the other to Gitaru servers. One terminal shall have one large display.

4.3.6.5.3 Operator workstations shall be connected to the SCADA web servers as follows.

(a) Two workstation terminals in Hydro Plaza. One workstation thin client shall be connected to Kamburu servers and the other to Gitaru servers. Each terminal shall have one large display. To be used for monitoring only

(b) Three workstation terminals in Stima Plaza. One workstation thin client shall be connected to Kamburu servers and the other to Gitaru servers. Each terminal shall have one large display. To be used for monitoring only.

4.3.6.5.4 Management workstations shall be connected to the configuration servers as

follows.

(a) One workstation terminal in Kamburu and Hydro Plaza shall be connected to the four configuration servers in Gitaru and Kamburu server clusters with switching between servers done manually by the administrators and engineers.

4.3.6.5.5 Management workstations shall be connected to the monitoring servers as follows.

(a) One workstation terminal with one large display in Stima Plaza

(b) One workstation terminal with one large display in Hydro Plaza

4.3.6.5.6 Contractor shall configure workstations for optimum remote desktop performance. Appropriate configurations shall also be carried out for cybersecurity purposes including but limited to:

(a) Blocking unused USB ports and usage of USB storage devices

(b) Blocking all ports on the thin client and on the RDP instance at the server except those required for the specific function the workstation terminal is to perform.

(c) Update server and allowed automatic updates.

(d) Blocking all connections from thin client except to the RDP server

(e) All other required settings as per cyber security requirements

4.3.7 Data Storage and Back up Architecture

4.3.7.1 Contractor shall configure connection of all the DMZ server virtual machines and applications to the NAS servers.

4.3.7.2 The two NAS servers shall be configured for high availability in a failover cluster. Each NAS server shall be mirrored for 100% data redundancy.

4.3.7.3 Contractor shall develop a storage architecture to ensure each NAS server data is mirrored for every virtualisation cluster in Kamburu and Gitaru.

4.3.7.4 Operations server clusters without NAS shall also be configured for data storage high availability and mirroring using the internal SSDs in both production hosts in each cluster.

4.3.7.5 Contractor architecture shall ensure low latency 10Gb/s connection between each server in a cluster and the NAS servers and between the two DMZ NAS in Kamburu and

Gitaru.10Gb/s ethernet link shall also be created between the operations servers in each cluster to enable sharing of each host server's storage in high availability configuration.

4.3.7.6 Contractor architecture shall ensure fast host replication between Gitaru and Kamburu storage servers on the DMZ servers.

4.3.7.7 Contractor shall develop a storage and back up architecture to meet the given functional requirements.

4.3.8 Performance Requirements

4.3.8.1 While developing the architecture, the contractor shall ensure a minimum of the following performance requirements are met for the following applications.

Applications (All Clusters)	number of concurrent connections/users	Redundant	Availability, %	Average Response time	Application instances	Average request rate /sec	Storage requests	Memory requirement
SCADA Time series data Historical server	50	Yes	100	<0.05s	1	500	High	Average
SCADA Events Historical server:	10	Yes	100	<0.05s	1	100	High	Average
SCADA web server 1	50	No	99.9	<0.2s	1	100	Low	High
SCADA web server 2	50	No	99.9	<0.2s	1	100	Low	High
Plant information management Visualisation web server	200	Yes	99	<0.2s	1	400	Low	Very High
Plant information management archive server	100	Yes	100	<0.05s	1	250	High	Average
SCADA assets monitoring server	200	No	98	<0.1s	1	TBD	TBD	TBD
SCADA assets monitoring web server (Orion)	20	No	98	<0.2s	1	TBD	TBD	TBD
Security management server	60	No	99	<0.05s	1	TBD	TBD	TBD
SCADA RCC control gateway server	50	Yes	100	<0.02s	1	1000	Average	Average
SCADA RCC control remote client's server 1	10	No	100	<0.02s	10	200	Low	Very High
SCADA RCC control remote client's server 2	10	No	100	<0.02s	10	200	Low	Very High
SCADA CDC control gateway server	20	Yes	100	<0.02s	1	400	Average	Average
SCADA CDC control remote client's server 1	10	No	100	<0.02s	10	200	Low	Very High
SCADA CDC control remote client's server 2	10	No	100	<0.02s	10	200	Low	Very High
Plant information management proxy server	50	Yes	100	<0.02s	1	1000	Low	Average
Operations Database server	10	Yes	100	<0.02s	1	200	High	Average

Applications (All Clusters)	number of concurrent connections/users	Redundant	Availability, %	Average Response time	Application instances	Average request rate /sec	Storage requests	Memory requirement
SCADA assets monitoring server additional polling engine	200	No	98	<0.1s	1	400	TBD	TBD
RCC/BCC Virtualisation server X4	20	No	99.9	TBD	1	TBD	TBD	TBD
Domain controller X4	50	No	99.9	TBD	1	TBD	TBD	TBD
Configuration server X4	5	No	99.9	TBD	5	TBD	TBD	TBD

TBD-to be designed.

4.3.8.2 The average performance given above are just estimates for initial design only. During design stage the performance parameters shall be examined further to arrive at the optimum configuration of the system.

4.3.8.3 The table above also shall assist to highlight the most critical and most intensive applications in the system

4.4 EQUIPMENT SPECIFICATIONS

4.4.1 Host Servers Specifications

4.4.1.1 General requirements

4.4.1.1.1 Servers shall be assembled into the cabinets by the contractor and shall be delivered to site in a completely assembled cabinet. All devices and components required to assemble the servers into the cabinet shall be supplied by the bidder irrespective of whether they are stated in the schedules or not.

4.4.1.1.2 Servers offered shall be complete with all hardware components, accessories, features and devices necessary for a complete functional rack mounted server computer irrespective of whether these features have been specified in these schedules or not.

4.4.1.1.3 The servers supplied will be used by employer to operate industrial control systems.

4.4.1.1.4 The offered servers shall be enterprise grade designed for 24/7 operation at the following environmental conditions:

(i) Temperature: 5 to 35°C (continuous)

(ii) Altitude: ≥ 1000mASL

(iii) Installation location: indoor with natural aeration only

4.4.1.2 Minimum specifications

No.	Feature	Minimum Requirements
1.	Processor type	Intel® Xeon® Gold series or Intel® Xeon® Platinum series *(Bidder to state exact model on offer)*
2.	No of processors & sockets	≥Two (2)
3.	No of cores on each processor	≥Eighteen (18)
4.	No of threads on each processor	≥Thirty-six (36)
5.	Total number of threads and vCPU	≥Seventy-two (72)
6.	Processor Base Frequency	≥ 3.0GHz
7.	Processor L3 Cache	≥ 39MB
8.	Ultra-Path Interconnect links	3@11.2 GT/s
9.	Processor TDP	≤220W
10.	Maximum Memory Speed supported by processor	≥ 3200 MHz
11.	Number of RAM slots	≥ Twenty-four (24)
12.	Installed RAM type	DDR4, RDIMM, ECC
13.	Installed RAM Speed	≥3200MT/s
14.	No of installed RAM modules	≥Eight (8)
15.	Size of each Installed RAM module	≥ 32GB
16.	Total installed RAM	≥ 256GB
17.	Storage drives bay:	≥8 SFF chassis on the front side, for hot swappable drives
18.	RAID & Storage controller	≥12GB/s SAS with mixed HDD & SSD support *(Bidder to state exact controller model and type on offer)*

No.	Feature	Minimum Requirements
19.	Type of installed drives	Hot plug SFF, SAS, 12G, 2.5-inch, mixed use SSD drives
20.	Size of each installed SSD drives:	≥ 960GB
21.	Number of installed SSD drives:	≥ Two (2)
22.	Total SSD storage size	≥ 1.92TB
23.	SSD cell type	SLC or eMLC
24.	SSD minimum endurance rating	≥ 3 DWPD (writes per day) & ≥ 5256 TBW (Terabytes Written) *i.e Five-year guarantee at three drive writes per day*
25.	Optical drive	One (1) DVD+/-RW drive
26.	Network controllers	≥Two (2) quad port 10Gb Base-T Ethernet controller and ≥One (1) four port 1Gb Base-T Ethernet controller *(Bidder to state exact controllers' model and type on offer)*
27.	Total number 10Gb Base-T Ethernet ports (RJ45diod)	≥Eight (8)
28.	Total number 1Gb Base-T Ethernet ports (RJ45)	≥Four (4)
29.	PCIE Expansion slots- PCIe X8, X16	≥ Eight (8)
30.	USB ports	≥ Two (2) rear ports & ≥ Two (2) front ports
31.	USB 3.0 ports	≥ Two (2)
32.	Video ports:	≥ one (1) DVI/DP/VGA rear port and ≥ one (1) 1 VGA/HDMI/DP front port *(The chosen ports MUST be supported by the KVM switch offered. Bidder to state the exact ports on offered server)*
33.	Power supply type	Hot plug, dual redundant power supply (1+1)

No.	Feature	Minimum Requirements
34.	Number of hot plug Power supply units	Two (2)
35.	Power rating of each power supply unit	≥ 1100W
36.	Power input rating	220-240V AC, 50Hz
37.	Power supply Cord	C13 to C14, PDU Style
38.	Mounting:	Rack type
39.	Form factor (fully configured):	1U or 2U
40.	Operating temperature without derating	0 to 35°C continuous
41.	Mounting accessories	Rack rails and cable management arm to be provided
42.	Manufacturer Warranty	3 years parts, and 3 years basic support
43.	Virtualisation software	As detailed in scope of supply and bill of materials
44.	Windows server licenses type	Perpetual Volume licenses only *(OEM or FPP and subscription licenses are not acceptable)*
45.	Windows Server licenses to be supplied	As detailed in scope of supply and bill of materials

4.4.1.3 Product Certifications

4.4.1.3.1 Device must be tested and approved for use in the EU or USA or Canada. Proof of testing and certification MUST be provided.

