Eskom	Specification	Tutuka Power Station

Title: **Tutuka Solar PV Plant Functional Specification**

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1. INTRODUCTION

The Eskom Integrated Long Term Plan and the Eskom Corporate Plan sets up the organisation for growth and maps out a low carbon future in a post-coal environment. The plan describes Eskom's participation in renewable energy and other technologies to deliver on opportunities that will add generating capacity and in turn aid in alleviating system constraints, while also pursuing a low carbon future.

The installation of Solar Photovoltaic (PV) at the existing Tutuka Power Station site was identified as one of the projects that could achieve these objectives. Tutuka Power Station Solar PV Plant will be located within the borders of South Africa in the Lekwa Local Municipality of the Gert Sibande District, Mpumalanga Province. The town Standerton is located about 25 km from the site. Coordinates of the central point are 26°47'0.60" S 29°21'17.30" E. Accessibility to the site can be gained along road R546 which adjoins to N3 via R23. The overall installation of Solar PV Plant at Tutuka Power Station comprises the following scope:

- The Contractor's scope of work shall cover, among any other activities indicated in this Employer's Requirements, the following (but not limited to) in relation to the Works:
    - The turnkey procurement and delivery of the studies, designs, engineering, licensing and permitting, manufacturing, factory testing, deliveries to Site (including customs duties and importation), project management, project cost control, supervision, documentation, labour, execution, erection, progress reporting, commissioning, testing, completion, training, and other works necessary to construct and safely operate the project,
    - All security, fire protection, health, safety, environmental, and socio-economic requirements as included in any relevant environmental and social assessments, Applicable Laws, Permits and Codes and any other project documents,
    - Grid connection works to the 132 kV distribution network via a new substation.
    - All plant, equipment, materials, and work required to complete the works; and,
    - Making good defects and warranty cover during the Defects Liability Period.

This document sets the minimum functional technical requirements to be fulfilled by the Contractor undertaking the Solar PV plant scope. The minimum codes and standards and training requirements regarding the Solar PV scope are also included.

This document is to be read in conjunction with: -

- The Engineering, Procurement, and Construction (EPC) contract.
- All applicable Codes and Standards as referred to in this document.

1.1 Employer's Objectives

The Employer's main objectives for the installation(s) are as follows:

- Participation in renewable energy and other technologies to deliver on opportunities that will add generating capacity and in turn aid in alleviating system constraints, while also pursuing a low carbon future.
- To install Solar PV technology at the Tutuka Power Station site with a minimum capacity of 24MWac and a maximum export capacity of 36MWac. The identified and Environmentally Authorised land has an area of 99ha, without considering the site constraints. When considering the constraints the available land area for development is estimated at approximately 35.50ha.
- The Employer's objective is to procure a fully operational utility-scale solar PV plant within the authorised project site. The plant design shall make efficient and effective use of the entire available

land area and incorporate proven technologies and engineering practices that maximise energy yield and overall performance while minimising lifecycle cost.

- All proposed solutions must comply with the technical, regulatory, environmental, and grid-connection requirements defined in this Functional Specification and must support the Employer's objective of achieving a low Levelised Cost of Energy (LCOE) and long-term reliable operation.

Table 1-1 Requirements – Capacities for Solar PV Plant

Estimated usable area [ha]	~ 35.50
Minimum DC Capacity [MWp]	28
Minimum DC/AC ratio	1.15
Minimum AC Capacity [MWac]	24
Maximum Export Limit [MWac]	36

2. SUPPORTING CLAUSES

2.1 Scope

This document intends to address the following:

- Employer's objectives with regards to the Works
- Description of the Works
- Employer's requirements of the Works
- The Employer's Basis for Design
- Performance Guarantees
- The limits of Scope and Supply regarding the Works
- Standards, Codes and Specifications applicable to the Works

2.1.1 Purpose

The purpose of the Functional Specification is to document the scope of work, on a lump-sum turnkey basis under an EPC Contract, all studies, permitting, design, engineering, procurement, manufacturing, deliveries to Site, execution, erection, commissioning, testing, completion, operation and maintenance (O&M) until taking over, making good defects and warranty cover during the Defects Liability Period, and other works necessary to construct a solar photovoltaic (PV) power Plant, the access road, the Site facilities and any additional infrastructure located at Tutuka Power Station.

2.1.2 Applicability

This document shall apply to the Tutuka Power Station Solar PV project.

2.2 Normative/Informative References

Parties using this document shall apply the most recent edition of the documents listed in the following paragraphs.

2.2.1 Normative

[1] ISO 9001 Quality Management Systems

[2] ISO 17025 Testing and Calibration

[3] 240-53113953 Manage Engineering Accountability Procedure

[4] 240-53114026 Project Engineering Change Management Procedure

[5] 240-53114002 Engineering Change Management Procedure

[6] 240-50317699 Manage Technical Queries Procedure

[7] 24240-53114194 Control of Non-conforming Product

[8] 240-53113685 Design Review Procedure

[9] 240-48929482 Tender Technical Evaluation Procedure

[10] 240-49910527 Procedure for Plan and Select Technologies

[11] 240-76992014 Project/Plant Specific Technical Documents and Records Management Work Instruction.

[12] Department of Environmental Affairs, National Environmental Management Act, 1998, (Act 107 of 1998), Amendment of the Environmental Impact Assessment Regulations Listing Notice 1 of 2014

[13] Grid Connection code for Renewable Power Plants (RPPs) connected to the electricity Transmission System (TS) or the Distribution System (Dx) in South Africa.

2.2.2 Informative

[14] [360-TUT-AABZ28-SP0008-7- Required Operational Capability Report for Tutuka Power Station PV Solar Project Rev 0. 11 June 2021.

[15] 360-TUT-AABZ4-D00221-1- Engineering Change Assessment Report for Tutuka Power Station PV Solar Project Rev 0. 11 June 2021.

[16] Wetland Delineation and Functional Assessment Report for Tutuka Solar PV Project, February 2015.

[17] Soils and Agricultural Potential Impact Assessment Report for Tutuka Solar PV Project, October 2015.

[18] Ecological Assessment Report for Tutuka Solar PV Project, March 2015.

[19] Avifauna Assessment Report for Tutuka Solar PV Project, October 2015.

[20] 360-TUT-AABZ26-RP0000-7 Concept Design Report for Tutuka Solar PV Power Plant, Rev 1, 05 July 2016.

[21] R00000308FRT01C -2022-10-13 Tutuka PV (Draft) Feasibility Report

[22] IPP907459217 SC0092 Dx IPP **CEL** both Dx SBA Tx SBA for Tutuka PS PV 36MW Facility- 17 June 2025 signed

2.3 Definitions

Definition	Description
Annual average GHI	Global Horizontal Irradiance (GHI) is the total irradiance from the sun on a horizontal surface on Earth. It is the sum of diffuse, horizontal, and direct irradiance, after accounting for the solar zenith angle of the sun.
Annual energy generation	AC electrical output of the system. This is electricity available for the grid, building load, or battery storage. When curtailment, i.e., clipping, is implemented, these curtailment losses are deducted from the annual energy generation total.
Array	An array is the PV plant configuration. The number of modules per string and strings in parallel constitutes an array. In this study, the PV plant or array is the same. In bigger plant designs, you can have multiple arrays represented in the PV plant.
Capacity Factor	The ratio between the total amount of energy the plant produces during a period and the amount of energy the plant would have produced at full capacity all the time in that period. i.e. Capacity factor = Total energy (kWh) produced in a time period ÷ energy (kWh) that could be generated if the plant operated at full capacity all the time in that time period.
Conservancy Tank	Conservancy tanks are used for the disposal both black water (sewage) and grey water (bath water and washing machine waters)
DC/AC Ratio	The ratio of total inverter DC capacity to total AC capacity.
Electrical Installation	Machinery, in or on any premises, that is used for the transmission of electrical energy from a point of control to a point of consumption anywhere on the premises, including any article that forms part of such an installation, irrespective of whether or not it is part of the electrical circuit, but excluding: Any machinery of the supplier related to the supply of electricity; Any machinery which transmits electrical energy in telecommunication, television or radio circuits; Any electrical installation on a vehicle, vessel, train or aircraft; Control circuits of 50 V or less, between different parts of machinery or system components, forming a unit, that are separately installed and derived from an independent source or isolating transformer.
Energy Yield	The ratio of the system's annual AC electric output in Year one to its nameplate DC capacity. Energy Yield = Net Annual Energy ÷ Nameplate Capacity.
IAC AFLR	Internal arc classification for type (operator safety) accessibility for the front, side, lateral side and rear side of the panel.
Irradiance	Irradiance is the radiant flux, i.e. power or solar energy, received by a surface per unit area. The unit of irradiance is measured in watt per square metre (W/m^2)
Module	The module converts solar irradiance into electric power. The module is the area within a PV panel that fulfil this function.
Nameplate DC Capacity	Maximum DC power output of the plant at the reference conditions. Nameplate Capacity (kW_{dc}) = Module Rated Power (W_{dc}) × 0.001 (kW/W) × Total Modules
Net Annual Energy	The total annual electric generation in the first year of operation.

Definition	Description
Performance Ratio	The performance ratio is a measure of the PV annual electric generation output in AC kWh compared to its nameplate rated capacity in DC kW, taking into account the solar resource at the system's location, and shading and soiling of the array. Performance ratio = annual energy (kWh) ÷ (annual POA total radiation (nominal) (kWh) × module efficiency (%))
Plant Efficiency	Annual energy generation of plant over nominal energy received on plane of array, i.e. PV module surface area
Plant Installation	Electrical installation within the power generating plant that constitutes to the generating of electrical energy.
Point of Control	Point at which a consumer can, on or in any premises, switch off the electrical installation from the electricity supplied from the point of supply
Point of Consumption	Point of outlet, or the supply terminal of machinery that is not connected to a point of outlet and that converts electrical energy to another form of energy, provided that in the case of machinery that has been installed for any specific purpose as a complete unit, the point of consumption is the supply terminals that have been provided on the unit of machinery for that purpose
Point of Connection (POC)	The electrical node on the Dx system where the solar PV plant's assets are physically connected to the Distribution network service provider's assets.
Point of Outlet	Termination of an electrical installation, which has been provided for connecting any electrical machinery without the use of a tool, provided that no connection to a busbar is deemed to be a point of outlet
Point of Supply	Point at which a supplier supplies electricity to any premises
PV System, PV Plant	A power system designed to supply usable electrical power by means of photovoltaics, consisting of an arrangement of PV modules, inverters, transformers, cabling, and other electrical accessories
Rapid Voltage Change (RVC)	Rapid fluctuation in voltage caused by switching events on the utility's network or within the customers' plant.
Renewables Grid Code	Grid Connection code for Renewable Power Plants (RPPs) connected to the electricity Transmission System (TS) or the Distribution System (Dx) in South Africa.
Septic Tank	Septic tanks are used for the disposal of sewage
System Engineer	System Engineer / Plant Engineer (SE): A competent and qualified site/plant-based discipline or System/Plant Engineer, who has the training, technical qualification and expert knowledge of the plant or systems affected by the engineering change.
Typical meteorological Year (TMY)	Typical meteorological year (TMY) is a collation of selected weather data for a specific location, listing hourly values of solar radiation and meteorological elements for a one-year period. These values are generated from hourly data from a much longer time period, (ideally 10 years or more). The hourly data is specially selected so that it represents the range of weather phenomena for the location in question, while still providing annual averages that are consistent with the long-term averages for the location in question.

2.3.1 Disclosure Classification

Controlled disclosure: controlled disclosure to external parties (either enforced by law, or discretionary).

2.4 Abbreviations

Abbreviation	Description
AFLR	A-(operator safety), Front, Lateral, Rear
AC	Alternating Current
AQL	Acceptance Quality Level
BESS	Battery Energy Storage System
BMS	Building Management System
BNEF	Bloomberg New Energy Finance
BTU	Battery Tripping Unit
C&I	Control And Instrumentation
CCTV	Closed-Circuit Television
CMS	Control And Monitoring System
CoC	Certificate of Compliance
CPU	Central Processing Unit
c-Si	Crystalline Silicon
DB	Distribution Board
DC	Direct Current
DCS	Distributed Control Systems
DIN	Deutsches Institut für Normung
DMZ	Demilitarised Zones
DNI	Direct Normal Irradiance
ECSA	Engineering Council of South Africa
EPC	Engineering, Procurement and Construction
FAT	Final Acceptance Test
FDS	Fire Detection System
GHI	Global Horizontal Irradiation
GPS	Global Positioning System
GSM	Global System for Mobile Communication
Ha	Hectare
HVAC	Heating Ventilation and Air conditioning
HMI	Human Machine Interface
IAT	Intermediate Acceptance Test
IEC	International Electrotechnical Commission
IED	Intelligent Electronic Device
I_{mpp}	Maximum Power Point Current
IP	Ingress Protection
IP	Internet Protocol
I_{sc}	Short Circuit Current
KKS	Kraftwerk Kennzeichnen System
LCD	Liquid Crystal Display
LPU	Large Power User

Abbreviation	Description
LV	Low Voltage (0 < LV < 1000V)
MCB	Miniature Circuit Breaker
MCCB	Moulded Case Circuit Breaker
Modem	Modulator-Demodulator
MW	Megawatt
MWP	Megawatt Park
MPP	Maximum Power Point
Ni-Cad	Nickel Cadmium
NCOU	Northern Cape Operating Unit
NMD	Notified Maximum Demand
NTP	Network Time Protocol
O&M	Operating And Maintenance
OHS	Occupational Health and Safety
OHL	Overhead line
OLE	Object Linking and Embedding
OPC	OLE for Process Control
OPC-DA	Object Linking and Embedding (OLE) For Process Control via Data Access
OT	Operational Technology
PAT	Provisional Acceptance Test
PDS	Plant Data System
PLC	Programmable Logic Controllers
P_{mpp}	Maximum Power Point Power
POA	Plane Of Array
POC	Point of Connection
PR	Performance Ratio
PV	Photovoltaic
RAID	Redundant Array of Independent Disks
RAM	Reliability, Availability and Maintainability
RMU	Ring Main Unit
RPPs	Renewable Power Plants
RTU	Remote Terminal Unit
SABS	South African Bureau of Standards
SAT	Site Acceptance Test
SCADA	Supervisory Control and Data Acquisition
SIT	Site Integration Test
SLD	Single Line Diagram
SMS	Short Message Service
SANS	South African National Standard
SNMP	Simple Network Management Protocol
STC	Standard Test Condition

Abbreviation	Description
TF	Thin-Film
TMY	Typical Meteorological Year
UPS	Uninterrupted Power Supply
USB	Universal Serial Bus
V_{mpp}	Maximum Power Point Voltage
V_{oc}	Open Circuit Voltage
XLPE	Cross Linked Polyethylene

2.5 Roles and Responsibilities

Compiler: Responsible to compile the document and to ensure that the content is integrated to reflect the requirements of every stakeholder forming part of this project.