4.4.1.3.2 Product certification from an EU or USA or Canada reputable firm MUST be provided along with the bid.

4.4.2 Cabinets & Accessories

4.4.2.1 General requirements

4.4.2.1.1 Cabinets and accessories shall meet requirements in clause 2.2,2.5,2.6,2.7,2.8

and 2.9

4.4.2.1.2 A minimum of the networking and power supply accessories detailed in scope of supply shall be supplied and installed into each cabinet.

4.4.2.1.3 Cabinet layout and electrical and structured cabling shall be designed and submitted for approval as detailed in clause.

4.4.2.1.4 Panel power supplies shall be designed and installed as per requirements of clause 6.2

4.4.2.1.5 Control room cabinets except server racks shall meet requirements in clause 3.4.11

4.4.2.2 Server Rack minimum specifications

4.4.2.2.1 Contractor shall supply install and commission IT server cabinets as detailed in the scope of supply.

4.4.2.2.2 In addition to requirements in clause 2.7.2 server racks shall meet the following minimum specifications

No.	Feature	Requirements
1	Overall requirements, wiring and workmanship	As per tender clause 2.7.2
2	Material	Sheet steel, ≥1.5mm
3	Surface treatment	Powder coats At least three coats, ≥90-micron thickness
4	Mounting position of the 482.6 mm (19") level	front and rear
5	Colour	RAL 7035
6	Load capacity	≥15,000 N
7	IK Code	IK08
8	Panel Size	42U
9	Dimensions	Width: 600 mm Height: 2,000 mm Depth: 1000 mm
10	Rack mount size	482.6 mm (19")
	Enclosure components and parts	
12	Enclosure frame with doors and roof plate	lot
13	Sheet steel side panels	Two (2)

No.	Feature	Requirements
14	Sheet steel door at the front, vented (vented surface area approx. 85% perforated), 180° hinges	One (1)
15	Lock front and rear: Comfort handle for profile half-cylinders and security lock each with at least two keys	Two (2)
16	Mounting angles, 482.6 mm (19") with variable depth and width	Four (4)
17	Spacers, height 50 mm, to raise a cover plate above the fan cut-out in the roof plate,	lot
18	482.6 mm (19") fastener, 1 U, conductive	≥12
19	Multi-tooth screws, conductive	≥25
20	IPPC wooden pallet	lot
21	Roof plate, solid multi-piece, with fan cut outs	lot
22	Sheet steel rear door, vented (vented surface area approx. 85% perforated) vertically divided, 180° hinges	lot
23	100mm base plate (plinth)	Lot
24	Cable ducts horizontal 60mm x 80mm and 100mmX80mm, quantity as per design	Lot, as per design
25	Sheet steel horizontal Punched section with mounting flange for device mounting and frame reinforcement	≥6
26	DIN rails	Lot, as per design
27	Sheet steel Side Pieces between 19-inch mounting rail side wall	Two (2)
28	1U sheet steel blanking plates	Lot, as per design
29	Solid sheet steel glanding plate with factory punched cable glanding holes	Two (2)
30	Electrical and other accessories	As per the scope of supply

4.4.3 Rack Console KVM switch

4.4.3.1 General requirements

4.4.3.1.1 Shall consist of an Integrated KVM console with:

(i) integrated retractable 19" LED-backlit LCD monitor.

(ii) 8port KVM switch for connecting to eight computer hosts.

(iii) Illuminated keyboard and touch pad.

(iv) Dual Rail housing

4.4.3.1.2 Physically the console shall consist of four main parts: Keyboard module, LCD monitor, rear KVM switch and Rack mounting devices/accessories.

4.4.3.1.3 The Dual Rail system shall separate the LCD module from keyboard/touchpad module so that they can move independently of each other. This shall allow the keyboard/touchpad to be pushed back into the housing and out of the way when not in use, while the LCD screen can be rotated up to the rack for convenient monitoring of server operation – the LCD module's range of rotation shall be adjustable to provide the best viewing angle.

4.4.3.1.4 Console shall support remote KVM over IP access through Ethernet. It shall have an ethernet port.

4.4.3.1.5 KVM switch shall support multiuser access via IP and locally via a secondary console.

4.4.3.1.6 Console shall be connected to the servers and workstations via KVM adapter cables designed to connect to the host computer USB and video port.

4.4.3.1.7 KVM cable shall consist of space-saving RJ-45 connectors on the console side and Cat 5e/6 cabling. Video connector and USB plug shall be connected to the cat5e/6 cable at the host PC side

4.4.3.1.8 The Console shall a secondary console port to allow access of computers connected to the LCD KVM switch from an external console

4.4.3.1.9 Console keyboard module shall consist of the standard 105 key keyboard, touch pad, KVM port selection buttons &LED', power and other status indication LED's and a front facing USB port Supporting an external USB mouse.

4.4.3.1.10 Dual Rail mounting shall allow LCD monitor to slide independently of the keyboard/touchpad

4.4.3.1.11 LCD module shall rotate up to 120 degrees and tilt for a more comfortable viewing angle

4.4.3.1.12 Keyboard shall have LED illumination light to illuminate the keyboard and touchpad to allow visibility in lowlight conditions.

4.4.3.1.13 Console shall have a port for firmware updates.

4.4.3.1.14 Servers and workstations in each cabinet shall be connected to the console.

4.4.3.1.15 Console shall allow easy computer selection via pushbuttons, Hotkey Mode, OSD (On-screen Display), or Browser-based GUI

4.4.3.1.16 Shall support multiple browsers: Internet Explorer, Chrome, Firefox, Safari, Opera, Mozilla, Netscape etc.

4.4.3.1.17 The KVM console mounting panels, brackets, levers and Switch casing/enclosure shall be made of steel.

4.4.3.1.18 Accessories, features and devices usual and necessary for a server cabinet rack mounted KVM console and switch shall be supplied and installed by the contractor irrespective of whether they have been specified or not.

4.4.3.1.19 Contractor shall connect the servers and the workstation computer on each cabinet to the KVM console. Accessories and devices required to do all the connections shall be supplied.

4.4.3.1.20 The offered KVM console shall be enterprise grade designed for 24/7 operation at the following environmental conditions:

(i) Temperature: 5 to 35°C (continuous)

(ii) Altitude: ≥ 1000mASL

(iii) Installation location: indoor with natural aeration only

4.4.3.2 Minimum specifications

KVM console shall meet the following minimum specifications.

No	Feature	Requirements
1	Secondary Console Ports	≥Two (2) USB ≥One (1) video (DVI/VGA/DP/HDMI)
2	External USB Mouse Ports	≥one (1)
3	Number of KVM Ports (RJ-45 Female)	≥Eight (8)
4	LAN Ethernet Ports (RJ45)	≥one (1)
5	Port selection Push buttons	≥Eight (8)
6	Port online status LEDs	≥Eight (8)
7	Port selected status LEDs	≥Eight (8)
8	Ethernet status LED	Two (2)
9	Console power status LED	one (1)
10	LCD power status LED	one (1)
11	KVM cable console connector	one (1) RJ45 male
12	KVM cable type	Cat5e/6/7
13	KVM cable length	≥2m

No	Feature	Requirements
14	KVM host adapter cable connectors	• Two (2) USB and • One (1) video (DVI/DP) *Video connector to be compatible with the server & workstation video ports*
15	KVM cables to be supplied for each Console unit	≥Eight (8) *(Unutilised cables to be provided as spares)*
16	LCD Monitor Panel size	19.0 inch
17	LCD Monitor Maximum resolution	≥ 1280 x 1024@75Hz
18	LCD Monitor brightness	≥250cd/m2
19	LCD Monitor Contrast ratio	≥1000:1
20	LCD Monitor Viewing angle	≥170°(V) /160°(H)
21	LCD Monitor Display colours	≥16. 7 M (True 8bit)
22	Power supply	Internal 220-240V AC, 50Hz power supply unit.
23	Power supply Cord	C13 to C14, PDU style
24	Operating temperature without derating	0 to 40°C continuous
25	Enclosure & support brackets	Robust steel construction.
26	Mounting type	1U rack
27	Mounting accessories	Rack slide rails to be provided
28	Manufacturer warranty	≥three (3) years

4.4.3.3 Product Certifications

4.4.3.3.1 Device must be tested and approved for use in the EU or USA or Canada. Proof of testing and certification MUST be provided

4.4.3.3.2 Product certification from an EU or USA or Canada reputable firm MUST be provided along with the bid.

4.4.4 Thin Client PC

4.4.4.1 General requirements

4.4.4.1.1 Thin client PC shall be **fan-less** light duty 64-bit PC to be used primarily for

remote access of virtual machines in the servers via RDP

4.4.4.1.2 Thin client PC's offered shall be complete with all hardware components, accessories, features and devices necessary for a complete thin client PC dedicated to virtual machines access irrespective of whether these features have been specified in these schedules or not.

4.4.4.1.3 The thin clients supplied will be used by procuring entity to interface operators to the SCADA client application. They shall be the primary interface to all SCADA operations by the operator. All features necessary for reliable and robust operator workstation for industrial control shall be provided

4.4.4.1.4 The offered thin client PC shall be enterprise grade designed for 24/7 operation at the following environmental conditions:

(i) Temperature: 5 to 35°C (continuous)

(ii) Altitude: ≥ 1000mASL

(iii) Installation location: indoor with natural aeration only

4.4.4.2 Minimum specifications

Thin client PC's shall meet a minimum of the following specifications

No.	Feature	Requirements
1	Processor cores/Threads	≥ Two (2)/Four (4)
2	Processor Base Frequency	≥ 2.4GHz
3	Processor Cache	≥ 4MB
4	Processor TDP	≤25W
5	Operating system	OEM Windows 10 IoT Enterprise LTSC
6	RAM type	≥DDR4-2400
7	Size of Installed RAM	≥ 8GB
8	Type of secondary storage	eMLC, NAND flash memory
9	Size of secondary storage	≥ 64GB
10	Flash memory Endurance	≥100 TBW (Terabytes written)
11	Graphics Memory size	≥1024 MiB *(Separate or in RAM)*
12	GPU clock	≥1000MHz
13	Video ports:	≥ Two (2) DVI/DP/HDMI ports.
14	Maximum video resolution supported on each video port	≥3840 x 2160 @ 60 Hz
15	Supported Display outputs	≥ Two (2) @ 3840 x 2160 resolution *(Minimum of dual display output)*

No.	Feature	Requirements
16	Gigabit Ethernet ports (RJ45)	≥One (1)
17	USB ports	≥ Two (2) rear ports & ≥ Four (4) front ports
18	USB 3.0 ports	≥ Two (2)
19	Audio	Internal amplified speaker system
20	Audio ports	standard 3.5mm line in and line out ports
21	Type of Power supply units	External
26	Power rating of power supply unit	≥ 65W
27	Power input rating	220-240V AC, 50Hz
28	Power supply Cord	C13/C14 to BS1363(IEC type G-British type) plug or C13 to C14 for panel mount applications
29	Mounting	Desktop or panel mount
36	Device Cooling	Natural, heat sink or solid state **fan less**
37	Continuous operating ambient temperature	10° C to +35°C
38	Operating Relative Humidity (non-condensing)	10 to 85%
39	Operating altitude without derating	≥1000 m
30	Supported remote desktop protocols	(i) Microsoft: Remote FX (RFX), RDP (ii) VMware®: RDP, PCoIP
31	Preinstalled Software applications	(i) Microsoft Remote Desktop Client (ii) VMware™ Horizon View™ Client (iii) Microsoft firewall (iv) Windows defender (v) Internet Explorer
32	Manufacturer Warranty	≥3 years

4.4.4.3 Product Certifications

4.4.4.3.1 Device must be tested and approved for use in the EU or USA or Canada. Proof of testing and certification MUST be provided.

4.4.4.3.2 Product certification from an EU or USA or Canada reputable firm MUST be provided along with the bid.

4.4.5 27.0 Inch LED backlit LCD monitor

4.4.5.1 General Requirements

4.4.5.1.1 Shall be connected to the thin client PC's via the KVM switch

4.4.5.1.2 Two displays shall be placed at each operator desk

4.4.5.1.3 At minimum each LCD monitors shall have three Video inputs an audio output and an audio input

4.4.5.1.4 The monitors shall be LED backlight LCD type or OLED type

4.4.5.1.5 Shall have ergonomic design for long period usage without eye strain

4.4.5.1.6 Shall be supplied complete with all accessories, features and devices required for operation and configuration of a computer monitor, connection to the KVM switches and power outlets and mounting/positioning brackets and accessories irrespective of whether these components are stated in these schedules or not.

4.4.5.1.7 The offered LCD monitor shall be enterprise grade designed for 24/7 operation at the following environmental conditions:

(i) Temperature: 0 to 35°C (continuous)

(ii) Altitude: ≥ 1000mASL

(iii) Installation location: indoor with natural aeration only

4.4.5.2 Minimum Specifications

Shall meet the following.

No	Feature	Requirements
1	Panel size	≥ 27.0 inch (68.5 cm)
2	Native resolution	≥ 3840 x 2160 @ 60 Hz
3	brightness	≥350cd/m^2
4	Contrast ratio	≥1000:1
5	Viewing angle	≥170°(V) /160°(H)
6	Display colours	≥16. 7 M (True 8bit)
7	Number of Video input ports	≥ Three (3)
8	Type of Video input ports	HDMI DP DVI Shall have at least one of each type
9	Audio Speakers	≥2W x 2 stereo
10	Audio inputs and outputs	One 3.5mm audio in and one 3.5mm audio out
11	Display tilt	-5° ~ +20°

No	Feature	Requirements
12	Swivel (angle)	+60° ~ -60°
13	Pivot (angle/direction)	90 ° (clockwise)
14	Height adjustment	0-120mm
15	Power supply	Internal 220-240V AC, 50Hz power supply unit.
16	Power supply Cord	C13/C14 to BS1363(IEC type G-British type) plug
17	Operating temperature	0 to 40°C continuous
18	Base and support brackets	Robust steel construction.
19	Manufacturer warranty	Three (3) years

4.4.5.3 Product Certifications

4.4.5.3.1 Device must be tested and approved for use in the EU or USA or Canada. Proof of testing and certification MUST be provided.

4.4.5.3.2 Product certification from an EU or USA or Canada reputable firm MUST be provided along with the bid.

4.4.6 75.0 Inch LED / IPS backlit Display

4.4.6.1 General Requirements

4.4.6.1.1 The device shall be connected to the thin client PCs via the KVM switch.

4.4.6.1.2 The device shall support Ultra High Definition (UHD)

4.4.6.1.3 The device shall support High Efficiency Video Coding HEVC which efficiently compresses / decompresses high-capacity UHD content, playing ultra-high-quality videos with half the network traffic of the existing H.264 codec.

4.4.6.1.4 The device shall support connections with external sensors via USB plug-in.

4.4.6.1.5 The device shall support high compatibility with professional AV controls to achieve seamless integration and network-based control.

4.4.6.1.6 The device shall support remote control and monitoring to enable monitoring the status of multiple displays in different locations in real-time.

4.4.6.1.7 The device Shall be supplied complete with all accessories, features and devices required for operation and configuration of a computer monitor, connection to the KVM switches and power outlets and mounting/positioning brackets and accessories irrespective of whether these components are stated in these schedules or not.

4.4.6.1.8 The offered device shall be enterprise grade designed for 24/7 operation with

guaranteed 5 years continuous operation at the following environmental conditions:

(i) Temperature: 0 to 35°C (continuous)

(ii) Altitude: ≥ 1000mASL

(iii) Installation location: indoor with natural aeration only

4.4.6.2 Minimum Specifications

The device shall meet the following.

No	Feature	Requirements
1	Screen Size	≥ 75"
2	Panel Technology	IPS
3	Back Light Type	Direct
4	Aspect Ratio	16:9
5	Native Resolution	≥ 3840 x 2160 (UHD)
6	Refresh Rate	50 Hz
7	Brightness	≥ 400 nits
8	Contrast Ratio	1,200:1
9	Dynamic CR	1,000,000:1
10	Color gamut DCI	≥ 80%
11	Viewing Angle (H x V)	178° x 178°
12	Color Depth	≥ 1.07 Billon colors (8 bit + FRC)
13	Response Time (Gray to Gray)	≤ 8 ms
14	Surface Treatment (Haze)	≤ 1%
15	Lifetime (Min)	≥ 50,000 Hrs
16	Operation Hours	(Hours/Day) 24/7
17	Portrait / Landscape	Portrait & Landscape
18	HDMI/DP interfaces	Yes (3), HDCP 2.2/1.4
19	External Control RS232C IN / OUT	≥ 1 ≥ 1 (4-pin RJ11)
20	External Control RJ45(LAN)	≥ 1
21	USB	≥ USB2.0 Type A (2)
22	Audio Out	≥ 1
23	Built-in Speaker	≥ 1
24	Internal Memory	≥ 8GB
25	Wi-Fi Built-in	Yes
26	Temperature Sensor	Yes

No	Feature	Requirements
27	Auto Brightness sensor	Yes
28	Local Key Operation	Yes (Power On/Off only)
29	USB Plug & Play	≥ 1
30	Content Share	Yes
31	Video inputs	≥ 4, with at least two (2) DP ports and two (2) HDMI ports
32	Play via URL	Yes
33	Screen Rotation	Yes
34	External Input Rotation	Yes
35	Gapless Playback	Yes
36	Setting Data Cloning	Yes
37	SNMP	Yes
38	ISM Method	Yes
39	3rd Party Compatibility	Yes
40	Smart Energy Saving	Yes
41	Operation Temperature	0°C to 40°C
42	Operation Humidity	10% to 80%
43	Power Supply	240 Vac, 50Hz
44	Power Type Built-In Power	Typ. 130W Max. 185W
45	BTU (British Thermal Unit)	≤ 819BTU/Hr
46	FCC (EMC) Certification	Class A
47	ErP(Environmental) Certification	Yes
48	Accessories	Remote Control (Battery 2ea) Power Cord, Regulation Book Phone to D-Sub9 Gender Stand Cable Holder
49	Manufacturer warranty	Three (3) years

4.4.6.3 Wireless presentation system

4.4.6.3.1 Each 75" large display shall be supplied with a wireless presentation device.

4.4.6.3.2 The device shall support wireless connection to the 75-inch displays.

4.4.6.3.3 The device shall support up to 2 users on-screen.

4.4.6.3.4 The device shall connect devices such as thin clients, laptop, tablet, smartphone

etc to the large display wirelessly.