Functional Responsibility: The Functional Responsible person is responsible to approve the content of the document and assure its correctness before the document is submitted for authorisation.

Authoriser: The document Authoriser is responsible to ensure that the correct processes were followed in developing this document and that the relevant stakeholders have been involved. The Authoriser also reviews the document for alignment to business strategy, policy, objectives, and requirements. He/she shall authorise the release and application of the document.

Project Manager: The role of the Project Manager is to facilitate the integration of this Solar PV functional specification with other project documents and translate it into a Works Information that will be issued to the market. The Project Manager will define the project strategy that will inform the project's conditions of contract.

Senior Manager: The role of the Senior Manager Engineering (Renewables) is to give assurance that the document has been reviewed and signed by all relevant parties before issuing for the procurement purposes.

Design Authority: A professionally registered engineer, or team in the employ of by the EPC contractor of appropriately registered built environment professionals including engineers, appointed and tasked to provide a detail design. The Design Authority carries personal and professional statutory and legal liability for the design.

2.6 Process for monitoring

The primary process for monitoring will be governed by 240-53113685 Design Review Procedure [8], which entails assuring that the design achieves the requirements set out in this document. Any changes to this document will be performed as per 240-53114026 Project Engineering Change Management Procedure [4].

2.7 Related/Supporting Documents

None

3. GENERAL REQUIREMENTS

3.1 Contractor's Scope of Work

1. The Contractor (as the Design Authority) is responsible for surveying, studies, permitting, design, engineering, manufacture, procurement and supply of all materials and labour, delivery to site, offloading, construction, erection, installation, off-site testing, on-site testing, commissioning, performance testing, provision of samples, preparation of all detail design drawings, as-built record drawings, maintenance manuals and instructions for the works, in accordance with the general requirements and performance requirements as detailed in this document.
2. The scope of work also includes the Operation and Maintenance (O&M) activities during the first 2 years of operation. The O&M scope of work is attached in Appendix D of this document.
3. The Contractor Provides the Works as per this document.

3.2 Contractor's Experience

3.2.1 EPC Contractor

1. The Contractor demonstrates proven experiences in engineering, procurement, execution and operation and maintenance of ground-mounted utility scale PV power plants.
2. The Contractor demonstrates successful execution of a minimum 20 MWac Category C (plants above 20 MVA) (cumulative capacity) completed commercial (not pilot or demonstration) ground mounted, grid connected, front-of-meter Solar PV project within the last 10 years, as the principle EPC Contractor, and where at least one of these successfully executed projects was ≥ 20 MWac.
3. The Contractor provides project details of the successfully executed project(s) in 2 above, such as the name of the Solar PV plant, location of the plant, name and contact details of developer, type of module technology, type of PV module mounting (fixed, tracking, etc) mechanism, installed nameplate DC capacity (MWp), plant AC capacity (MWac), duration of construction (months), commercial operation date, photographs (if possible), and proof verifying completed PV plant.

3.2.2 Key Personnel's Experience

1. The Contractor ensures that only qualified personnel with the relevant experience (relevant to this project and technology utilised) are included in design, construction, commissioning, and operation of the plant.
2. The Bidder provides detailed CVs of each personnel responsible for the works.
3. If any replacement is required during the construction and operation, the Contractor ensures that the replacement has equivalent or higher experience and qualifications than the one replaced.

3.3 Operation and Maintenance

1. The scope of the Operation and Maintenance phase is further captured in Appendix D of this document.

3.4 Training

1. The Contractor to provide training on overall plant design, construction, commissioning and operating and maintenance on all Plant that is part of this scope.

2. Within 60 days of the award of the contract, the Contractor shall prepare and submit to the Employer, for review, a complete training programme based on the guidelines and requirements specified in this section. The Contractor shall subsequently liaise with the Employer to discuss and finalise the training programme and ensure that it can be integrated with the Employer's own training and development agenda. The training programme shall be agreed with the Employer at least 6 months before the start of commissioning.
3. On specific systems training to be provided:
    3.1. 14 days prior to safety clearance of plant to allow these staff to be able to perform operating and isolations if they need to do safe shutdown of plant and/or perform isolations as per the Employers Plant Safety Regulations or Operating Regulations for High Voltage Systems.
    3.2. 14 days prior to any Inspection, Test, and Commissioning activities.
4. Class-room training (theoretical training) to be completed 30 days prior to exporting power for the first time.
5. Training is based on classroom training and on-site (on-job) training during construction and commissioning.
6. The Employer requires 80 staff members to be trained on engineering, operations, and maintenance of the PV Plant. These staff members consist of 15 engineers, 20 managers/supervisors, 40 technicians/operators as well as 5 training officers.
7. The Contractor shall identify the required training to operate and maintain the plant. The training includes but is not limited to:
    7.1. Plant description and design including single line diagram
    7.2. Construction and installation method
    7.3. Safety during construction and commissioning
    7.4. Introduction to each test type and measurement methods
    7.5. Test evaluation procedures and test result interpretation
    7.6. Trouble shooting procedures
    7.7. A checklist of what to do in case of system failure
    7.8. Emergency shutdown/isolation procedures
8. In addition to the on-job training, the Employer's technicians and/or engineers will assist and witness all activities on the plant.
9. The following training shall be provided at an operation, maintenance, fault finding, and root cause analysis level.
    9.1. All Control & Instrumentation systems in the PV Plant, including monitoring and data capturing system.
    9.2. All SCADA hardware and software systems on the plant. Training must include software/network/diagnostic tools where applicable, to enable troubleshooting and configuration.
    9.3. Training must include operation and adjustment of grid parameters of the PV Facility via SCADA.
    9.4. Remote monitoring and resetting.
    9.5. Local monitoring, troubleshooting, and resetting.
    9.6. Electrical protection systems within the PV Facility.

9.7. Electrical isolation and earthing of the plant to be able to isolate and earth the plant as required by the Plant Safety Regulations and the Operating Regulations for High Voltage Systems.

9.8. Operation and maintenance on MV switchgear and transformers. This includes the relevant support equipment such as protection, interlocking, and communication equipment.

9.9. Inverter Technician Training: specification, functioning and safe operation following the manufacturers O&M Manual (troubleshooting for error codes, repair, software for inverter, fault finding on the DC Plant).

9.10. Data Acquisition System and PLC Training.

10. The Employer is notified of and involved in any scheduled or unscheduled on-site maintenance activities. Notification of scheduled training during preventative maintenance activities to be at least 10 working days prior to the training taking place. In addition, continuous formal training must be provided.

11. All training material to be submitted to the Employer in printed and digital format. All drawings, manuals, and software for training shall be provided by the Contractor. This includes training material for Operators, Engineers, and Technicians.

12. The training material provided for Engineers are required to be detailed to the level of a System Engineer. Engineers are required to be able to fully configure any system of the PV installation, including the Control Monitoring System (CMS).

13. The Contractor shall provide all training materials in hard copy and electronic copy to the trainees prior to the actual commencement of O&M training.

    13.1. Training material for classroom training shall be based on O&M manual content, in addition to detailed operating and maintenance plans and procedures.

14. The training to be conducted by knowledgeable and certified instructors with:

    14.1. minimum three (3) years' experience in MW scale solar PV construction and commissioning for training on design, construction, and commissioning.

    14.2. minimum five (5) years' experience in operation and maintenance of MW scale solar PV for training on Operation and Maintenance

15. All classroom training sessions are video recorded by the Employer at its expense for future use as an orientation/teaching aid during the commercial operating period. Virtual training workshops and training sessions will be recorded and made available to the Employer.

16. All training to take place on site at Tutuka Power Station, or any place agreed with the Project Manager.

4. TECHNICAL REQUIREMENTS

4.1 Project Definition

4.1.1 PV Plant Description

1. The works comprise of the design for **a fixed tilt or tracking PV plant** with a minimum of 24 MWac capacity and a maximum evacuation capacity of 36 MWac on a site with an Environmental Authorized land of 99ha. This 99ha area does not consider all the site constraints. The site is within Tutuka Power Station in the Mpumalanga Province.
2. The PV plant will be designed to comply with environmental basic assessment requirements as stipulated in the Department of Environmental Affairs, National Environmental Management Act, 1998, (Act 107 of 1998), Amendment of the Environmental Impact Assessment Regulations Listing Notice 1 of 2014 [12].
3. The PV plant will be connecting via a Loop-In Loop-Out (LILO) arrangement to the existing New Denmark – Tutuka PS 132 kV OHL. The PV plant will comprise of ground mounted solar photovoltaic (PV) modules and associated infrastructure.
4. The PV plant shall comprise of ground mounted solar photovoltaic (PV) modules and associated infrastructure.
5. The PV plant shall be designed to C4 in according to ISO 9223 for nonferritic and ferritic materials
6. The Civil works shall be designed for a fully functional PV plant and to withstand the site conditions.
7. The Contractor provides a PV Plant with a minimum design life of 25 years, with minimum annual average plant guaranteed availability of 98%.
8. The PV Plant shall operate in an automatic mode producing electrical power for evacuation into the electrical grid/network whenever sufficient sunlight is available and is monitored and operated as per the requirements in this document. The generation output of the PV facility shall be limited to the Maximum Export Capacity (MEC) that will be finalised and agreed with the Grid Access Unit. The current Cost Estimate Letter (CEL) indicates a MEC = 36 MW. .
9. The EPC Contractor performs the role of the O&M Contractor during the O&M period. The O&M period for the PV plant is defined in Appendix D. The main PV Plant breakdown structure is summarised in Table 4-1.

Table 4-1: PV Plant breakdown structure

Sub-system / Component	Description
PV Modules	PV modules, generally of same technology, type, size, and from the same manufacturer, are connected in series to form strings, and generate direct current (DC) electricity by converting sunlight via the photovoltaic effect.
Mounting Structures and foundations	PV module mounting structures for the chosen technology and appropriate foundations, required to support the PV modules at the required orientation relative to the sun, while providing structural support and protection.
Combiner boxes, Fuse boxes	Collects and combines the DC electricity from the PV module strings, with adequate protection and monitoring before connection to the Inverter.
Inverters	Converts DC electricity to AC electricity before connection to the LV/MV transformer. The inverters are equipped with suitable protection, monitoring, ventilation, and cooling systems.

Sub-system / Component	Description
LV/MV Transformers	Step-up transformers to transform the output voltage of the inverter to the required operating voltage on the Medium Voltage (MV) side of the transformer.
MV and LV Switchgear and protection, including Solar PV Collector Substation	Switchgear and protection at MV level to enable power distribution and electrical protection up to the PoC. The switchgear uses integrated CTs and VTs to provide statistical energy metering and measurement. Switchgear and protection is also necessary for the supply of auxiliary loads.
Inverter cabins/stations	An inverter cabin/station houses the inverter/s. It may also house LV/MV transformers, and switchgear. Each inverter cabin/station will connect to other inverter cabins/stations on the site.
Cabling	DC and AC Cabling with associated infrastructure, such as trenches, sleeves, etc. DC cabling is required for the DC side of the plant, i.e. from the PV modules, to the combiner boxes, and up to the input of the inverter. AC cabling is required from the output of the inverter to the LV/MV transformer, and up to the PoC. AC and DC cabling is also required for the supply of auxiliary loads.
Protection	Plant and equipment protection including earthing, lightning, surge protection, fire detection and protection, etc.
PV collector substation / MV busbar	All the power generated by the Solar PV plant is evacuated to the grid through a PV collector substation (if required).
Meteorological station	Specific monitoring equipment and instruments installed at specific positions on the Solar PV plant to provide solar resource, environmental, and weather data.
Auxiliary Power Supply	Auxiliary power supply for the PV plant. This also includes any emergency backup power supply systems.
Battery Tripping Unit (BTU)	Battery Tripping Units where required providing DC supply to the switchgear control and protection circuits.
Uninterrupted Power Supply (UPS)	Uninterruptable power supply (UPS) system with a battery bank to provide uninterruptable source of power to the CMS equipment in the server and control rooms of the PV Plant.
O&M Building(s)	O&M buildings to consist of new Server and Equipment room, Spares/Stores and Security Access Control Building. All with the required HVAC, Fire detection and protection, lighting, and small power loads such as distribution boards and BTUs.
Water Supply and Reticulation	Potable water supply and reticulation system for the Security Access Control Building. Process water supply and reticulation system for the PV plant, including PV module cleaning and dust suppression.
Sewage and Waste Disposal	Sewage and waste disposal system for the Security Access Control Building.
Control and Monitoring System (CMS)	Also referred to as SCADA, is a supervisory control and data acquisition system, whose architecture comprises of computer hardware, networked data communications and a graphical user interface (GUI) or human machine interface (HMI).
Security systems and Access Control building	Includes all security systems and infrastructure (security fencing, surveillance and alarm system, lighting, etc.)

10. Solar PV Plant auxiliary supply equipment

10.1. Tutuka Solar PV Collector Substations (if required).

10.2. Tutuka Solar PV facility essential back-up supplies.

11. A Security Access Building shall be located at the main gate of of the Solar PV Plant at Tutuka Power Station
12. It is preferable that road asphalt surfacing material be used (asphalt or block paving) for the main access road

4.1.2 PV Plant Operational Requirements

1. The Contractor shall consider the following boundary conditions for determining the optimum PV plant:
   1.1. The Contractor shall comply with the requirements indicated in the Environmental Authorisation.
   1.2. The Contractor shall identify, assess, and duly account for all site constraints and servitude requirements that may influence the design, construction, and operation of the PV Plant. This assessment shall include, but shall not be limited to, the presence and protection of existing pipelines, overhead and underground powerlines, public and private roads, railway infrastructure, conveyor systems, and any other applicable linear or fixed infrastructure. The Contractor shall ensure that all works are planned and executed in compliance with relevant statutory servitudes, rights-of-way, easements, and associated restrictions.
   1.3. The minimum installed DC capacity shall be 28MWp. The installed DC capacity shall be defined as the aggregate rated power of all PV modules under Standard Test Conditions (STC).
   1.4. The minimum required DC/AC ratio is 1.15. Accordingly, the minimum installed AC capacity shall be 24MW. The installed AC capacity shall be defined as the aggregate rated power output of all inverters operating at unity power factor (pf = 1.0) at a temperature of 50 °C.
   1.5. The maximum export capacity at the grid connection point, as indicated in the Cost Estimate Letter (CEL), is limited to 36MW.
   1.6. The Contractor shall deliver a PV Plant that satisfies the technical and regulatory constraints while ensuring long-term operational efficiency, optimised Levelised Cost of Energy (LCoE), high performance, and high availability throughout the operational life of the facility
2. The PV plant shall comply with the Renewables Grid Code. A PV plant of maximum 36MWac falls under Category C (plants above 20 MVA) of the Renewable Grid Code, therefore, the plant shall comply with all the requirements of a solar PV plant under category C.

4.1.3 PV Plant Location

1. The Project is located within the borders of South Africa in the Lekwa Local Municipality, of the Gert Sibande District Municipality, in Mpumalanga Province. It is near the Tutuka power station, which is near the town of Standerton. Coordinates of the central point are 26°47'0.60" S 29°21'17.30" E.
2. Accessibility to the site can be gained along road R546 which adjoins to N3 via R23.
3. The proposed site boundary co-ordinates are summarised as follows (co-ordinates may change after the basic assessment is completed):

Table 4-2: Tutuka Site co-ordinates

Site Boundary		
	Latitude	Longitude
NW corner	26°46'53.49"S	29°21'10.45"E
NE corner	26°46'51.28"	29°21'34.56"E
SE corner	26°47'13.22"S	29°21'35.56"E
SW corner	26°47'6.20"S	29°21'2.60"E
SW bend	26°46'57.05"S	29°21'10.46"E
Site Centre Point		
Centre Coordinates	26°47'0.60" S	29°21'17.30" E.
Coordinates of the Project's Power Line/Cable		
Cable Route Alternative 2		
Start point (PV Site)	26°46'53.68"S	29°21'11.16"
Blend point	26°46'46.05"S	29°21'9.68"E
Blend point	26°46'47.40"S	29°20'51.64"E
Blend point	26°46'39.62"S	29°20'45.44"E
Blend point	26°46'23.60"S	29°20'48.53"E
End point (Substation)	26°46'22.22"S	29°20'59.07"E
Coordinates of the Project's Access Roads		

4.1.4 PV Plant Point of Connection

1. The indicative design considers an AC electrical reticulation through inverter station(s). Each station contains at least 1 x inverter, 1 x transformer, and secondary distribution switchgear.
2. Each inverter is connected to the transformer via an AC disconnect switch for isolation and maintenance purposes.
3. The switchgear is used to connect to other adjacent stations and for inverter isolation and protection. The LV auxiliary supply for each inverter station is provided by LV/LV transformer inside an inverter cabin/station.
4. The generated power from each station is evacuated through to the 132 kV busbar at the PV Collector switchgear through underground cabling.
5. The Contractor designs the AC cables along with the associated scope such as cable routes and trenches from the switchgear to the evacuation point. This must be according to requirements detailed in this document and according to requirements from Water Use License permit and Environmental permit.

4.1.5 Solar Resource and Temperature

1. The Contractor shall provide the meteorological data to be used for the design of the solar PV plant.

4.1.6 PV Plant Design Definition

1. The Contractor shall develop the detailed design in full compliance with the general requirements and performance specifications as set out in this document and takes liability for the design.

2. The Contractor shall comply with the latest revisions of the codes, standards and guidelines as indicated in this Functional Specification and as indicated in Appendix C.
3. The Contractor shall ensure that all designs are signed off by a respective Engineering Council of South Africa (ECSA) registered Professional Engineer.
4. The Contractor must submit their detailed designs to the Project Manager for review and comment prior to procurement and construction of the PV Plant.
5. The Contractor labels the PV Plant and documents using the Kraftwerk Kennzeichnen System (KKS) coding standard; 240-93576498, KKS coding standard, 240-71432150, Plant Labelling Standard and 240-109607332, Eskom Plant Labelling Abbreviation Standard provided by the Employer.
6. The Contractor designs the PV Plant with consideration of approved Environmental Permit and Water Use License Permit.
7. The Contractor designs the PV Plant with due consideration to the site environmental conditions, particularly in relation to wetland, high wind, temperature, mist/fog, corrosivity, lightning, hail, and dust.
8. The design data specified in this document and those dimensions shown on the tender drawings are intended for tendering purposes only. The Contractor is required to take the actual measurements onsite before proceeding with design and manufacture of the complete works as dimension accuracy remains the responsibility of the Contractor.
9. The Contractor defines the PV Plant performance and provides the guaranteed performance ratio and plant availability calculation along with detail calculation and losses assumptions. The Contractor uses industry standard methods for carrying out yield and performance ratio calculations and demonstrates the basis of the calculations. The Contractor, as part of the design, takes into account all requirements as stipulated in the Grid Connection Code for Renewable Power Plants (RPPS) Connected to the Electricity Transmission System (TS) or the Distribution System (DS) in South Africa. The Contractor ensures that design and construction of the PV Plant complies with current standards and statutory obligations arising from current legislation and regulations, including statutory legislation and codes of practice, and relevant South African and international standards.
10. The Contractor always ensures compliance with all applicable health and safety regulations during design, construction, and operation of the PV Plant in accordance with OHSAS 18000 and in accordance with the Eskom Health and Safety Specification provided in the Contract.
11. If there is a conflict of method, or level of provision, the Contractor adopts the specification, recommendation, or regulation with the most stringent conditions. The Contractor submits details of any such conflicts and the provisions adopted.
12. The Contractor designs the PV Plant with due consideration to the minimisation of lifecycle costs (achieving an optimal balance between delivered kW, kWh, reliability, life cycle cost, maintainability, and overall cost effectiveness).
13. The Systems are designed for ease of future deconstruction and recycling and be designed for disassembly with an associated end of life waste management plan.
14. With respect to any surveys or analysis of existing infrastructure relevant to the facility installation, the Employer does not assume responsibility for the completeness or accuracy of such surveys and analysis. The Contractor reviews, validates and subsequently assumes responsibility for the scope and accuracy of any such data relevant to completion of the works provided by the Employer and to be relied upon by the Contractor and be responsible for planning, specifying and executing any additional site investigations required in order to satisfy itself that the required level of scope and accuracy of data and analysis has been obtained, so as to not in any way affect the performance of its obligations.

15. Plant coding shall be undertaken by the Contractor and submitted to the Employer for review. As such the Contractor shall make available the following documentation after coding which shall include, but not limited to:
    - 15.1. Mechanical Plant
        - 15.1.1. Piping And Instrumentation Diagrams (P&IDs)
        - 15.1.2. Interface List
        - 15.1.3. Process Flow Diagrams (PFDs)
        - 15.1.4. Detailed Layout Drawing
    - 15.2. Electrical Plant
        - 15.2.1. Single line diagrams
        - 15.2.2. Electrical board general arrangements (GA)
        - 15.2.3. Cable schedule
    - 15.3. C&I Plant
        - 15.3.1. C&I architecture drawings C&I Cubicle GA
        - 15.3.2. Cable block diagrams
        - 15.3.3. Remote control station lists
        - 15.3.4. Cable schedules
    - 15.4. Civil Structures
        - 15.4.1. Site layouts
        - 15.4.2. Building layouts
        - 15.4.3. Building sectional layouts
        - 15.4.4. Building floor plans per level
        - 15.4.5. Underground services layouts
        - 15.4.6. Cable rack & support
        - 15.4.7. Building lists (including room equipment lists)
16. The Contractor shall list all project documents (soft copies and hard copies) for submittal on the transmittal with the following metadata fields:
    - 16.1. Title of the document
    - 16.2. Document Unique Identification number
    - 16.3. Revision number
    - 16.4. Name of Discipline
    - 16.5. Reason for issuing/submission
    - 16.6. Sender’s detail
    - 16.7. Sent date
    - 16.8. Recipient’s Details
    - 16.9. Date received
    - 16.10. Quantity of documentation referenced on the transmittal

16.11. Number of copies

16.12. Format/medium submitted

16.13. Sender signature

16.14. Recipient signature, once submitted, to acknowledge receipt.

17. The Contractor shall ensure that document has the following as a minimum attribute on the cover page:

17.1. Title of the document

17.2. Document Unique identification number (Eskom number)

17.3. Contractor Document number, if applicable

17.4. Document status

17.5. Revision number

17.6. Document Type

17.7. Document security level

17.8. Document revision table/history

17.9. Page number on the footer

17.10. Document Author/Authorizer

17.11. Document Originator Contractor

17.12. The following additional attributes are important for technical documents:

17.12.1. Package/System name, sub-system if applicable

17.12.2. Unit/s number

17.12.3. Contractor name

17.12.4. Contractor number

17.12.5. Plant Identification Codes

18. For consistency it is important that all documents used within a specific domain follow the same layout, style and formatting standard. Every document shall comply with the following font specifications:

18.1. Font Colour: Black

18.2. Main Headings Font Type: Arial, Bold, Capital Letters

18.3. Main Heading Font Size: 12pt

18.4. Sub-headings Font Type: Arial, Bold, Title Case

18.5. Sub-headings Font Size: 11pt

18.6. Body Font Type: Arial, Sentence Case i.e., only the first letter of the first word is a capital letter.

18.7. Body Text Font size: 11pt

18.8. Line Spacing: 1.5 line spacing

18.9. Margins: standard

18.10. Alignment: full justification to be used

18.11. Paragraphing: one line skip between paragraphs

18.12. Pagination: centred page numbers (about 0.5 inches from bottom)

18.13. Indentations: standard tab for all paragraphs (about 0.4 to 0.5 inches)

19. The header shall include the project name, document title, document number, revision number and page number.

4.1.7 Material Quality Specification

The Contractor shall:

1. Ensure that all components and materials supplied are designed, manufactured and tested in accordance with the latest applicable South African and international standards. For aluminium-based materials BS EN 1706 latest applicable version and for structural related materials shall be in line with EN 10025. ASTM or an equivalent International Standard
2. Ensure that Equipment Products, Components and/or Accessories conform to all applicable Product Safety Standards appropriate for the intended markets.
3. Ensures that the quality and performance of materials and products are appropriately certified under a suitably approved scheme.
4. Ensure appropriate certification and independent testing has been carried out on any materials and products proposed.
5. Ensure materials and products used are suitable for the service conditions.
6. Ensure that all works, materials, parts, components etc. supplied are new, both in the construction of the PV Plant and maintenance of the PV Plant throughout the O&M Period.
7. Not use any materials or substances that are generally known at the time of use to be deleterious, a health risk, or a fire hazard, either in use or in their manufacture.
8. Ensure that, where possible, all materials used are recyclable.
9. Not use substances known to deplete the ozone layer, whether or not specifically excluded from use by current EC legislation, as refrigerants or foaming or filling agents for insulation.
10. Not use any materials or substances that support mould, bacterial growth or vermin or cause objectionable odours under service conditions.
11. Ensure materials and products delivered to site bear the manufacturer's name, brand name and any other data required to verify that their performance and specification complies with the requirements of this document and the Employer’s Project Specific Requirements.
12. Ensure materials and products are appropriately CE/UL marked or SABS approved. Material Test Reports (MTR) or material certificates whether ferritic or non-ferritic type materials
13. Follow the manufacturers' instructions on the use of materials and products.
14. Select materials & products with regard to standardisation and availability of spare parts and for ease of maintenance.
15. Ensure the same manufacturer is used for materials or products of a similar type and that identical parts of similar products are interchangeable.
16. Ensure that materials and components are transported and stored in accordance with manufacturer’s guidelines.
17. Not use plant and equipment prior to Handover other than for testing, commissioning, and demonstration.