4.4.6.3.5 The device shall have enhanced security features.

4.4.6.3.6 The device shall have touch back support.

4.4.6.3.7 The device shall support central management.

No	Feature	Requirements
1	Operating system Windows (supported)	• 7/8/8.1/10/11 32 & 64 bit • macOS 10.14/10.15 • Android 9 & 10 • iOS 11, 12 & 13
2	Video outputs	≥1 HDMI 1.2
3	Output resolution	1920x1080 @60Hz
4	Audio Via	• HDMI • Analog via Audio Jack 3.5mm • S/PDIF
5	Frame rate	≤ 30fps
6	Number of sources simultaneous on screen	2
7	Number of simultaneous connections	16
8	Authentication protocol	WPA2-PSK in stand-alone mode
9	Wireless transmission protocol	IEEE 802.11 a/g/n
10	Reach	≥ 30m (100 ft) in between devices
11	Frequency band	• 2.4 GHZ • 5 GHz
12	Connections	≥1 Ethernet LAN 100Mbit ≥3 USB ≥1 Audio analog line out on mini jack socket (3.5mm) ≥1 digital S/PDIF
13	Noise Level	Fan less
14	Anti-theft system	Kensington lock
15	Certifications	FCC/CE
16	Power supply Standard	220VAC plug
17	Operating temperature	0 to 40°C continuous

No	Feature	Requirements
18	Humidity Storage	0 to 90% relative humidity, non-condensing
19	Manufacturer warranty	Three (3) years (Possible to extend to 5 years)

4.4.6.4 Product Certifications

4.4.6.4.1 Device must be tested and approved for use in the EU or USA or Canada. Proof of testing and certification MUST be provided.

4.4.6.4.2 Product certification from an EU or USA or Canada reputable firm MUST be provided along with the bid.

4.4.7 Dual display KVM switch

4.4.7.1 General Requirements

4.4.7.1.1 The device shall be connected to the two thin client PC video &USB outputs and its outputs connected to the KVM extender transmitter.

4.4.7.1.2 The device shall have a minimum of four Video inputs and two video outputs. Four USB outputs and two USB inputs.

4.4.7.1.3 The KVM switch will be positioned at the operator desk.

4.4.7.1.4 The KVM switch video inputs MUST be compatible with the thin client PC display outputs.

4.4.7.1.5 The KVM switch shall support touch input from two touch Monitors to the connected devices in a similar fashion to the keyboard.

4.4.7.1.6 Each KVM switch shall contain a console port for configuration and management. If software is required for configuration of the switch, it MUST be provided.

4.4.7.1.7 KVM switches shall be supplied complete with all accessories, features and devices required for connection of dual display monitors, keyboard & mouse to two dual display output from thin client PC's irrespective of whether these components are stated in these specifications or not.

4.4.7.1.8 The offered KVM switches shall be enterprise grade designed for 24/7 operation at the following environmental conditions:

(i) Temperature: 0 to 35°C (continuous)

(ii) Altitude: ≥ 1000mASL

(iii) Installation location: indoor with natural aeration only

4.4.7.2 Minimum specifications

The device shall meet the following.

No	Feature	Minimum Requirements
1	Number of host computer input connections	≥ Two (2)
2	Number of video inputs	≥ Four (4) *(two dual display inputs)*
3	Number of displays supported	≥ Two (2) *(dual display support)*
4	Maximum video resolution supported	≥3840 x 2160 @60Hz
5	Type of display ports supported by the switch.	DVI or DP or HDMI *(The type of video input and output ports MUST be compatible with the thin client's video outputs, bidder to specify ports on offer)*
6	Number USB input ports	≥ two (2), one per PC input.
7	Number of USB console ports on the KVM switch for connection of keyboard, mouse and other peripherals	≥ Four (4)
8	USB type supported	USB 2.0 & USB 1.1 must be supported
9	Output (console) Audio terminals	Two (2) 3.5mm audio in out jack ports
10	Input (host) Audio terminals	Four (4) 3.5mm audio in and out jack ports
11	Port selection	Hotkey, Pushbutton
12	LEDs input online /Selected	Two (2) one for each host with colour status
13	Power supply	220-240V AC, 50Hz internal or external power supply unit.
14	Power supply Cord	C13/C14 to BS1363(IEC type G-British type) plug
15	Operating temperature	0 to 40°C continuous
16	Casing/Enclosure	Robust steel construction.
17	Mounting	Desktop
18	Manufacturer warranty	Three (3) years

4.4.7.3 Product Certifications

4.4.7.3.1 Device must be tested and approved for use in the EU or USA or Canada. Proof of testing and certification MUST be provided

4.4.7.3.2 Product certification from an EU or USA or Canada reputable firm MUST be

4.4.8 Other Operator workstation Accessories

The following accessories shall be supplies for each operator workstation

4.4.8.1 Rugged, heavy-duty keyboard with the following features

(a) 104 keys full windows keyboard US international format
(b) LED Backlit Keys
(c) watertight sealed, washable, and dustproof
(d) Ergonomic palm rest
(e) 2m USB cable connection

4.4.8.1.2 Rugged, heavy-duty Optical mouse with the following features

(a) compact, ergonomic, lightweight, fully sealed mouse with 3-button scroll that is washable and waterproof. Resistant to dirt, debris, water, soap and other disinfectants.
(b) Waterproof and Dustproof IP67
(c) 2m USB cable connection

4.4.8.2 Extension socket strip with the following features

(a) Rated for 16A current and 240V AC
(b) LED lit switch
(c) At least Four universal socket outlets
(d) Cord wires to be at least 1mm2
(e) Heavy duty enclosure

4.4.9 Server Cabinet Enterprise Grade Ethernet Switch

4.4.9.1 General requirements

4.4.9.1.1 Switch shall be assembled into the cabinets by the bidder and shall be delivered to site in a completely assembled cabinet. All devices and components required to assemble the ethernet switch into the cabinet shall be supplied by the bidder irrespective of whether they are stated in the schedules or not.

4.4.9.1.2 Two (2) Cisco C9300-24UX-A ethernet switches or equivalent ethernet switches meeting the following requirements shall be supplied, installed into the Gitaru operations cabinet, configured and tested by the contractor.

4.4.9.1.3 Switches offered shall be complete with all hardware components, accessories, features and devices necessary for a complete functional rack mounted switch irrespective of whether these features have been specified in these schedules or

not.

4.4.9.1.4 The Switches supplied will be used by employer to operate industrial control systems.

4.4.9.1.5 The offered switches shall be enterprise grade designed for 24/7 operation at the following environmental conditions:

(i) Temperature: 5 to 35°C (continuous)

(ii) Altitude: ≥ 1000mASL

(iii) Installation location: indoor with natural aeration only.

4.4.9.2 Minimum Specifications

No	Feature	Minimum Requirements
1.	Model & Type	Cisco Catalyst C9300-24UX-A or an equivalent from Cisco
2.	Device Type	Switch - 32 ports - L3 - managed - stackable
3.	Subtype	Multi Gigabit Ethernet
4.	Copper Ports	Twenty-four (24), 10G /5G /2.5G /1G /100M UPOE Modular Uplinks
5.	SFP ports	Eight (8) 10G SFP+
6.	Switching capacity	≥640 Gbps
7.	L3 Forwarding Rate (64-byte packets)	≥476.19 Mpps
8.	Total number of MAC Addresses	≥32,000
9.	Number of VLAN IDs	4094
10.	Total number of IPv4 routes (ARP Plus learned routes)	≥32,000
11.	Cisco License	Network Advantage
12.	IPv6 routing entries	≥16,000
13.	Multicast routing scale	≥8,000
14.	QoS Scale entries	≥5,120
15.	ACL Scale entries	≥5,120
16.	Packet Buffer per SKU	≥32 MB

No	Feature	Minimum Requirements
17.	Net Flow entries capacity	≥128,000
18.	DRAM	≥8 GB
19.	Flash	≥16 GB
20.	Total Switched Virtual Interfaces (SVIs)	≥1000
21.	Form factor:	1 rack unit (RU)
22.	Power Over Ethernet	UPOE
23.	Jumbo frame Support	9198 bytes
24.	Authentication Method	Kerberos, RADIUS, Secure Shell (SSH), TACACS+
25.	Stackable	Yes
26.	Advanced Switching	Layer 3
27.	Features and protocols that shall be supported	802.1x authentication, ARP inspection, Dynamic Trunking Protocol (DTP) support, Energy Efficient Ethernet, Link Aggregation Control Protocol (LACP), Multiple Spanning Tree Protocol (MSTP) support, PIM snooping, Port Aggregation Protocol (PAgP) support, Quality of Service (QoS), Rapid Per-VLAN Spanning Tree Plus (PVRST+), Remote Switch Port Analyzer (RSPAN), SSH support, ARP support, Shaped Round Robin (SRR), Syslog support, Trivial File Transfer Protocol (TFTP) support, Uni-Directional Link Detection (UDLD), VLAN Trunking Protocol (VTP), Virtual Route Forwarding-Lite (VRF-Lite), Virtual Routing and Forwarding (VRF), Weighted Tail Drop (WTD), radio resource management (RRM), Access Control List (ACL) support, Bridge protocol data unit (BPDU), Cisco Stack Power technology, Cisco StackWise-480 technology, Control plane protection (CoPP), DHCP snooping, DHCP support *(Bidder to state compliance to these requirements and indicate any deviation)*
28.	Manageable	Yes

No	Feature	Minimum Requirements
29.	Routing Protocol	EIGRP, RIP-1, RIP-2, RIPng
30.	Remote Management Protocol	CLI, RMON 1, RMON 2, SNMP 1, SNMP v2c, SNMP v3, SSH, TFTP
31.	Power supply configuration	Dual redundant power supply (1+1)
32.	Number of Installed Power supply units	Two (2)
33.	Power supply voltage and type	220-240V AC, 50Hz
34.	Power supply units rating (both)	≥1100W AC
35.	Power supply Cord	C13 to C14, PDU style
36.	EMI and EMC Compliance	CISPR 22 Class A, CISPR 24, EN 61000-3-2, NOM, EN 61000-3-3, EN55024, EN50082-1, EN 61000-6-1, EN 61000-4-4, EN 61000-4-2, EN 61000-4-3, EN 61000-4-6, CCC, ICES-003 Class A, EN 61000-4-5, FCC CFR47 Part 15, UL 60950-1, IEC 60950-1, EN 60950-1, UL 60950-1 Second Edition, KCC, RoHS, FCC Part 15 A, AS/NZS 3548 Class A, BSMI Class A, CAN/CSA C22.2 No. 60950-1, EN 60950-1 Second Edition, IEC 60950-1 Second Edition, VCCI Class A, KN24, KN22 Class A, EN 300386, AS/NZS CISPR 22, CNS 13438, EN 55022 Class A
37.	Mounting accessories	Rack slide rails to be provided
38.	Manufacturer warranty terms & Pre-installed Licences	• SMARTnet licence • 3-year hardware warranty-replacement &SLA • Cisco software access • Cisco 24/7 online support

4.4.9.3 Product Certifications

4.4.9.3.1 Device must be tested and approved for use in the EU or USA or Canada. Proof of testing and certification MUST be provided.