18. Provide suitable packaging for the protection of all materials and equipment during delivery, storage, and where exposed to damage on site. The Contractor returns re-usable packaging to the supplier. The Contractor takes particular care to protect and maintain plant and equipment delivered early.
19. Examine materials and products supplied when delivered to site and immediately prior to installation. The Contractor replaces any damaged or faulty materials or products.
20. Store all materials on raised boarded platforms under weatherproof covers and/or according to manufacturers' specifications.
21. Ensure that module pallets should not be stacked more than two (2) pallets high, unless otherwise stipulated in the manufacturer guidelines, and the foundation on which the pallets are stored should be levelled and compressed to prevent any subsidence taking place while in storage. PV modules shall always be handled by no less than two (2) installers, carried from the box to the tracker/structure table while holding the module in four (4) places at all times. PV modules in the field should never be placed face down on the ground and should also never be stacked horizontally on top of each other but rather resting against each other in a vertical fashion.
22. Protect all materials and equipment which may be exposed to damage, inclement weather, or ultraviolet light.
23. Ensure that sensitive plant and equipment items are not exposed to dirt or dust at any time to maintain manufacturers' warranties and long-term reliability.
24. Repair any damage to finished materials and equipment prior to handover of the PV Plant.
25. Maintain the minimum level of spare parts throughout the maintenance period and provides to the Project Manager prior to the handover of the PV Plant.

4.2 Civil

4.2.1 Introduction

- This specification includes the following work to be performed by the Contractor, but not limited to:
  a. The Contactor shall perform all required site investigations, topographic surveys, service detection surveys, hydrologic and geohydrological surveys and geotechnical investigations as deemed necessary.
  b. The detail design, procurement and construction of all civil works which includes the foundations, mounting structures, plinths and supporting structures for equipment (transformers, etc.), water supply, sewage, waste disposal, and storm water reticulation systems, O&M Buildings, vehicle parking bays, roads, parking areas, security fencing, water supply, reticulation, and storage.
  c. The supply of detailed design, construction drawings, method statement, design report, and construction specification for the construction of the PV Plant, civil structures, foundations, buildings, roads, and all other associated supporting structures.
  d. Corrosion protection and design of the finishes of the plant and equipment in accordance with the relevant norms and standards.
  e. All necessary interface requirements and liaison provided by the Contractor.

4.2.2 General

- Details and drawings of any civil works which are not expressly included in this Contract but which, in the opinion of the Contractor, are necessary for the completion and proper execution of the project to be included by the Contractor and submitted to the Employer for acceptance. The Contractor clearly indicates the proposed scope regarding these additional items.
- The design, procurement and execution of all civil works to be performed by the Contractor according to the applicable norms and standards and obtaining approval of any permits but not limited to Environmental Permit and Water Use License Permit.
- The Contractor ensures that all buildings, structures, cable trenches/routings, internal roads, fencings, and service routes which are incorporated in this contract are functionally and efficiently located and that each building/component is sized for optimum space usage.
- The Contractor submits the design calculations/drawings of the building/civil items which are within this scope of work for review, acceptance, and comments by the Employer.
- No construction is started prior to acceptance by the Employer. The Employer provides comments after the design is submitted by the Contractor, however the Contractor shall note they still remain liable for all designs in their entirety.

4.2.2.1 Preparation and Site Establishment

- The Contractor is responsible for all site preparation and site established required for the construction of facilities.
- The Contractor liaises with third parties that have access to the Site.
- The Contractor is responsible for site preparation, e.g. Clearing and grubbing, dust control, excavation and backfilling, grading, levelling, earth moving, soil improvement, dredging, relocation of any cables, pipes present on site etc.
- The Contractor is responsible for providing site storm water drainage and sewage drainage systems.

- The Contractor is responsible for providing all construction facilities including, but not limited to, provisions for temporary Contractor's office, warehouse, toilets, workshop for site construction purpose, vehicles, mobile equipment, temporary power generators, construction electricity, construction water, and any other provisions required for site preparation and during construction.
- The Contractor shall perform surface grading (if required) for site establishment and construction of the facilities.
- The Contractor shall demolish and remove all temporary facilities upon the Substantial Completion date including restoration of areas.
- The Contractor shall remove all construction rubble.

4.2.2.2 Design

- Services provided by the Contractor in the design phase include but not limited to:
  a. Complete design in accordance with the requirements of this specification.
  b. Detail design of PV modules mounting structures, foundations, O&M buildings, building services, roads, parking areas, fencing, sewer and stormwater drainage, water supply and storage and all other associated supporting structures.
  c. The Contractor shall conduct all Geotechnical, hydrology, underground-services and topography related investigations in order to determine the foundations and mounting structure solution including all other civil and structural related design. The solution on foundation is according to approved permits (Environmental and Water Use License).
  d. Method statements for the installation of the foundations and mounting structures.
  e. Sizing and optimizing of the different components.
- All calculations relating to the civil work and all drawings are prepared and submitted to the Employer for review and acceptance. Calculations are arranged in a logical sequence and include such sketches and annotations as may be required to make them self-explanatory.
- Calculations clearly identify the subject of the calculations and include, but are not limited to the following information:
  a. Project name
  b. Contractor's name
  c. Name of the civil design engineer, including registration number as professional engineer registered with ECSA or international equivalent
  d. Contract No.
  e. Date of calculation
  f. Revision No.
  g. Name of the item
  h. Page No.
  i. Assumptions used for design purposes
  j. Codes and standards used
  k. Computer programmes used
  l. Loading imposed by structures, plant and equipment during the erection, commissioning, operation and maintenance

m. Safety factors and combinations of loads used
n. Calculations of all components
o. Settlement of plant and equipment foundations
p. Reference sources (including textbooks and design manuals used)
q. Reference to the appropriate drawing
r. Selected materials and finishes
s. Manufacturer's technical specifications

- The foundation and PV mounting structures are designed for the worst combination of dead loads, construction live loads, plant loads, impact and dynamic effects due to operation of plant, maintenance loads, wind loads, and temperature effects.
- Drawings prepared by the Contractor to include complete construction details including but not limited to:

a. General arrangement layouts
b. Foundation layouts
c. Layouts and sections of the different components
d. O&M Buildings
e. Roads and parking including all related earthworks and terrace related details
f. Sewer and storm water drainage
g. Water supply and storage
h. Concrete and reinforcement drawings and schedules
i. Construction joint schedules
j. Details of embedded parts
k. Details of the PV mounting structure and fixing
l. Structural steel detailing and corrosion protection
m. Details of all plinths, openings, box-outs, holding down arrangements, grouting, connections etc. required for plant and equipment.
n. As built drawings

- The Contractor is responsible for the detail design of the works and is responsible for ensuring that the design satisfies all structural, dynamic, seismic, acoustic, hydraulic, safety and environmental requirements of all permits and statutory obligations, as applicable in South African laws. As a minimum, The Contractor shall consider the loads and load combinations in accordance with SANS 10160 including hail conditions. Uplift and downforce load at each tilt angle must be provided and must be under PV module manufacturer approved loads.
- The Contractor submits design calculations, specifications and drawings of the civil items which are within his scope of work for comments to the Employer and the Employer's representatives.
- All calculations are submitted in electronic format.
- The Contractor supplies details of the computer programs used and any certification of approval by independent authorities are given for the programs used.
- Drawings are to be submitted in Bentley Microstation compatible software and in acrobat pdf formats as a minimum.

- Contractor is liable for all designs in their scope of works.
- All civil and structural designs to be designed and approved by professional civil engineer registered with ECSA or international equivalent.

4.2.2.3 Prior to Fabrication and Construction

- Electronic copies of all design calculations and electronic copies of all drawings are submitted for acceptance to the Employer, before the relevant fabrication or construction work is carried out. In addition, one set of hardcopies of all drawings and calculations are provided. The Contractor's programme allows for the Employer to review the documents prior to the Employer's acceptance and at least one revision following the Employer's initial comments.
- Acceptance of the Contractor's drawings or calculations by the Employer does not relieve the Contractor of any of his obligations to meet all the requirements of the Contract or relieve the Contractor of his responsibility for the adequacy of design, calculations, and drawings.
- A detailed Construction Work Programme, broken down to specific tasks and time allocated for completion of each task be submitted, including time for review by the Employer.

4.2.2.4 Fabrication and Construction

The works provided by the Contractor include:

Inspections & Test Plans (ITP) alternatively called Quality Control Plans (QCP), or were necessary Method Statements indicating how and when activities will be carried out and who shall witness such activities

a. Provision of all equipment which are required by the Contractor.
b. Supply, fabrication, and erection of the foundations, O&M buildings.
c. Construction of the PV modules mounting structures.
d. Construction of security systems (fences, gates), perimeter roads, internal roads.
e. Grouting of all structural steelwork. The Contractor provides details of materials and method of grouting including epoxy type non-shrink materials for acceptance by the Employer.
f. Testing of the welding work to be done in accordance with SANS 1200H.
g. Corrosion protection of the steel supporting structure, roofing material, bolts, nuts and embedded parts in accordance with SANS 121 and SANS 1200HC.
h. Building Services–lighting, power supply, C&I, water and sewage,
i. HVAC, shall be in accordance with SAN 10147 including refrigerants compliance to Ozone Depletion Layers (ODI)
j. fire detection and fire protection shall be signed off by competent SAQCC certified personnel or an international equivalent

- All concrete is tested as follows: slump test and compressive strength test in accordance to SANS 3001. After placing and compaction, concrete is finished to a smooth, even surface by means of steel floats or other suitable equipment. Concrete is cured by protection against loss of moisture and rapid temperature changes.
- Steel framed structures are designed in accordance with SANS 10162, South African Steel Construction Handbook (latest edition). The structural design is carried out in accordance with structural design code of practices.

- Road design component criteria are to accommodate the construction and operation of the plant. The design of roads, storm water management and pavement design to conform to SANS 1200, TRH series for roads, THM series for roads, UTG series for roads, COLTO specification.
- Storm water, water supply, and sewage reticulation systems.

4.2.3 Civil Design Requirements

- The Contractor engages a competent qualified Professional Civil Engineer registered with ECSA or international equivalent, experienced (minimum 5 years' experience) in the design of similar work to be fully responsible for the design.
- The Contractor complies with the South African codes for buildings and structures within his scope of works as well as the standards listed in the specification.

4.2.4 Surveys, studies and reports

- The civil engineering scope shall include, but not limited to:
  a. Topographical Study
  b. Geotechnical Study
  c. Hydrological Study
  d. Design (Design document, full set of drawings, scope of work and specifications,)
  e. Construction
  f. Deliverables
- The Contractor shall carry out the topographical, geotechnical, hydrological or other surveys and studies that might be necessary in addition to the studies provided by the Employer to carry out the Works with Good Industry Practice and in compliance the Applicable Laws, Permits and Code. Any surveys, studies provided by the Employer are strictly on a non-reliance basis unless otherwise communicated by the Employer, and the Contractor need to satisfy himself with such documentation and carry out any further studies and investigations as deemed required (at his own cost within the EPC Contract price) in order to accept ground risk.
- The Contractor shall, as a minimum, prepare and complete the following surveys, studies and reports:
  a. Structural (including but not limited foundation, pile load and pull-out testing) analyses, including mounting structure's length-pile foundations calculations and length-pile model.
  b. Pull-Out tests.
  c. Flooding and drainage studies to complete the flood risk assessment of the Site.
  d. Seismic study: The Contractor shall make its own investigation of the seismic activity in and around the Site and shall design the Plant accordingly
  e. Ecological regeneration plan for the re-vegetation, regeneration and restoration plan of the Site's ecosystem.
  f. Ground resistivity test.
  g. Access route assessment, access management plan and Traffic Management Plan.
  h. Environmental and Storm water management plan
  i. Waste management plan

4.2.5 Topographical Survey

- The Contractor shall do a topographical survey of the proposed PV site.
- The Surveyor shall be required to carry out the services as governed by the South African Council for Professional and Technical Surveyors (PLATO Act 40 of 1984 as amended).
- The Surveyor shall perform a topographical survey in accordance with the Land Survey Act, Act No 8 of 1997, and the Survey Regulations, as amended.
- The Surveyor is required to provide the following minimum services:
  a. Collection and collation of topographical information for the area.
  b. The Surveyor is required to collect all data describing the site boundaries and servitudes registered over all properties covering the site.
  c. Methods and work procedures to be submitted to Eskom prior to commencement of works.
  d. Identification or establishment of survey beacons
  e. Identification and protection of existing beacons for use in survey reference.
  f. Establishment of new beacons within survey area for survey purposes where existing beacons are insufficient or do not exist.
  g. Field work – Surveying
     i. The survey is based on the LO-System WGS84 reference system of the national triangulation. Specifications and accuracy must be in accordance with the requirements of TMH 11: Standard Survey Methods.
     ii. A survey of the area for the proposed sites must be done by a qualified surveyor taking into consideration the fact that the actual site may be situated anywhere within the allocated boundaries. The Surveyor must locate the existing services within the site area.
     iii. The Surveyor ensures that there are enough benchmarks as well as surveyed points to establish a detailed contoured surface in order to complete design.
     iv. The survey also identifies the position of existing servitudes. This includes but not be limited to culverts, kerbs, manholes, telephone servitudes, sewer servitudes, potable water servitudes, electrical lines, fences, gates, watercourses, existing infrastructure, road reserve boundary, etc.
     v. The survey is provided as a set of labelled co-ordinated points (label y, x, z).
     vi. The Surveyor provides a full list of actual descriptions used.
  h. Mapping and production of detailed survey drawings.
     i. The digital terrain model consists of ASCII files stored on flash/hard drive and supplied to Eskom.
     ii. The design files of the package used when the DTM was generated is provided.
     iii. Separate files are provided for spot heights and for detail points or it must be clearly separated when contained in one file.
     iv. The Surveyor shall supply a list explaining the point description codes together with the DTM.
     v. One master drawing (incorporating all survey layout plans) is supplied to Eskom on Flash drive/hard drive in DWG and DXF formats.

vi. The contour interval shall be 0.5m for ground slopes less than 10% and 1.0m for ground slopes in excess of 10%.

vii. The grid spacing is 100m.

viii. Only points indicating details that are on ground level can be used for contouring and are to be included as “Layer 1”. The Survey control pegs must be provided as “Layer 2” and the remaining information e.g. manhole positions, on other layers.

ix. The survey points must include features so as to be able to determine existing road surface widths, road levels, culvert and pipe inlet and outlet levels, stream beds, drainage paths, side drains, drainage structures, services and manholes.

x. The digital information must be provided on a Flash drive/hard drive.

4.2.6 Geotechnical Study

- The Contractor shall do a detailed geotechnical study to perform the mounting structure foundation design and to design all other foundations that will be required. This will include a geotechnical study for the design of the roads.
- The scope of services as a minimum shall include a geotechnical subsurface investigation using soil borings to determine subsurface soil conditions and stratification. Information obtained from the subsurface exploration and from subsequent laboratory testing is to be incorporated into a geotechnical engineering analysis. This analysis shall evaluate the stability of the in-situ soil and its capacity to support the proposed project features.

4.2.7 Hydrological Study

The Contractor shall undertake a detailed hydrological impact assessment and geohydrological survey and submit the associated report(s) and result(s) to the Employer. The design recurrence interval shall be for a 24 hour 1:50 year flood event.

The hydrological impact assessment shall be developed considering two different scenarios (1) prior to PV plant construction, and (2) post PV plant execution, including the proposed drainage system). It shall focus on the development of a flood risk assessment, storm water management plan (inclusive of drainage infrastructure design), and erosion management plan to address potential issues of flooding and soil erosion.

- The Contractor shall undertake a hydrological and geohydrological survey and submit the associated report and result to the Employer.
- The Plant shall be designed for minimum water consumption.
- Based on the hydrological study and flooding risk assessment (FRA), the Contractor shall design a drainage system that handles the runoff from the extreme storm event thereby preventing the Project from being flooded.
-

4.2.7.1 Foundations

- The Contractor designs, procures, and construct the foundation for PV module mounting structure and for all buildings and civil works according to the results based on detailed geotechnical investigation.

4.2.7.2 Mounting Structures

- The Contractor designs, procures, and construct the suitable mounting structure according to geotechnical study and according to Environmental permit and Water Use License Permit.
- The structure withstands all possible static, dynamic, and seasonal load at site condition.
- All PV mounting structures are off-the-shelf products as much as possible. Engineered solutions are only allowed for specific circumstances only after consultation with the Employer.
- The proposed mounting structures (product) have proven track record and the product has been installed in PV projects of similar capacity.
- The mounting structures are designed for optimum PV module orientations and performance.
- The row-to-row distance is selected to minimize the shading losses. The row-to-row shading losses shall not be more than 2.5%. The Contractor must provide supportive calculation to verify row to row shading loss.
- The mounting structure shall be designed for minimum 25 years of operation and the Contractor provides minimum 10 years as warranty on material/product.
- The Contractor provides the mounting structure solutions which is efficient, cost effective, and reliable. The design reduces installation time and material waste.

4.2.7.3 Inverters housing

The inverters shall be suitably mounted to prevent water or dust ingress and be shaded against direct sunlight. Inverters must have a shelter to reduce direct exposure to the sun.

Ingres Protection of Inverters shall be in line with relevant condition of applicable IP ratings

- If containerised inverter/transformer solutions are proposed, sufficient ventilation (or air-conditioning if necessary) to maintain optimum performance and to avoid any unnecessary equipment derating or damage must be ensured.
- For central inverters, the Contractor designs, procures, and constructs the suitable inverter cabin for the Project, according to recommendation from inverter manufacturer (if applicable).
- For central inverters, the inverter cabin includes proper fire detection, fire protection, lighting, and a ventilation system.

4.2.7.4 O&M Buildings

- The O&M Building cater for minimum: -
  a. Control room for 2 persons with 2 operator desks and an engineering station
  b. Two (2) closed offices
  c. Open plan offices for 20 persons
  d. Board room for 25 persons with video conferencing facilities
  e. Documentation room
  f. Server room (air-conditioned room for sensitive electronic equipment)
  g. Security equipment room
  h. Kitchen with a tea-room
  i. Male and female ablution facilities with change rooms including washrooms and lockers

j. Storeroom

- O&M Buildings to also include Spares warehouse and workshop, Hazardous chemical store, Meteorological station, and Security building.
- The workshop with the spares warehouse building shall be suitably sized to carry out all routine off plant servicing as well as breakdown maintenance. The spares warehouse to have large roller shutter doors that will enable a truck with a 10ton crane to drive into the building. A covered parking area next to the warehouse building must be provided for a maintenance tractor and its attachments. The workshop and stores building could incorporate an overhead crane.
- The Contractor ensures that space for each section (room or partition) in O&M building(s) is sufficient for its intended purpose.
- The Contractor designs O&M building(s) according to ergonomic principles (Eskom standard 240-56355808 Ergonomic Design of Power Station Control Suite Guideline) and sound Solar PV Plant practice.
- The O&M building(s) include proper fire detection, fire protection, and ventilation systems according to requirement set out in this specification.
- The O&M building(s) shall be designed in accordance to the National Building Regulations and Building Standards Act No. 103 of 1977.
- The Contractor shall submit all plans and designs to the local authority as stipulated in the National Building Regulations and Building Standards Act No. 103 of 1977.
- The O&M building is equipped with normal quality lighting as per the requirements in SANS 10114-1, as well as essential lighting with battery pack backup in case normal lighting fails as per SANS 10114-2. The minimum lux level is as per OHS Act.
- The Contractor considers Eskom Architectural technical specification 240-56364535 to select the appropriate material for O&M building.

4.2.7.5 Access Roads, Perimeter Road, and Internal Roads

- The Contractor designs, procures and constructs suitable access roads, perimeter roads, and internal roads for providing access and security during construction and operation.
- The Contractor uses the existing Provincial Route Road for access to the site and maintains the road (if required) during the construction and operation of the Project.
- The design must be according to approved Environmental permit and Water Use License permit.
- The Contractor considers the topsoil to be removed during construction process as low as possible and uses the existing roads inside the site area as much as possible.
- The road design provides sufficient slope (camber 2%) for drainage of rainwater and must include the proper drainage system.
- The perimeter road is wide enough to provide sufficient access to heavy trucks during construction and maintenance of the Project. The minimum width of the perimeter road is around 4.5 m wide. The internal roads provide sufficient access to the Inverter cabin, O&M building(s), Meteorological stations, and any civil infrastructure built for the Project.
- The design of roads, storm-water management and pavement design to conform to SANS 1200, TRH series for roads, THM series for roads, UTG series for roads, COLTO specification.

4.2.7.6 Drainage

- The Contractor shall design and constructure a drainage system suitable for the Plant design lifetime. Site conditions (specifically climatic and rainfall data and the Site's configuration and topography) shall be taken into account to protect the Project against erosion and flash-flooding or other types of flooding. The drainage works shall be located within the area secured for the Site. No additional area outside of the Site shall be provided or utilised.
- Based on the hydrological impact assessment and flooding risk assessment, the Contractor shall design a drainage system that handles the runoff from an extreme storm event, thereby preventing the Project from being flooded.
- In this regard, the drainage philosophy will require two parts:
    - External drainage: To protect the Plant against external water runoff though the watershed from the neighbouring areas of the Site; and,
    - Internal drainage: To manage the runoff generated from rainfall within the Site.
    - The external drainage shall be designed for a 1:50 year return period. Conditions shall also be checked to assess the risk of floor levels being inundated (buildings, inverters, and transformers) and a flood risk assessment presented to the Employer with the conclusions and potential mitigation measures.
    - The internal drainage system shall be designed for a 1:50 year return period. The internal drainage system shall be designed in a manner that water drains away from the permanent Site infrastructure, and that other infrastructure (such as trenches, ducts, or cable conduits) do not act as part of the drainage system.
- Roads and trafficable areas shall be designed to guarantee a minimum transverse slope of at least 2 % to allow surface water runoff to drain away in accordance with formal flood risk assessments indicating acceptability.
- Existing drainage courses shall be maintained as far as possible. Before any discharges off-Site, the discharge water shall be treated to retain or neutralise unacceptable pollutants. Provisions shall be required in respect of surface water and Plant drainage. All drains and liquids discharged from the Plant shall be disposed in accordance with the EIA, the EMPr, the EA, and the relevant permits.
- Longitudinal or transversal elements of the drainage system shall not block circulation within the solar field which significantly increase the distance to reach Plant equipment for maintenance.
- Surface drainage in areas which may be contaminated by oil shall be routed via an appropriate oily water drainage system with an oil separator.
- Drain channels and ditches shall be covered in concrete in case it is needed due to the water speed, in order to avoid erosion at the bottom and walls of the drain channels and ditches.
- The Contractor shall provide a Stormwater management plan, including the maintenance requirements for the drainage system proposed.
- No water-induced erosion is allowed within the Site. The drainage system shall be designed to prevent erosion.
- All drainage designs shall conform to the SANRAL drainage manual

- The Contractor designs, procures and constructs suitable drainage system for the site according to approved Environmental permit and Water Use License permit.

4.2.8 Construction Specifications

- All civil engineering construction work complies with the requirements of SANS 1200: Standard Specification for Civil Engineering Construction.
- All steel materials supplied and erection of the steelwork comply with the requirements of:-
  a. SANS 2001 – CS1:2012 Ed.1.01 – Construction works Part CS1 – Structural steel works
  b. SANS 2001 – Construction Works – Part CC1 – Concrete Works (Structural)
- For surface treatment of steelwork provided under this contract, see SANS 121: 2011 - Hot dip galvanized coatings on fabricated iron and steel articles - Specifications and test methods and SANS 1200HC: 1988 - Standardized specification for civil engineering construction Section HC: Corrosion protection of structural steelwork.
- All buildings comply with the requirements of SANS 10400: National Building Regulations.
- All buildings works comply with the requirement of the Model Preamble for Trades (1997) as issued by the Association of South African Quantity Surveyors.
- The Employer will provide standard specifications and drawings for security fence. The contractor to adopt the standard design for the local topography of the project.

4.2.9 Project Cooperation

The Contractor's attention is drawn to the work done by others (if any), working on the project, prior to and simultaneously. Close cooperation, exchange of information, careful scheduling and planning on a continuous basis is required to minimise interference and to ensure co-ordination between designs and good working practices are always maintained.

In addition, the Contractor is required to work continuously with the Employer in identifying, assessing, monitoring, and managing interface issues. Where change is required, these items are to be included in the risk register; such changes are only implemented by means of notification to the Employer and the Employer's representatives.

Communication Plan shall development indicating the communication protocols in interaction between all stakeholders

4.2.10 Codes and Standard

The Contractor complies with the latest revisions of the standards as per Appendix C.

4.3 Electrical

4.3.1 Scope of Work

1. The Contractor is responsible for the detail design, plant interface design, manufacture, factory testing, supply, delivery, off-loading, move into position, installation, assembly, testing and commissioning of all new equipment forming part of the PV electrical scope. In line with Quality Controls (QCP) and Inspection & Test Plans (ITP) approved and accepted by the employer
2. The electrical works shall include the following items, but not limited to:
   2.1. The generation equipment including cabling and connection and all auxiliary systems.
   2.2. Protection and control equipment for the whole system, connection, interlocking and inter-tripping.

2.3. Inverter stations (where applicable), operational meters, LV/MV transformer, MV switchgears and auxiliary transformers

2.4. Temporary construction power supplies

2.5. Installation of power supply for trackers (where applicable)

2.6. Electrical building services to all buildings and LV auxiliary distribution board for power, lighting, emergency lighting, ventilation, etc

2.7. Electrical distribution system at voltages suitable for the layout and power requirements

2.8. Internal and external normal and emergency lighting

2.9. Small power systems

2.10. UPS systems

2.11. Lightning protection system and Plant Earthing

2.12. Underground evacuation line for the Plant to its respective substation, according to the Plant layouts, Applicable Laws, Permits and National Regulations and Codes

2.13. Security and surveillance systems and equipment

2.14. Site lighting compliant with the Applicable Laws, Permits, Codes and Standards

2.15. Any additional equipment required to meet the Grid Code requirements at the Point of Connection, such as reactive compensation equipment or harmonic filters.