4.4.9.3.2 Product certification from an EU or USA or Canada reputable firm MUST be

provided along with the bid.

4.5 INSPECTION AND TESTING

All components and panel/cabinet assemblies shall be tested in accordance with the relevant IEC and IEEE Standards to verify compliance with the requirements of the Standards and this specification.

4.5.1 Type Test

4.2.2.3.12 Type test Reports/certificate Requirements

(a) Type tests shall be certified by an EU/USA/Canadian National Standards and Testing Authority (NSTA) or by a third-party Reputable Testing Authority accredited by an EU/USA/Canadian National Standards and Testing Authority (NSTA).

(b) Where a body other than NSTA stated above is used to certify the type-test reports, a copy of the certificate of accreditation shall be attached.

(c) Results of type test shall have been conducted at least 6 months and not more than fifteen years prior to the date of tender submission. The contractor shall submit contact details (Title, email, and fax) of certifying laboratory during design.

(d) Testing materials and equipment in Type Test Reports shall have the same code/ country / manufacturer and technical parameters as offered materials and equipment. Type tests of non-conforming materials/equipment shall not be accepted.

(e) Type Test Reports shall include all items tested and results confirming that they meet the requirements of applied standards as stipulated in Tender Documents.

(f) Type Test reports shall have Report Numbers for authentication.

(g) Current contact information of the testing and certification authority shall be provided during design

4.2.2.3.13 Product certifications approved through testing by from the following bodies will be accepted: UL, CE, FCC, RoHS, TUV GS where stated

4.2.2.3.14 Type test reports and product certificates shall be provided during design or at bidding stage in accordance as detailed in the tender.

4.5.2 Factory Acceptance Tests

4.2.2.3.15 The procuring entity personnel shall witness the factory tests in person.

4.2.2.3.16 All equipment in scope of supply shall be subject to testing and inspection prior to delivery to site

4.2.2.3.17 Contractor shall prepare a test plan as per detailed in clause 1.9 for approval as detailed in clause 1.7

4.5.3 General Equipment Tests

4.2.2.3.18 These tests shall be carried out on all equipment in scope of supply

4.2.2.3.19 Visual Checks: General Check of the panels/cabinets in respect of dimension, finishing, construction, wiring & ferules verification lay out equipment on the panel, make and rating of instrument etc.

4.2.2.3.20 Operational tests: Operation tests on all equipment to prove correctness of wiring of various circuits as per the approved design

4.2.2.3.21 Setting range and Functional tests

4.2.2.3.22 Power on checks

4.2.2.3.23 Insulation/dielectric tests

4.2.2.3.24 Network/communication checks

4.2.2.3.25 For moving parts e.g., slide rails, a minimum of ten consecutive mechanical operations shall be carried out in quick succession to confirm the healthiness of the cubicle assembly

4.5.4 Specific Equipment Tests

4.2.2.3.26 All routine tests as per specified standard shall be carried out in the factory or site

4.2.2.3.27 During design the contractor shall prepare a detailed test plan for factory tests and site tests for approval as detailed in clause 1.7

4.2.2.3.28 Functional testing shall be carried out for all components and systems to verify that the system meets requirements.

4.5.5 Functional & Performance Tests

4.2.2.3.29 Functional tests shall be carried out to confirm the whole system meets the given requirement.

4.2.2.3.30 Testing shall be carried out to ensure all the systems meets performance requirements as detailed in the performance requirements.

4.2.2.3.31 Applications developed under this contract shall be tested to ensure all specified requirements have been met. Software functional testing shall be carried as per ISO/IEC/IEEE 29119. Procedure shall be developed

4.2.2.3.32 Contractor shall prepare a detailed test plan for approval incorporating all tests to be carried

5 PARTICULAR TECHNICAL SPECIFICATIONS - UNDERGROUND FIBRE OPTIC CABLE WORKS

5.1 GENERAL REQUIREMENTS

5.1.1.1.1 The contractor shall supply all necessary materials, install, test and commission a 48 core Optical Fiber-based network comprising appropriate passive devices and establish a Network connection between Gitaru Power Station, T-off Gitaru Central Office, T-off Matendeni Radio Room, to Kamburu, from Hydro Plaza to Matendeni Radio Room, and from Kamburu to KPLC 220kv substation.

5.1.1.1.2 The distance is approximately 15kms, however, the actual distance shall be confirmed by the bidders during the mandatory site visit.

5.1.2 Scope of Works.

5.1.2.1.1 The Fibre Optic cable shall be installed at a depth of not less than 1 meter, and at any road crossing, the cable shall be installed within a suitable size of Galvanized Iron (GI) pipes installed in micro tunnels across the area covered by the road and its shoulders.

5.1.2.1.2 For additional mechanical protection, the cable shall be installed inside a suitable HDPE conduit, and the path shall be marked with well secured and engraved "FOC" slabs at intervals of 30 meters. Two parallel conduits shall run along the full fibre optic path. A suitable warning tape shall be installed 300mm above the HDPE conduit to serve as an early warning in the event of excavation works along the cable path.

5.1.2.1.3 Secured manholes shall be constructed to house interconnection points and slacks of the optical fibre cables at appropriate intervals as per design and at the road crossings. Prefabricated manholes-measuring 1200mm wide, 1200mm long, and 1200mm deep shall be constructed to provide adequate mechanical and environmental protection of the interconnection points. The joints shall be housed in a standard waterproof hardened PVC fibre enclosure to provide additional mechanical protection of the joints.

5.1.2.1.4 The contractor shall supply suitable Optical Fiber patch panels to be mounted on the existing LAN cabinets at Gitaru Power station, Gitaru Central Office, Matendeni Radio Room, Kamburu Power Station, KPLC 220kV SS and Hydro Plaza as detailed in the scope of supply.

5.1.2.1.5 The contractor shall provide accurate test reports for the links, reference documents for the various equipment, and as-built documents for the network

infrastructure and route design & maps.

5.1.2.1.6 The optic fibre cable shall be installed in a cemented "GI" pipe at the waterways. Gabions shall be built to enhance the protection of the fibre cable at the waterways.

5.1.2.1.7 The fibre optical cable shall be inspected and tested after the installation to ensure the link can support 25G transmission speeds across the link.

Maximum acceptable loss			
Wavelength	Fiber Attenuation per KM	Connector Loss	Splice Loss
1310nm	<0.4dB	<0.75dB	<0.1db
1550nm	<0.3dB	<0.75dB	<0.1dB

These values are as per TIA/EIA and other industry specifications.

5.1.2.1.8 The contractor shall provide a comprehensive warranty for all components of the link for one year from the date of issuance of the completion certificate by KenGen, upon completion of all works.

5.2 SURVEY AND DESIGN

5.2.1 General Requirements

5.2.1.1 The contractor shall develop route designs and network designs that will be approved by the procuring entity as detailed in clause 1.7

5.2.1.2 The approved route and network designs will be used for implementation.

5.2.1.3 A concept design is presented in the specification drawings for guidance purpose only during the bidding process.

5.2.1.4 The following are design features and services of the network that bidders shall consider:

5.2.1.4.1 Architecture shall be based on best industry practice and international fibre installation standards; the underground cable shall run at the given route within employer's land/premises.

5.2.1.4.2 The proposed design shall integrate to the existing KenGen network as per the requirements given under network and communication particular requirements.

5.2.2 Route Design

5.2.2.1 The contractor shall provide a detailed route design based on actual survey on the ground.

5.2.2.2 The design will be based on the current road design and will layer other utilities (Water, Sewer, and power)

5.2.2.3 The route design shall be detailed and shall include all the fibre accessories such as manholes, road markers, joints, crossings, gabions, concrete envelope, screen bags, bridge attachments, soil treatment area, landmarks etc with GPS coordinates with accuracy of 2meters or better.

5.2.2.4 Design will be submitted in KMZ, AUTOCAD, ARCGIS and PDF formats.

5.2.2.5 Route design coordinates shall be accurate to 2meters.

5.2.3 As-Built Documents.

5.2.3.1 The contractor shall update the drawing onsite as per actual implementation, marking the underground objects and the new route line in the drawing by red colour and shall include all other network components e.g., Splicing boxes, Manholes, ODF etc.

5.2.3.2 All the GPS information for manhole/handhole, road/bridge/river crossing, OFC route bending, etc. should be kept with accuracy of 1meter.