3. The electrical scope of supply shall include all electrical equipment, whether or not specifically referred to in this section, which is necessary to complete the Works.

4. All electrical supplies, electrical protection, communications, cabling, small wiring, lighting, heating, small power, earthing and any other electrical items shall be provided. All the equipment shall be designed to be maintainable and replaceable with the minimum practicable impact on adjacent equipment and the minimum practicable requirements for enabling works and heavy equipment.

5. The power distribution system shall be designed such that stability of operation, current carrying capacity and satisfactory fault levels are maintained throughout the complete works system under all possible operating, maintenance, and fault conditions. Detailed protection grading studies, fault level calculations and protection settings shall be submitted for acceptance. The Contractor shall provide the following power system studies:

5.1. Load flow studies to assess equipment ratings, voltage profiles and losses.

5.2. Fault level studies - short circuit current levels and flows to assess equipment capabilities.

5.3. Transient stability studies (with information from and to the requirements of the Grid Operator) to assess system responses to events such as fault disturbances and effect of tripping major equipment (evacuation line or transformer).

5.4. Harmonic studies to assess harmonic distortion levels and penetration and effectiveness of any potential mitigation measures.

5.5. Electrical protection studies.

5.6. Equipment rating selection calculation.

5.7. Insulation co-ordination in accordance with SANS 60071.

5.8. Earthing study.

5.9. Interlocking system study in accordance with industrial good practices.

5.10. Grid Code compliance study, in accordance with all requirements of the National Standards, all Applicable Laws, Permits and Codes.

5.11. Any other studies to prove the validity of the design.

4.3.2 Electrical HV interconnection

1. The battery limit is the 132 kV MV voltage level
2. Supply, installation, termination and testing of the respective MV circuits from the Plant to its respective substation (respective MV switchgear located at the electrical room) shall be carried out under the Contractor's scope of works. The EPC Contractor, will be responsible for the underground routing, including the construction of troughs and electrical raceways, of the incoming MV power cables from the PV Plant inside the Collector substation's boundary fences only.
3. The Contractor will be responsible for the routing, including the construction of troughs and electrical raceways, of the incoming MV power cable and Communication cables from the PV Plant Substation to the Point of Connection (POC).
4. Supply and installation of the respective PV Plant's Power Plant Controller (PPC) shall be carried out under the EPC Contractor's scope of works.
5. Any patch cords or communication cables required for connecting the substation control room to the respective Plant SCADA system (via the patch panel cabinet), for connecting the power quality and metering equipment with the PPC, and for the connection of the PPC with the patch panel cabinet shall be supplied and installed by the Contractor.
6. Necessary supply, installation, termination and testing of the fibre optic communication cables, between the substation and the PV Plant shall be the responsibility of the Contractor.

4.3.3 General Electrical Requirements

1. The Plant shall be capable of operating within the technical limits specified in this section and according to all Applicable Laws and Regulations, Standards, Permits and Codes:

   1.1. All electrical components must be contained in component specific enclosures following the OEM's recommended IP enclosure rating and taking into account the most extreme climatic and environmental conditions on the Site.

   1.2. The Plant shall be designed for 1,500 VDC configuration.

   1.3. Designed access systems to electrical equipment shall comply in full with the requirements and recommendations of the relevant Standards. Specific attention shall be given to meeting the appropriate safety legislation and approved codes of practice.

   1.4. All equipment shall be designed to ensure the continuity of operation under all working conditions and climatic conditions on Site as the first consideration and to facilitate inspection, maintenance and repairs and maximise availability. The system design shall ensure a high level of reliability, which shall be achieved by adopting suitable redundancy and sparing philosophy.

   1.5. All precautions shall be taken in the design of equipment and of the Plant to ensure the safety of personnel concerned with the operation and maintenance of the Plant. Safety, isolation, locking, and interlocking facilities shall comply with the Standards and Good Industry Practice.

2. Unless otherwise specified, the minimum equipment enclosure classifications for non-rotating electrical equipment shall be as follows:

   2.1. Indoors only in totally enclosed rooms with provision for limiting ingress of dust: IP31.

   2.2. Indoors, except as noted otherwise: IP54.

2.3. Indoors in areas subject to water spray, or heavy condensation: IP55 or better.

2.4. Outdoors except as noted otherwise: IP55 or better.

3. All switchgear, transformers and other electrical equipment shall be capable of operating at its rated current continuously, without overheating, at full power and shall take account of the temperature rise of the equipment from other sources, preferably without assistance from forced cooled ventilation or air conditioning. Where reliance on forced cooled ventilation or air conditioning is necessary the cooling system will be at least N+1 redundant.
4. Electrical equipment shall be constructed to withstand the specified maximum short circuit currents and durations without the temperature exceeding the value permitted for the related class of insulation. The equipment shall be considered as being operated at maximum permitted current prior to the inception of short circuit current.
5. The final temperature attained as a result of the passage of short circuit current shall not cause permanent damage or deterioration sufficient to reduce the normal operating characteristics below those specified.
6. Electrical equipment located in hazardous areas shall be provided with special enclosures suitable for hazardous classification of the areas according to the guidelines provided in statutory regulations and codes. All equipment installed or used in hazardous areas shall be certified as suitable for such.
7. The Contractor shall comply with Codes and standards listed in Appendix C of this specification.

4.3.4 PV Capacity

1. The Contractor uses the area designated in the Environmental Permit and Water Use License Permit for design and installation of the Solar PV Plant.
2. The minimum installed DC Capacity shall be 28 MWp. The Plant installed DC Capacity is the sum of all the installed PV module rated nominal power output at Standard Test Conditions (STC).
3. The installed DC to AC rated capacity of PV Plant is further optimised considering the local climatic and environmental conditions.
4. The PV array sizing does not overload and overheat its corresponding inverter (as per manufacturer's recommendation) at any time during the year.
5. The Contractor designs the string size in such a way that the inverter always operates within its MPP range throughout anytime of the year and throughout the project lifetime.

4.3.5 The Contractor provides the PV capacity information according to requirements set in the Appendix C: Tender Returnable Schedule Technical Schedules in the 559-1098627662 Tutuka Solar PV Plant Tender Technical Evaluation Criteria.PV Modules

1. The Contractor supplies and installs the PV Modules to achieve the specified levels of performance (set out in section 4.12 of this document) for the required design life of 25 years under the prevailing site environmental conditions.
2. The PV modules shall be crystalline silicon technology.
3. The PV Modules must have been installed in at least three (3) commercial plants of similar DC peak power which have been in successful operation for at least one (1) year.
4. All PV modules shall be installed according to the manufacturer's specifications.
5. If using multiple-row trackers that are driven by a single actuator, then all rows/tables driven by the actuator shall be connected to the same inverter.

6. The selected PV module manufacturer shall be on the Bloomberg New Energy Finance (BNEF) PV Module Tier 1 list as of the date of publishing of the tender documents. Locally assembled PV modules could be considered as Tier 1 if a clear link can be demonstrated to one of the manufacturers appearing on the BNEF Tier 1 list. The Contractor provides proof and supporting documentation that the offered PV module manufacturer is on the BNEF PV Module Tier 1 list.
7. The bidder shall provide a PV module datasheet indicating the Tier 1 manufacturer name and a letter from the manufacturer stating the PV module relevant track record information referred to above.
8. All PV modules to be supplied for the Plant shall be of the same type, make, size, and from a single manufacturer.
9. The PV module manufacturer selected shall also be DNV/TUV/Bureau Veritas/IEC or third party certified.
10. Minimum technical characteristics for the selected PV modules shall be:
    10.1. The photovoltaic cells of the PV modules shall be activated in the solar spectrum as defined by STC within SANS 61215-1.
    10.2. PV modules shall comply with a minimal safety class II according to IEC 60364-4-41:2005+AMD1:2017, SANS 61140 & SANS 61204.
    10.3. PV module rear junction box should include at least 3 by-pass diodes to protect against partial shading and module overheating as well as fly leads fitted with IP67 rated pin type "multi-Contact" connectors or equivalent with a clear indication of polarity for the connections, connectors must not be interchangeable, and have an ampacity rating not less than the maximum series fuse rating of the PV module.
    10.4. PV modules shall have a positive initial power tolerance.
    10.5. PV module cables shall be long enough to allow the PV modules to be interconnected electrically in series to form the desired strings inter-connection between the PV modules with a minimum length of 1 meter.
    10.6. PV module cable connectors shall be at least IP67 rated (as defined in EN 60529), pin type "multi-Contact" connectors or equivalent with a clear indication of polarity for the connections. Connectors shall fulfil the safety requirements and tests of EN 62852, must not be interchangeable, and have an ampacity rating not less than the maximum series fuse rating of the PV module.
    10.7. The PV module connectors must be protected against dust and water while waiting to be plugged with PV cable connectors.
    10.8. All PV module connectors shall be same type and make.
    10.9. PV modules independent PID testing, and verification tests should be performed, and results provided in accordance with SANS 61215 and SANS 61730-1.
    10.10. The Contractor provides the flash test data from the manufacturer (measurement according to IEC 60904-1) for each module to be installed in the project. The sum of power in flash test data is equal to or higher than peak power of the Plant.
    10.11. The Contractor is responsible to decide the module arrangements to minimize the losses due to mismatching. The Contractor uses a proper sorting method and only modules from the same set are used in the same string.
    10.12. The PV modules shall be capable of operating in the most extreme climatic and environmental conditions on Site and will be designed to ensure the highest possible reliability in operation and to ensure minimum and efficient required maintenance over the lifetime of the installation.

10.13. The PV modules must be certified for resistance to a suction pressure of 2400 Pa and an increased distributed mechanical load of 5400 Pa on the front glass surface (wind, snow, hail and ice).

10.14. The encapsulant used for the PV modules should be polyolefin based, UV resistant and PID resistant in nature. No yellowing of the encapsulant with prolonged exposure shall occur. The encapsulant shall have the following properties.

Parameter	Value
Gel content	> 75%
Transmittance	>90%
Volume resistivity	> 1×10^{15} Ω.cm
Peeling strength with glass	> 40 N/cm

10.15. The sealant used for edge sealing of PV modules shall have excellent moisture ingress protection with good electrical insulation (Break down voltage >15 kV/mm) and with good adhesion strength. Edge tapes for sealing are not allowed

This is already addressed in the IEC standard EN1895 and for gel content ASTM D-2765 then during transportation ASTM D 1876 are Quality Control in test in adhesion, Crosslinking Ration and Dimensional stability

10.16. The active electrical components within each PV module shall be electrically insulated from the metal casing (frame), the rear cover and the front glass surface. The insulation must withstand 1,500 VDC between the short-circuited module output leads and the metal frame and the rear and front covers.

10.17. PV modules shall have a front surface protected with tempered glass and a manufacturer-applied anti-reflective coating. The PV modules have frames sufficiently resistant to corrosive environments (Aluminium Alloy, Anodized Aluminium, etc.). Frameless PV modules shall not be considered.

10.18. The module frame shall be made of anodized aluminium, which shall be electrically & chemically compatible with the structural material used for mounting the modules. It is required to have provision for earthing to connect it to the earthing grid. All transportation, storage, handling, and installation of the modules are in accordance with the specifications from the manufacturer, so as not to void the module manufacturer's warranty.

11. Each PV module shall permanently display a technical characteristics nameplate carrying the following information as a minimum:

11.1. Name of manufacturer

11.2. Type or model number

11.3. Serial number

11.4. Polarity of terminals or leads (colour coding is acceptable)

11.5. Maximum system voltage which module is suitable for

11.6. Safety class

11.7. Date and place of manufacture on label or traceable from serial number

11.8. The nameplate itself shall be designed for minimum design lifetime of 25 years under high UV radiation and temperature

12. Moreover, the PV modules shall comply with the following technical specifications:

12.1. Module efficiency, greater than or equal to 20%

12.2. Bifaciality Factor, where applicable, shall be greater than or equal to 70% ±5%

12.3. Minimum cell temperature of -40 °C

12.4. Operating temperature between -40 °C and 85 °C

12.5. PV Module design lifetime greater or equal to 25 years

12.6. Nominal Module Operating Temperature (NMOT) lower than or equal to 44 °C ±2 °C (NMOT @800 W/m2, 20 °C, AM 1.5, Wind speed 1 m/s)

12.7. Maximum Power Temperature coefficient greater or equal to -0.37%/°C

12.8. Guaranteed light induced degradation lower or equal to 2%

13. The PV modules minimum guarantees from the manufacturer are:

13.1. Guaranteed minimum power output of 98% during the first year of operation.

13.2. Linear maximum degradation coefficient guarantee of 0.55 % per year from year 2 to year 25

13.3. Guaranteed minimum output of 90% of the nominal power after 10 years of operation

13.4. Guaranteed minimum output of 80% of the nominal power after 25 years of operation

13.5. Workmanship Product guarantee against manufacturing defects for a minimum of 10 years

14. The PV module manufacturer shall comply with the following:

14.1. ISO 90001 — Quality management system

14.2. ISO 14001 — Environmental management system

14.3. OHSAS 18001 – Occupational health & safety

15. The Contractor verifies the quality of PV modules according to the requirements set in the inspection, test, and commissioning section of this specification. In addition, the PV modules shall have valid certifications issued by reputable testing institutions according to IEC and other standards, such as:

15.1. SANS 61730-1: Photovoltaic (PV) module safety qualification, Part 1: Requirements for construction

15.2. SANS 61730-2: Photovoltaic (PV) module safety qualification, Part 2: Requirements for testing,

15.3. SANS 61215: Crystalline silicon terrestrial photovoltaic (PV) modules — Design qualification and type approval

15.4. IEC 61701: Photovoltaic (PV) modules – Salt mist corrosion testing

15.5. IEC 60068-2-78: Environmental testing - Part 2-78: Tests - Test Cab: Damp heat, steady state

15.6. IEC 60068-2-68: Environmental testing — Part 2-68: Tests — Test L: Dust and sand

15.7. Module flash test data from manufacturer, measurement according to IEC 60904- 1: Photovoltaic Devices- Part-I: Measurement of Photovoltaic Current-Voltage Characteristic

15.8. IEC TS 62804: Photovoltaic (PV) modules - Test methods for the detection of potential-induced degradation

15.9. ISO 17025 conformity requirements

15.10. Limited product and peak power warranty

16. The Contractor provides PV modules complying with the minimum specific technical requirement set in the Tender Technical Schedules.