5.2.3.3 As built documents in KMZ, AUTOCAD, ARCGIS and PDF formats shall be submitted to the procuring entity as detailed in clause 1.7

5.3 EQUIPMENT SPECIFICATIONS

5.3.1 Fibre Optical Cable

5.3.1.1 General Requirements

5.3.1.1.1 The underground 96 Core cable will be Single Mode, compliant with ITU-T R G.652.

5.3.1.1.2 The contractor shall supply all necessary materials, install, test and commission a 96 core Optical fibre-based network comprising appropriate passive devices and establish a Network connection between Gitaru Power Station, T-off Gitaru Central Office, T-off Matendeni Radio Room, to Kamburu and from Hydro Plaza to Matendeni Radio Room.

5.3.1.1.3 Mandatory site visit will be done to confirm the distance; however, we approximate it to be about 15kms.

5.3.1.1.4 The contractor shall supply suitable Optical Distribution Frame patch panels to be mounted on the existing LAN cabinets at Gitaru Power station, Gitaru Central Office, Matendeni Radio Room, Kamburu Power Station and Hydro Plaza.

5.3.1.1.5 The fibre optical cable shall be inspected and tested after the installation to ensure 25G transmission speeds across the link.

5.3.1.2 Minimum specifications

NO	Feature	Minimum Requirement
1.	Number of cores	≥96
2.	Cable type	Single mode (OS 2)
3.	Transmission Speeds	25 Gbps across one pair without multiplexing
4.	UV protection	UV resistant jacket
5.	Operating Temperature	Outstanding loss consistency across a wide range of temperatures.
6.	Rodent protection	Rodent protection by a suitably treated jacket.
7.	Water protection	Gel filled loose tubes to protect against water penetration. Dry, super absorbent polymers (SAPs) Eliminate water migration in cable interstices.
8.	Fire and smoke resistance	Flame retardant jacket, low smoke zero halogen
9.	Bending	Cable shall withstand repeated wrapping and unwrapping without damage or attenuation change
10.	Installation	Underground installation
11.	Attenuation	≤0.4 [dB/km] @ 1310nm ≤0.30[dB/km] @ 1550nm
12.	Attenuation vs Wavelength Max difference	≤0.03[dB/km] @1285-1330nm ≤0.02[dB/km] @1525-1575nm
13.	Dispersion coefficient	≥-3.4 ≤3.4 [ps/(nm • km)] @ 1285-1340 nm ≤18[ps/(nm • km)] @ 1550 nm ≤22[ps/(nm • km)] @ 1625 nm
14.	Zero dispersion wavelength	1312± 12 [nm]
15.	Zero dispersion slope Typical value	≤0.091 [ps/(nm² • km)] 0.086 [ps/(nm² • km)]
16.	Cladding diameter	125.0 ± 1.0[µm]
17.	Cladding non-circularity	≤1.0
18.	Coating diameter	245±7[µm]
19.	Coating strip force	1.7 [N] ≥1.3 ≤8.9 [N]

5.3.2 Underground Fibre HDPE Conduits

5.3.2.1 General Requirements

5.3.2.1.1 The Cable conduits/ducts shall protect OFC Underground cables from external physical and chemical damage and eliminates maintenance costs common to buried cables.

5.3.2.1.2 Two conduits shall be installed in parallel with one serving as a spare path and for future use.

5.3.2.1.3 Conduit dimensions shall be at least 32mm exterior side and 26mm inner diameter and must support OFC by blowing at 4 Km distance using a 10-bar pressure.

5.3.2.1.4 The duct will be white in colour, with 2mm thick single red strip externally (at every 90° angle) and cream on the inner side.

5.3.2.1.5 Supply of HDPE 32/26mm pipe shall include supply and installation of all the couplers, end plugs, etc.

5.3.2.2 Minimum specifications

No	Feature	Minimum Requirement
1.	Conduit Type	HDPE
2.	Inner Layer	Silicone with cream inner side
3.	Colour	Black with blue strip
4.	Labelling	KENGEN-SCADA - yyyy= mm/yyyy (Month & Year of manufacture) =Spacing of the labelling will be 1.0m. (The year will be changed to the right year of manufacture)
5.	Outside diameter (mm)	32
6.	Inside diameter (mm)	26
7.	Standard straight length (m)	16000m X 2
8.	Standard length coils (m)	Min 50
9.	Min. bending radius (mm) 6m length	Bidder to state
10	Min. bending radius (mm) coils	150

5.3.3 Warning Tape

5.3.3.1 Minimum specifications

No	Features	Requirements
1.	Tape Type	PVC OR PE
2.	Width	10cm
3.	Thickness	0.1mm
4.	Standard length (m)	15000m
5.	Background Colour	Yellow
6.	Mark words	- Enlarged up to the full width - Durably - Printed in black colour 2m apart
7	The words	'CAUTION: Do not dig! KENGEN O.F.C Cable underneath: Contacts KENGEN (0711036766/0711036767) shall be displayed on the warning tape at intervals of half (0.5) meters

5.3.4 Markers

5.3.4.1 Minimum specifications

No	Features	Requirements
1.	Marker Type	• Joint Marker – Used to indicate positions where the cable has been spliced/joined. • Directional markers – Used to indicate the cable route direction. The marker will be buried to a 300mm depth.
2.	Marker Material	Prefabricated concrete block
3.	Marker Colour	MUST be white (2 coats) with the wordings done in conspicuous black colour
4.	Labelling	Text height of 25mm (with < having 60mm height) 15mm spacing between the lines, all black in colour and sink engraved to 2mm depth.
5.	Marker Height	400mm (from ground surface)

No	Features	Requirements
6.	Marker Design build	Rectangular concrete block stem (L=115mm, W=115mm and H=750mm) on a base (L=315mm, W=315mm and H=100mm).
7.	Marker wording	KENGEN O.F.C Cable (With Logo) (25mm high) etched/sunk to 2mm depth on the front face of the vertical structure.
8.	Marker Position	Fixed along the cable route, 1.0m off the OFC position and to the side nearer the edge of the road reserve.
9.	Marker Points	• Location of splice points/joints. • OFC route change - where the cable route cuts across the road as it changes from one side of the road to the other. • Crossings of roads, waterways and railways – where the OFC path cuts across existing roads/railway/water ways. • Points where the cable is placed close to other existing structures. • Every 30 meters

5.3.5 Manholes

5.3.5.1 General Requirements

5.3.5.1.1 All Underground OFC Joint splicing shall be housed inside the manholes. Manholes shall be installed at strategic locations for future junctions and for inspection.

5.3.5.1.2 Sufficient slack shall be left at each end of the cable in the manhole to allow proper cable termination and enough spare cable to facilitate repair of damaged OFC sections. Slack coils must be stored without violating the minimum recommended slack coil diameter as specified in the cable specs depending on the size.

5.3.5.1.3 The cable shall be marked and labelled at each Manhole and at all entry and termination points of the fibre optic cables.

5.3.5.1.4 The soil around the manhole shall be compacted and stabilized and in line with the provided drawings.

5.3.5.1.5 Upon final acceptance of the conduit system, all man holes shall be free of debris.

5.3.5.2 Minimum specifications

No	Features	Requirements
1.	Manhole size of Chambers	1200mm [L]*1200mm [W]*1200mm [D]
2.	Manhole Cover	Mechanically lockable with special key and fully water and weatherproof.
3	Manhole Chamber materials	High strength with reinforced concrete
4	Manhole cover materials	Glass Reinforced Polymer (GRP) such as Sheet Molded Compound (SMC).
5	Manhole chamber cover Load rating	≥135KN (SANS 558 Medium Duty)
6	Manhole Slack Management brackets	• Inside the chamber • Position to secure the splicing boxes. • ≥ 8 x 50mm split cable entry holes.
7	Manhole Chamber Drainage	Knock out drain at the bottom.
8	Manholes labelling for polymer hardened cover	Wording "KENGEN SCADA O.F.C" (With Logo) 100mm below the top

5.3.6 Splice box

5.3.6.1 General Requirements

5.3.6.1.1 The OFC splice boxes will be used in each Joint and in each Access point of the network, for underground cables.

5.3.6.1.2 The splicing box will be housed inside a Manhole.

5.3.6.2 Minimum specifications

No	Features	Requirements
1.	Splice Type	Dome shaped
2	Enclosure IP Rating	IP-68 environmental protection level (water and fine dust proof).
3	Locking Design	Boltless locking design (no tools needed for open and close).
4	Splice box Material	Ruggedized
5	Splice box Strength	≥100N Impact and Pull Force
6	Splice box Metallic parts	Stainless (anti-rusting)

No	Features	Requirements
7	Splice box	Should be suitable for fusion
8	Mechanical sealing	Thermoplastic rubber protection tube.
9	Splice box position characteristics	• aerial • direct buried. • pipelined • wall mounting • manhole installations
10	Splice box design build	• ≥ 4x entry ports of Max 23mm diameter. • Sealable counterparts.
11	Splice box weight	≤2.5Kg.
12	Continuous operating ambient temperature	0° C to +55°C

5.4 CIVIL WORKS

5.4.1 Standard Trenching for Normal soil.

5.4.1.1 General Requirements

(a) Standard/Normal soil is that which is not very loose, sandy or eroded. It refers to normal red, black cotton and brown soil as well as laterite sub-rocky soil, often referred to as (murram).

5.4.1.2 Minimum specifications

No	Features	Requirements
1.	Trenching Depth	≥1000mm
2	Trench width at 1000mm (bottom)	300mm
3	Trench width at 0 depth (Top)	400mm
4	Compacted treated Bedding at bottom of trench	150mm
5	Warning Tape depth	750mm
6	Depth of compacted treated backfill at top of trench	450mm
7	Width of compacted treated backfill and erosion protection at top of trench	2400mm

5.4.2 Special Trenching with Gabion protection.

5.4.2.1 General Requirements

5.4.2.1.1 Gabions will be employed mainly at river/lagga crossings, where installed optic fibre cables can be damaged by flood waters.

5.4.2.2 Minimum specifications

No	Features	Requirements
1.	Gabion mesh-wire	• ≥ 2.8mm galvanized wire with double twist. • The Wire should be Hot Deep Galvanized class 1 at 366g/m2 of zinc coating
2	Gabion rocks	100mm - 150mm (natural solid non-porous hard-rock.)
3	Inside the gabion	• The ducts should be GI 65mm internal diameter, 76mm external diameter galvanized steel pipe. • Protrude 1m on both ends of the gabion to interface with the regular HDPE duct.
4	Trenching Depth	1500mm
5	Trench width at 1500mm (bottom)	300mm
6	Trench width at 0 depth (Top)	400mm
7	Compacted treated Bedding at bottom of trench	150mm
8	Depth of compacted treated backfill at top of trench	600mm
9	Width of compacted treated backfill and erosion protection at top of trench	1000mm

5.4.3 Reinforced Concrete Covering

5.4.3.1 General Requirements

5.4.3.1.1 Concrete mixture must be Class A: 1:2:4 (Cement-Sand-Gravel) ratio by weight or volume.

5.4.3.1.2 Typically, and for this project, ratio by weight will be used: x1 50kg bag of cement (Simba Cement or Bamburi or any other Kenya Bureau of Standard Approved cement), to 100kg of Sand to 200kg of Aggregate.

5.4.3.1.3 The average wheelbarrow holds approximately 50kg of sand or ballast, traditional method of: x1 50kg bag of Cement to x2 wheelbarrows of river Sand to x4 wheelbarrows of Aggregate is acceptable.

5.4.3.1.4 The Cement must fresh (not expired) and without damage from humidity or from water splash.

5.4.3.1.5 The river Sand must be clean and without foreign particles like soil, wood, plastics, etc.

5.4.3.1.6 The Aggregate can be collected locally or brought in from ballast stone crusher plant. However, it must be clean and contain particles that are within 15mm to 20mm in diameter.

5.4.3.1.7 Clean Water is to be added and mixed to a thick but fluid mix that pours freely and is easily workable. Water– cement ratios of 0.45:1 to 0.60:1 by weight are more typically used.

5.4.3.1.8 Concrete Mixing machine must be used to attain a clean homogenous mix.

5.4.3.1.9 A Concrete Vibrator machine must be used to attain a perfect concrete consolidation; free from air bubbles and homogenous across the covered area—helps to avoid cracks from weaker areas.

5.4.3.1.10 Concrete Curing must be undertaken for a minimum of seven (7) days.

5.4.3.1.11 Water shall be poured on the curing concrete early in the morning and late in the evening when the temperatures are low to avoid immediate evaporation.

5.4.3.1.12 The curing concrete should be covered in guinea bags and covered with a two (2) inch layer of sand; to help retain the water longer over the curing concrete.

5.4.3.2 Concrete Reinforcement Rebar minimum specifications

No	Features	Requirements
1.	Metal rebar rods	Use three (x3) of 10mm D along the whole length of the specified length of the trench to be reinforced.
2	Rebar of diameter	• 8mm are used at 200mm separation over the 10mm D rebar (over the whole length of the trench). • Binding wire will be used to fasten the 8mm rebar to the 10mm D rebar.
3	Rebar mesh	For Separation between the 10mm D rebar rods is 150mm—totalling to a 300mm wide.
4	Rebar Reinforcement	To be placed at 100mm from the surface of the concrete slab and 50mm from the edges of the concrete slab and along the full length of the trench that is to be covered in reinforced concrete.

5.4.4 Road Crossing

5.4.4.1 General Requirements

5.4.4.1.1 Road crossing will be done using directional drilling or thrust boring.

5.4.4.2 Minimum specifications

No	Features	Requirements
1	Bores depth	• ≥ 1.5m across spur subsidiary roads • ≥ 2m across the main highway from the tarmac level
2	Bores exit at a depth	≥ 1.5m; same level as the trench.
3	Bores span lengths	15m-20m but could span to a maximum of 30m if need be. The equipment must be able to drill bores spanning to a maximum of up to 30m long:
4	Bore drilling equipment	drill bores spanning to a maximum of up to 30m long
5	Bore drilling head	accommodate rock drilling bits: for rocky ground.
6	Post Boring	Two galvanised iron conduit 100mm internal diameter,114mm external diameter (one to act as spare for future use) are to be inserted through the bore.
7	Bores marking	both ends with marked reinforced concrete pillars.
8	Bore Conduits	inside a bore must be equipped with draw-wires
9	The operation pits	must be backfilled, unless there is need to install a Hand-hole on the pit location

5.5 FIBRE INSTALLATION, TESTING AND COMMISSIONING

5.5.1 Outdoor splicing of OFC shall be carried out in a tent or in a special vehicle. Splicing of OFC shall not be carried out uncovered outdoors. In the process of splicing the environment must be dustproof, damp-proof and quake-proof. The tools and materials must be clean. The operator must wear special working clothes and hats.

5.5.2 When splicing the pipe OFC, the cable shall be hanged on the man-hole walls or higher positions between brackets, the remained OFC must be put into the manholes.

5.5.3 Both sides of the OFC joints shall be bended flexibly, and the remained cable shall be

coiled inside the manholes according to the curve requirements.

5.5.4 The OFC shall be cut with optical fibre cutters, steel saws are not allowed.

5.5.5 When using optical fibre splicing instrument, the specification of factory manual and operating instruction must be obeyed.

5.5.6 When splicing the optical fibre, the optical fibres shall be arranged as per the factory order, and splicing shall be done one after the other.

5.5.7 The average optical fibre splicing loss (αj) on very few points may be larger than the specified number, but within one optical regeneration section, the average optical fibre splicing loss of a same fibre must meet the specification.

5.5.8 If during splicing the optical fibres, the splicing instrument cannot display the splicing loss value or cannot guarantee the splicing quality, an OTDR shall be used to monitor the fibres loss.

5.5.9 Completed splicing points shall be protected with heat-shrinking tubes, and the tubes shall shrink evenly without gas bubble in it.

5.5.10 The optical fibre protection sheath or coating removal, end face processing, fibre splicing, heat shrinking tube operation etc shall be continuously carried out without interruption. The fibre splicing joints shall be fixed and arranged in order.

5.5.11 The spliced fibres shall be held with a retained length of not less than 0.8m for single end, and 1.5m for both ends; as to the sub-aqueous cable, not less than 1.5m. The holding bending radius shall be not less than 40mm. Both sides remaining cable shall be marked with core numbers, kept in order without twisting or compression.

5.5.12 Attenuation coefficient, length, position and loss of all splice joints shall be measured in accordance with IEC 793-1 and EIA 455 standards using an Optical Time Domain Reflect meter (OTDR) and a buffer fibre shall be used in the measurements. The results shall be recorded as a trace and in a table format. The length of fibre shall be tested at the same time.

6 PARTICULAR TECHNICAL SPECIFICATIONS - TOOLS & ACCESSORIES

6.1 OPTICAL TIME DOMAIN REFLECTOMETER OTDR

6.1.1 General Requirements

6.1.1.1.1 Complete unit shall consist of:

(a) Quad Multi/Single-mode OTDR Module,

(b) Remote test unit,

(c) Optical loss Fibre analyser module

(d) Wi-Fi adapter to connect test unit to the web application.

(e) Web based application for management and analysis.

6.1.1.1.2 OTDR shall have a user-friendly interface for ease of data analysis, easy of setting up, operating and facilitate quick troubleshooting.

6.1.1.1.3 OTDR Shall detect and measure closely spaced faults including data centre and storage area environments.

6.1.1.1.4 OTDR shall be the quad mode for testing both multimode and single mode fibre.

6.1.1.1.5 OTDR shall be able to perform Macro bend detection.

6.1.1.1.6 OTDR shall allow segment selection for fibre analysis within a longer segment.

6.1.1.1.7 OTDR shall be able to easily characterize all connectors, splices, and areas of high loss with graphical view.

6.1.1.1.8 OTDR Shall support Multiple wavelengths application.

6.1.1.1.9 OTDR shall support Splitter detection.

6.1.1.1.10 OTDR shall be complete with all hardware components, accessories, features, and devices necessary for a complete functional site deployment irrespective of whether these features have been specified in these specifications or not.