4.3.6 DC Interconnections and Cabling

1. Purpose designed double insulated PV cables and safety connectors shall be used for all DC connections. The DC cables shall be designed according to National Standards and International Standards, and shall have the following minimum technical requirements:
    1.1. All cables and connectors used in the PV array shall be of solar grade and rated for harsh climatic conditions, including high temperatures, UV radiation, rain, humidity, and dirt for the design life (25 years) of the Plant.
    1.2. Cables' insulation material and cable routing method should be in accordance with any applicable Site restrictions.
    1.3. The bifacial PV modules, where applicable, must account for the maximum current that could be generated from the rear side shall be considered for defining the maximum current generated by the PV modules for the cable sizing calculation. To define the maximum current from the rear side the worst-case scenario as a combination of the following needs to be accounted for:
        1.3.1. Highest possible albedo on Site.
        1.3.2. Highest bi-faciality gain considering the whole tracker motion range, sun geometry and irradiance.
    1.4. Wires with sufficient capacity shall be designed and used so that maximum DC voltage-drop (including diode voltage drop) between the PV modules and the inverter at full power complies with all applicable SANS Standards and Codes.
    1.5. Cable terminations shall be made with suitable cable lugs & sockets, crimped properly, and passed through brass compression type cable glands at the entry & exit point of enclosures, or equivalent.
    1.6. When using lugs for cable termination, tinned copper lugs are required when terminating copper conductors, and aluminium lugs when terminating aluminium conductors. When terminating aluminium conductors onto equipment with either copper or brass terminal fixing points, bimetallic lugs shall be used.
    1.7. All cable/wires shall be clearly marked with permanent and UV resistant markings identifying type, place of manufacture, and date of manufacturer.
    1.8. Enhanced resistance to heat and fire, with low smoke emissions, and halogen free.
    1.9. DC voltage maximum rating of 1,500 V.
    1.10. Wiring located above ground and secured to the PV Module mounting structures shall be secured to the mounting structures utilizing UV-resistant devices and secured in a manner such that no exposed wiring is in direct contact with unfinished metal edges or direct sunlight.
    1.11. DC cabling shall not be located above ground except when fastened along the PV module mounting structures. DC cable runs between structure rows shall be underground.
    1.12. String cables between the PV modules and the string combiner boxes / string inverters do not need to be armoured. However, if directly buried they shall be protected by corrugated HDPE conduit, including from the trench up to the electrical enclosure termination point or one (1) meter above ground, whichever is less.
    1.13. Conduits shall be sealed with a proper material to take environmental conditions into consideration, i.e., UV light, rain, etc., preventing water and animal ingress.
    1.14. Cables between the string combiner boxes and the inverters shall not be armoured. Both ends of the cable (from the trench up to the electrical enclosure termination point or one (1) meter above ground, whichever is less) shall be protected by corrugated HDPE conduit. Conduits shall be sealed with appropriate expanded foam spray or similar to prevent water and animal ingress.

1.15. All string and main cables must be permanently labelled at both ends. The label shall provide information about the corresponding inverter, string combiner box, and string number.

1.16. All cables must be fixed. Under no circumstances shall cables bear any mechanical load on their terminations (strain relief).

1.17. Cables shall be tied or cleated to cableways using materials specifically designed for UV resistant tie elements. Cables shall be arranged neatly in cableways and bundled, where and if appropriate. Conductive cable ties shall not be used on single-phase cables. Cables shall be properly supported and secured to avoid loose cables and the risk of undue mechanical strain. Cableways shall be selected and erected so as to minimise the damage arising from mechanical stress, e.g., by impact, abrasion, penetration, tension, or compression during installation, use, and maintenance.

2. Cables shall be arranged and securely fastened to structures with suitable cable tie solutions noting that:

2.1. Cables to avoid direct contact with sharp edges of metallic components of the structure

2.2. Cables to be protected against direct sunlight, considering UV-ducting protections when this will not be possible (i.e., for the spaces between the table structures/trackers)

2.3. If using plastic ties, these shall be specifically designed for the purpose of sorting and fastening cables and shall be UV protected and have a design lifetime of 25 years

2.4. If using metallic ties, these shall have proper edge protection to avoid damaging the cables

2.5. Cable joints shall not be allowed.

3. The solar cable to be used shall be unipolar electrolytic tinned copper, class 5 (flexible) and ZZ-F solar type cable according to IEC 60228 (conductors of insulated cables) and SANS 10142 / IEC 60364 (electrical installations), and will have the following minimum characteristics:

3.1. Flame retardant, according to SANS 60332 / IEC 60332

3.2. Halogen free, according to SANS 60754-1 and -2 (Gases evolved during combustion of cables)

3.3. Low smoke emission, according to SANS 61034-1/2. Transmittance luminous > 60%

3.4. Low emission of corrosive gases, according to SANS 60754-2

3.5. Lifetime 25 years, according to IEC 60216-2

4. Alternative solar cable type H1Z2Z2-K 1.5/1.5 1kV (1.8kV) DC according to standards IEC 62930 / UTE C 32-502 can be used. This solar cable will have the following minimum characteristics:

4.1. Flame retardant, according to IEC 60332:2018

4.2. Fire protection, according to EN 50305-9; DIN VDE 0482 part 266-2- 5

4.3. Halogen free, according to IEC 60754-1:2011/A1:2019

4.4. Low smoke emission, according to IEC 61034-1/2:2005/A2:2020.Transmittance luminous > 60%

4.5. Low emission of corrosive gases, according to IEC 60754-2

4.6. Lifetime 25 years, according to IEC 60754-2

4.7. Resistance to ultraviolet rays, according to EN 50618 and TÜV 2Pfg 1169-08

5. In case Central Inverters are used, the cable to connect from the string combiner box to central inverters will be type AL XZ1 (S) 1.5/1.5 (1.8kV):

5.1. Insulation: Cross-linked polyethylene (XLPE)

5.2. Outer sheath: Low smoke zero halogen (LSZH) polyolefin DMO1 type according to HD 603-1,

5.3. Ambient temperature: -40 °C to +90 °C

5.4. Short circuit temperature 250 °C (Five second maximum)

5.5. halogen free, flame resistant, and fire retardant

6. The Contractor designs for cable losses of below 1.5% on DC cable circuits. Evidence of a detailed wiring loss analysis is submitted as part of the design submission.
7. DC string, array and main cabling are selected and installed in such a way to prevent the risk of leakage currents. Single-core conductors are used for the enforcement of cable protection against outer impact.
8. The area inside DC cable loops is kept as small as possible to reduce the induction of unwanted voltages and currents, for example due to lightning strikes.
9. Insulation and resistance measurements are carried out after every cable installation to locate any possible faults and records kept so that faults can be identified in future.
10. Module connectors and DC cables connectors shall be compatible and from the same manufacturer throughout the whole PV Plant.
11. The DC connector type should be MC4 or equivalent.
12. The Contractor uses cables with connectors which are contact-proof and designed to avoid corrosion.
13. The Contractor provides DC connections and cabling complying with the minimum specific technical requirement set in the Tender Technical Schedules.

4.3.7 PV String Combiner Box

1. Strings of PV modules may be combined in parallel in a combiner box, which shall be sized according to the number of string inputs, power, and voltage. The PV combiner box shall have the following minimum technical requirements:

   1.1. Shall be metallic with appropriate environmental protection (plastic combiner boxes will not be accepted) with proper sunshade / sun protections.

   1.2. Protection class IP 65 or above, and mechanical impact resistance shall be at least IK08.

   1.3. Suitably rated load break switch disconnectors for utilisation category DC21B in compliance with SANS 60947-5-1.

2. The combiner box includes a DC short circuit protection device for the disconnection of supply in case of fault conditions.
3. The combiner box includes DC string protection for each string and operates at a maximum DC Voltage of 1500 VDC.
4. The disconnector switch to provide protection and isolation capabilities, which is:

   4.1. Accessible without opening the combiner box.

   4.2. Lockable door switch interlock.

   4.3. Double pole to isolate both the positive and negative PV array cables.

   4.4. Capable of breaking under full load.

   4.5. Equipped with safety signs.

5. The combiner box must have the capability to house the devices for overcurrent protection for each individual string, string level monitoring equipment, on-load disconnector switch for array isolation and surge arrestors for over voltage protection.
6. Over-current protection (fuses with disconnect bases in each positive and negative string input).

7. String monitoring device interface with the SCADA and PPC system for single string current monitorisation and visual alarm in the PPC room in case of abnormal string operation. The protocol used should be able to time stamp the IO of any alarms activated.
8. PV specific surge arrester type II with the appropriate nominal discharge current capacity, maximum surge current, and voltage protection rating.
9. Earthing bars connected to the Plant earthing system.
10. Ventilation lugs to be used to prevent condensation forming inside.
11. Fully labelled and colour coded wiring.
12. Conduit and cable entry into string combiner boxes shall be through the bottom or sides of the enclosure only.
13. The combiner box is equipped with sun shields were exposed to direct sunlight. To prevent overheating inside the box, reduced terminal occupancy is considered. The place of installation location shall be easily accessible and offer a secure base for working on the device.
14. Resistance Temperature Detector (RTD) type or semiconductor type temperature sensor shall be provided to monitor the cabinet temperature.
15. The cable labelling and single line diagram of connections inside the combiner box is kept in each combiner box.
16. The combiner box (only primary combiner boxes if the design considers secondary combiner boxes) includes the string monitoring system which communicates to the SCADA/CMS server.
17. Suitable communication interface shall be provided to communicate the data to SCADA. The following parameters shall be measured/ monitored and made available at SCADA:
    17.1. String current
    17.2. Bus voltage
    17.3. Output current
    17.4. Cabinet temperature
    17.5. DC disconnector switch ON/OFF status
    17.6. SPD operating status

4.3.8 Grid Tie Inverters

1. The Contractor provides a grid-tie inverter arrangement that gives overall optimal energy yield over the life of the Project, considering the site conditions and the proposed module layouts and shading assessment.
2. All inverters to be supplied for the Plant shall be of the same type and from a single manufacturer.
3. The inverters shall comply with all necessary manufacturers' specifications in relation to interconnection with other Plant components. Attention is drawn to the following areas:
    3.1. Inverters can be central or string type
    3.2. The inverters shall be designed and constructed for continuous operation under the most extreme climatic and environmental conditions on Site
    3.3. The inverters shall be designed to provide the required Maximum Capacity at the Point of Connection with power factor 1 and 50ºC of operational temperature.

3.4. Any grounding of negative/positive pole shall be done according to the PV module manufacturer's requirements.

3.5. The Contractor shall employ inverters capable of complying with the Renewable Grid Code requirements of South Africa (power factor, harmonic distortion, voltage ride through, ramp rate control) along with any proposed additional power conditioning equipment

3.6. The harmonic distortion (THD) shall be less than 3% at 100% load.

3.7. The Inverter shall be capable of providing reactive power compensation at night

3.8. The inverter shall meet all relevant Laws, Consents, and Standards including but not limited to the following requirements and international standards:

3.8.1. Protection type IP (SANS 60529)

3.8.2. SANS 62109-1, IEC 62109-2

3.8.3. Equipment safety and protection class (SANS 62103 or EN 50178)

3.8.4. DC overvoltage protection

3.8.5. Surge protection (SANS 61643-11/-12)

3.8.6. Anti-islanding protection

3.8.7. CE declaration to conformity

3.8.8. DIN VDE 0126-1-1

3.8.9. EMC guideline SANS 61000-6-1, SANS 61000-6-2, SANS 61000-6-3, SANS 61000-6-4

3.8.10. Voltage guideline SANS 62103, EN 50178

3.8.11. Electrical safety SANS 60950-1

3.9. The protection system shall be selected and coordinated in line with the requirements of the Grid Operator

3.10. A proven communication protocol compatible with Plant control system and SCADA system at the substation shall be provided (The chosen protocol must be capable of timestamping of IO signals). All inverters can be controlled / supervised by the same software or SCADA/CMS system presented in this specification

3.11. Incorporate display which shows performance values and faults

3.12. For string inverters, active string monitoring is required

3.13. Each inverter shall be connected to the earthing protection system by an appropriate arrangement

3.14. Inverters shall have at multiple MPPTs.

3.15. Inverter shall have a minimum European efficiency of 98%

3.16. Maximum system DC voltage should be 1,500 VDC

3.17. IP Protection shall be at least IP54 for indoor in case of central inverters and IP65 for string inverters, for outdoor installation and shall be suitable for the Site-specific environmental conditions.