6.1.1.1.11 A Live web application shall be provided to manage projects from a desktop or mobile device.

6.1.2 Minimum Specifications

No.	Feature	Requirements
1.	Modules	• OTDR module • Fiber Inspector probe • Visual Fault Locator • Wi-Fi adapter

No.	Feature	Requirements
		• Web application • Accessories as detailed below.
OTDR Module Specifications		
2.	Form factor	Handheld
3.	Cable Type	Single mode & multi-mode
4.	Wavelengths	850 nm +/- 10 nm 1310 nm +/- 25 nm 1550 nm +/- 20 nm 1625 nm +/- 20 nm
5.	Compatible fiber types	• 50/125 µm • 62.5/125 µm • Single Mode
6.	Event dead zone	• 850 nm: 0.5 m • 1300 nm: 0.7 m • 1310 nm: 0.6 m • 1550 nm: 0.6 m
7.	Attenuation dead zone	• 850 nm: 2.5 m • 1300 nm: 4.5 m • 1310 nm: 3.6 m • 1550 nm: 3.7 m
8.	Dynamic range	• 850 nm: 28 dB • 1300 nm: 30 dB • 1310 nm: 32 dB • 1550 nm: 30 dB
9.	Max distance range setting	• MM: up to 40 km • SM: up to 130 km
10.	Distance measurement range	• 850 nm: 9 km • 1300 nm: 35 km • 1310 nm: 80 km • 1550 nm: 130 km
11.	Reflectance range	• 850 nm: -14 dB to -57 dB • 1300 nm: -14 dB to -62 dB

No.	Feature	Requirements
		• 1310 nm: -14 dB to -65 dB • 1550 nm: -14 dB to -65 dB
12.	Sample resolution	3 cm to 400 cm
13.	Pulse widths (nominal)	• 850 nm: 3, 5, 20, 40, 200 ns, • 1300 nm: 3, 5, 20, 40, 200, 1000ns • 1310/1550 nm: 3, 10, 30, 100, 300, 1000, 3000, 10000, 20000 ns
14.	Test time (per wavelength)	Auto setting: • MM - 5 sec • SM - 10 sec
		Quick test setting: • MM - 2 sec • SM - 5 sec
		Best resolution setting: • MM - 2 to 180 sec M • SM - 5 to 180 sec
		Fault Map setting: • MM - 2 sec (typical) • MM - 180 sec (max) • SM - 10 sec (typical) • SM - 180 sec (max)
		Data Center OTDR setting: • MM - 1 sec (typical at 850 nm) • MM - 7 sec (max) • SM - 20 sec (typical) • SM - 40 sec (max)
		Manual setting: • MM-3, 5, 10, 20, 40, 60, 90, 120, 180 sec • SM - 3, 5, 10, 20, 40, 60, 90, 120, 180 sec
Fibre Inspector probe specifications		
15.	Magnification	-200X
16.	Light source	Blue LED

No.	Feature	Requirements
17.	Power source	TFS mainframe
18.	Field of View (FOV)	• Horizontal: 425 µm • Vertical: 320 µm
19.	Minimum détectable particle size	0.5 µm
20.	Operating temperature	0° C to 50° C
Visual Fault Locator specifications		
21.	On/Off control	Mechanical switch and a button on the touch screen
22.	Operating wavelength	650 nm
23.	Spectral width (RMS)	±3 nm
24.	Output modes	Continuous wave Pulsed mode (2 Hz to 3 Hz blink frequency)
25.	Connector adapter	2.5 mm universal
26.	Laser safety (classification)	Class II CDRH Complies to EN 60825-2
General specifications and accessories		
27.	Fibre Test Reference Cords (TRCs)	• ≥Two (2), 50 µm Multimode SC/SC • ≥Two (2), 50 µm Multimode SC/LC • ≥Two (2), 50 µm Multimode LC/LC • ≥Two (2), 9 µm Single Mode SC/SC • ≥Two (2), 9 µm Single Mode SC/LC • ≥Two (2), 9 µm Single Mode LC/LC • ≥Two (2), 9 µm Single Mode FC/FC • ≥Two (2), 9 µm Single Mode FC/LC • ≥Two (2), Single Mode 9 µm SC/E200 APC
28.	TIP-KIT	• LC, SC and FC bulkhead adapter tip • 1.25 mm universal tip • 2.5 mm universal tip
29.	Calibration	Period 1 year
30.	Battery	≥ Lithium-ion battery pack, 7.2 volts

No.	Feature	Requirements
31.	Battery life	≥ 8 hr Auto OTDR operation, dual wavelength no video probe connected, 150 m of fiber
32.	Integrated Wi-Fi	IEEE 802.11 a/b/g/n; dual band (2.4 GHz and 5 GHz)
33.	EMC	EN 61326-1
34.	Certifications	CE - Conformite Europeene. Conforms to the requirements of the European Union and the European Free Trade Association (EFTA).
35.	Power Supply	240V AC, 50Hz, 3pin British type connector cord.
36.	Carrying Case	To be provided
37.	Manufacturer Warranty	≥ 1 year

6.1.3 Product certifications

6.1.3.1 Device must be tested and approved for use in the EU or USA or Canada. Proof of testing and certification MUST be provided

6.1.3.2 Product certification from an EU or USA or Canada reputable firm MUST be provided along with the bid

6.2 FIBRE OPTIC FIELD FUSION SPLICING EQUIPMENT

6.2.1 General Requirements

6.2.1.1 The device shall have high precision and accurate core alignment.

6.2.1.2 The device shall have wind protection, this is to reduce overall splice time.

6.2.1.3 The device shall have a high-capacity lithium-ion battery, with ability to perform up to 300 splices.

6.2.1.4 The device shall have an easy splice protector positioning system.

6.2.1.5 The device shall have universal sheath clamps for standard 250 um fibre but also 900 um loose tube fibre types.

6.2.1.6 The device shall have Fibre Retention clamps.

6.2.1.7 The device shall have a multi-function carry case and workstation.

6.2.1.8 The device shall have tool-less replaceable electrodes.

6.2.1.9 The device shall be Touch screen enabled.

6.2.2 Minimum Specifications

No.	Feature	Requirements
1	Type	Fiber Fusion Splicing Kit (Fully ruggedized for shock, dust, and moisture)
2	Applicable Fibres	• Single-Mode (G .652 and G .657) • Multi-Mode (G .651), DS (G .653), NZDS (G .655) to conform ITU-T standards
3	Fibre Count	Single fiber
4	Cladding Diameter	80 - 150 µm
5	Coating Diameter	100 µm - 1,000 µm
6	Fiber Cleave Length	5 - 16 mm
7	Typical Average Splice Loss	• 0.02 dB with SM, • 0.01 dB with MM, • 0.04 dB with DS, • 0.04 dB with NZDS, measured by cut-back method relevant to ITU-T standards
8	Splicing Time	• ULTRA FAST mode — 6 seconds. • SM FAST mode: Avg. 7 to 9sec. • SM AUTO mode: Avg. 14 to 16sec.
9	Arc Calibration Method	Automatic, real-time and by using results of previous splice when in AUTO mode, manual arc calibration function available
10	Splicing Modes	≥100 pre-set and user programmable modes
11	Splicing Method	Automated Core Alignment
12	Splice Loss Estimate	Based upon dual camera core axis alignment data
13	Storage of Splice Result	≥10,000 results stored in the internal memory in FIFO
14	Fibre Display	X or Y, or both X and Y simultaneously. Front or rear monitor display options with automated image orientation
15	Magnification	320X for single X or Y view, or 200X for X and Y view
16	Viewing Method	Dual Cameras
17	Display Screen	≥4.7-inch TFT colour LCD monitor

No.	Feature	Requirements
18	Operating Condition	0 - 5,000 m above sea level, 0 to 95%RH and -10 to 50°C respectively
19	Mechanical Proof Test	1.96 to 2.25N
20	Tube Heater	Built-in tube heater with 30 heating modes; auto-start function
21	Tube Heating Time	• ≤23 seconds with FP-03 sleeve • ≤17 seconds with FP3 (40) • ≤15 seconds with slim 60 mm and 40 mm sleeves
22	Protection Sleeve Length	60 mm, 40 mm, micro sleeves
23	Splice/Heat Cycles with Battery	Typical 200 cycles with power save functions activated
24	Electrode Life	≥5,000 Arc Discharges
25	Fusion Splicer Electrodes	Capability to replace; include a pair of spare electrodes, replaceable without tool.
26	Power Supply	Auto voltage selection from 100 to 240 V AC and detachable BTR-09 Li-ion battery & Charger Cord
27	Terminals	USB 1.1 (USB-B type) for PC communication. Mini-DIN (6-pin) for HJS-02/03
28	Wind Protection	Maximum wind velocity of 15 m/s. (34 mph)
29	Carrying Case	At least 1
30	Work Tray	At least 1
31	Power Supply connectors	British type plug
Splicing Kit to include all necessary Accessories		
Optical Fibre Cleaver with casing		
32	Application	Single fibres: • 250-900 µm coating • 125 µm cladding
33	Cleave Length	• 900 µm: 10-20 mm, • 250 µm: 6-20 mm
34	Blade lifetime	≥60,000 fibre cleaves
35	Includes	• Adapter Plate

No.	Feature	Requirements
		• Scrap Collector • Wireless interface: Bluetooth 4.1 LE • ≥2 AAA Rechargeable Battery • ≥1 AAA Battery Charger
Splicer V-groove Cleaning Kit		
36	Eye Loupe with 3X to 12X magnification	At least 1
37	LED Pen Light with momentary or constant on switching	At least 1
38	Instruction Sheet with illustrations	To be provided
39	Canvas Carrying Case	To be provided
40	Splicer V-groove Cleaning Refill Kit includes	• At least 1 Can FPF1 Cleaning Fluid • At least 1 Scrubber Brush • At least 1 Sweeper Brush • At least 10 packs Cotton Swabs (250 swabs) for precision cleaning
Splice Protection Micro Sleeves (Heat shrink sleeves)		
41	Outer Tube	Polythene
42	Strength member	Stainless Steel
43	Sleeve 60mm	At least 1 Pack of 1000 pcs
44	Sleeve 40mm	At least 1 Pack of 1000 pcs
45	Sheath Clamp	At least 1
46	Electrodes (spare)	At least 1
47	Sleeve Loader	At least 1
48	USB Cable	At least 1
49	Alcohol Dispenser	At least 1
50	Splicer Carrying Strap	At least 1
51	Quick Reference Guide	To be provided
52	Software & Hardware	Warranty Two (2) years (includes Software Upgrades)

6.2.3 Product certifications

6.2.3.1 Device must be tested and approved for use in the EU or USA or Canada. Proof of testing and certification MUST be provided

6.2.3.2 Product certification from an EU or USA or Canada reputable firm MUST be provided along with the bid