3.18. Inverters are provided with lockable DC disconnect switch and AC disconnect switch for isolation

3.19. If outdoor type inverters are considered these shall be designed to withstand the most extreme climatic and environmental conditions on Site

3.20. If indoor type inverters are considered, these shall be provided within an inverter station/cabin designed to withstand the most extreme climatic and environmental conditions on Site. The air flow and cooling design of the inverter station/cabin should be adequately calculated to avoid overheating of the inverters.

3.21. Each enclosure/station/cabin has sufficient ventilation (or air-conditioning if necessary) to maintain optimum performance and to avoid any unnecessary equipment derating or damage shall be ensured.

3.22. Any conduit coming in and out of the inverter station/cabin shall be sealed with appropriate expanded foam spray or similar to avoid water and rodent ingress.

3.23. The inverters shall be suitably mounted to prevent water or dust ingress and shaded against direct sunlight. Temperature and moisture content control should be provided.

4. In the case where bifacial PV modules are used, the string inverters cannot be installed beneath the PV modules to avoid shadows, hot points, or other potential issues.
5. String Inverters must have a shelter to reduce direct exposure to the sun.
6. The inverters and inverters' manufacturer shall have a proven track record in commercial international projects, and comply with the following requirements:

6.1. All inverters to be supplied shall have been in operation in at least three (3) commercial plants commutative to200 MWac or higher nominal power (not demonstration projects), for at least twelve (12) months and have recorded a technical availability of at least 98% for twelve (12) consecutive months of operation

6.2. The inverter manufacturer shall conform to the following requirements:

6.2.1. Manufactured inverters for more than 5 years

6.2.2. Capacity installed is more than 1,000 MW

6.2.3. Production capacity is more than 500 MW per year

6.2.4. Have supplied inverters to at least three (3) different projects in the past two (2) years which have all been financed non-recourse.

7. A letter of confirmation certifying that the above requirements are met shall be issued by the inverter manufacturer and received by the Employer.
8. The inverter manufacturing facilities should be certified according to:
9. ISO 9001 Quality Management System and in compliance to ISO 17025 were testing and calibration is required this part best addressed in SHE Inverters selected for the Project has a minimum of 10 years product guarantee against manufacturing defects.
10. The Contractor submits calculations for ensuring electrical compatibility between the inverters and the PV modules selected including selection of appropriate inverter dimensioning factor and ensuring system voltages lie within acceptable MPPT ranges across the range of operating conditions for the site and for the long-term operation of the project.
11. All transportation, storage, handling, and installation of the inverters is in accordance with the specifications from the manufacturer, as not to void the inverter manufacturer's warranty.
12. The inverters comply with the minimum specific technical requirement set in the Appendix C: Tender Returnable Schedule Technical Schedules in the 559-1098627662 Tutuka Solar PV Plant Tender Technical Evaluation Criteria.

4.3.9 MV/LV Transformers

4.3.9.1 General Requirements

1. The Contractor designs, manufacturers, inspects, tests, delivers at site, and installs transformers suitable for solar PV duty and all associated scope required for the design life under the prevailing site environmental conditions.
2. The transformers shall comply with all Applicable Laws, Consents, Permits, Codes and Standards, specifically with 240-56227520 Eskom Standard for Large Power Generator Transformers in Power Stations, 240-68973110 Eskom Standard for Specification for Power Transformers rated for 1.25MVA and above and with Highest Voltage of 2.2kV or above and SANS 60076 and all references mentioned in it. It shall also meet SANS 555 (as applicable for mineral oil transformers). Any other relevant standard mentioned in the technical specification and the planning guidelines of the transformer must be respected. Note the Eskom standards take precedence. All transformers shall be of low-loss design and the construction, performance, and testing of the transformers shall be in accordance with SANS 60076.
3. All transformers shall be of low-loss design, and the construction, performance, and testing of the transformers shall be in accordance with SANS 60076 and type tests shall be performed for each transformer design.
4. All transformers shall be oil filled type except indoor type auxiliary transformers that shall be dry type.
5. The transformer windings shall be copper or aluminium and shall be suitably bonded and braced to provide adequate short circuit strength. All terminal connections shall be made of copper.
6. All transformers shall be equipped with tap changers. The diverter switches of all on load tap changers shall be in a separate tank from the transformer windings and the oil level maintained from the main tank oil conservator. The no-load voltages, tap range, impedance, and losses shall be selected to enable full output under all operating conditions which allow for the highest and lowest system voltage operation and shall not be restricted over the specified ambient range. The calculations of the tapping range shall be subject to approval by the Employer.
7. In the event of cost justification, the step-up phase-shifting transformer with controlled thyristor circuit for secondary voltage of 132kV will be preferred, which will be grid-tied to the distribution network for control of power flow
8. The radiators may be mounted separate from the tank or mounted on the transformer tank and shall be hot dip galvanized, whilst the transformers' tanks, conservators and marshalling kiosks shall be painted.
9. The protection class shall be at least IP55 for outdoor transformers and at least IP4X for indoor transformers.
10. Vibration and noise levels of all transformers shall be in accordance with best commercial practice, the acceptable value is less than 85 decibels. Every care shall be taken to ensure that the design and manufacture of all transformers with their accessories shall be such to reduce noise and vibration to acceptable level and to comply with special requirements on safety and reliability.
11. Where the bottom plate of the transformer tank will be in direct contact with the surface of the foundation, anti-vibration pads shall be provided for insertion between the transformer and its foundation.
12. The anti-vibration mountings shall be of oil and weather resisting rubber or other approved material, capable of operation at temperatures from -10 ºC to +80 ºC. Due regard shall be given to irregularities in the tank base and the plinth surface. Anti-vibration mountings for separately mounted equipment such as coolers and pumps are not required.

13. For MV/LV transformers with exposed electrical parts, access to the transformer must only be possible when the low voltage switch is open and the earth switch on the medium voltage side is closed.
14. The transformers are designed with adequate transformer protection with the following as minimum:
    14.1. restricted earth fault protection
    14.2. over current protection
    14.3. thermal overload protection
    14.4. Over voltage protection
15. The Contractor provides a full set of type test reports along with operation and maintenance manual for the transformer. The O&M manuals are in addition to any instructions or parts lists packed with or attached to the equipment when delivered.
16. The LV/MV transformers selected for the Project comply with the minimum specific technical requirement set in Tender Technical Schedules.

4.3.9.2 Oil filled Transformers

1. All oil filled transformers shall comply with the relevant environmental, fire safety, and local regulations and Standards. No oil filled transformer shall be installed indoors.
2. The oil used as insulating medium shall be biodegradable.
3. All oil filled transformers shall be fully oil sealed without requiring any refilling activity for the entire lifecycle.
4. The transformer shall be designed to withstand the three-phase short circuit on the low voltage side for maximum fault current and three second duration.
5. Insulation material shall be Class A and it shall be constructed by thermally upgraded insulation paper.
6. Each transformer shall be complete with oil conservator, oil level indication/alarm, silica gel breather, oil temperature/alarm/tripping, pressure relief/alarm/tripping, quick pressure rise relay and Buchholz gas and surge protection/tripping/alarm. In addition, each transformer shall include winding temperature indication with alarm and tripping contacts.
7. A magnetic type of oil level gauge showing the full oil level range shall be provided for each individual section (main tank and on load tap changer as applicable) of the vessel. In addition, high and low oil level alarm back to the Plant SCADA system shall be provided together with the oil level indication and measurement of the oil temperature.
8. Oil transformers will have sampling devices which shall be fitted at the top and bottom of the transformer main tank so that oil samples maybe taken with the transformer energised. The sampling at the top of the LV/MV transformer shall include a down pipe and valve to enable the oil samples to be collected at the bottom of the tank (no more than 1.2 m from ground level).
9. Cooling shall be either ONAN or ONAF. Where ONAF is proposed, the Contractor shall justify the use of ONAF cooling system.
10. The climatic class is C2, suitable for outdoor installation. The transformer is suitable for operation, transport, and storage at ambient temperatures down to -25 ºC.
11. The fire class is F1 as transformers may be subjected to fire hazard, hence restricted flammability is required.

4.3.9.3 Dry Type Transformers

1. Dry type transformers shall conform to the requirements of SANS 60076-11 and shall be categorized as follows:
   1.1. climatic class C2
   1.2. insulation class F
   1.3. environmental class E2
   1.4. fire behaviour class F1
2. Only flame retardant and self-extinguishing materials shall be used for the construction of dry type transformers. No fillers must be added to the cast-resin moulding material that would reduce its mechanical stability.
3. The thermal expansion of the windings (either copper or aluminium) and the cast-resin shall be duly considered, and room shall be provided to take care of thermal stresses that might result from different thermal expansion coefficients.
4. Dry type transformers shall have AN (Air Natural) type of cooling.
5. Winding temperature indication shall be provided through two redundant winding temperature sensors PT100 with pockets at each low voltage winding of each phase. The temperatures will be monitored by the Plant SCADA system in the Plant control room.

4.3.9.4 LV/MV Inverter Transformers

1. The LV/MV inverter transformers shall be used to connect the inverters to the MV AC collection system. LV/MV inverter transformers shall step up the inverter output voltage to MV, where the rating of the transformer shall not be less than the maximum AC rating of the associated inverter(s). The transformer manufacturer shall formally confirm the compatibility of the inverters with the LV/MV transformers.
2. The power load of the LV/MV transformer shall be designed to withstand the entire operating range of the inverters at different temperatures.
3. If the LV/MV Inverter transformers are located in the same housing as the inverters, local requirements in terms of protection and separation between the two components shall be followed.
4. The LV/MV transformer shall comply with the following:
   4.1. Three-phase
   4.2. The transformer is a two or three winding transformer. Where a three winding transformer is used, two of the windings are for the low voltage (LV) side where two inverters can be connected, and the third winding is for the MV side of the transformer
   4.3. Equipped with cooling system suitable for intended installation
   4.4. Designed, procured, and tested in compliance with SANS 60076
   4.5. Rated MV voltage level: to be determined by the Contractor according to MV grid rated voltage or MV/HV transformer rated voltage
   4.6. Rated LV voltage level: to be determined by the Contractor according to PV inverter AC rated output voltage
   4.7. Off load tap changer with minimum five positions -5%, -2.5%, 0, +2.5%, +5%
   4.8. Protection against overload, short-circuit up to inverter, internal failure, over-temperature, overpressure

4.9. Suitable for the environment at the Project Site

4.10. Specific data of transformer shall be guaranteed: load and no-load losses, impedance (%)

4.11. Condition monitoring shall be provided (e.g., oil temperature, oil level, pressure, etc.)

4.12. All documentation, certificates and test protocols shall be provided

4.3.9.5 Auxiliary Transformers

1. The auxiliary transformers shall be designed so that with the whole Plant running at full load, the transformers low voltage windings will be loaded as follows:

   1.1. 80% in case of 1 x 100% transformers

   1.2. 40% in case of 2 x 100% transformers

2. The auxiliary transformers shall be indoor/outdoor type. If they are indoor type, they shall be flame retardant dry cast resin transformers. Furthermore, they shall be located adjacent to the associated switchboards in a suitable safety enclosure, connected by busbars or by cable connection to the associated switchboard.
3. Connections to the transformer bushings shall be by flexible copper connections. It shall be possible to remove these flexible connections to permit testing of the cables and transformer separately.
4. Auxiliary transformers shall have a manually operated off-load tap-changer (2 x ± 2.5%, with changeable terminal connections) on the high voltage side.

4.3.10 Switchgear

4.3.10.1 General

1. All switchboards shall be of the industrial, extensible, metal clad, cubicle type arranged as freestanding units with minimum ingress protection of at least IP 54 and constructed and tested in accordance with the appropriate Standards.
2. All MV switchgear shall be designed for a nominal voltage according to SANS 1019 and SANS 62271, to be internal arc certified IAC AFRL according to SANS 62271-200.
3. A type test certificate compliant with SANS shall be supplied for the unit(s) offered. For RMU switchgear, the short-circuit rated duration requirement of one (1) second is acceptable.
4. The rated insulation levels (rated short-duration power-frequency withstand voltage, rated lighting impulse withstand voltage) shall be according to the SANS/IEC 62271.
5. The switchgears shall be equipped with suitable anti-condensation heaters and shall be designed for bottom entry MV cables.
6. The LV switchgear shall be designed for a nominal voltage of 400/230 V (according to SANS 1019) and to withstand a short-circuit current of minimum 10% higher than required by calculations for a duration of one (1) second.
7. Switchgear busbars, circuit breakers, cable compartments and LV compartments shall all be contained in separate compartments and barriers shall be provided between the compartments to prevent the spread of ionised gases.
8. Busbars shall be manufactured from electrolytic copper and shall be capable of carrying full current continuously along the entire length of the busbar without exceeding maximum allowable standard temperatures. Busbars, busbar connections, and insulation materials shall be capable of withstanding, without damage, the thermal and dynamic effects of short-circuit fault current according to the

outcomes of the electrical power system studies, equivalent to the short time rating of the associated switchgear. Facilities shall be provided to accommodate thermal expansion of the busbars and associated components.

9. Check-synchronising facilities shall be provided as required. The switchgear main incomers, interconnectors, and bus-section circuits shall be interlocked according to SANS 62271-200 to prevent the paralleling of two incoming supplies to a switchboard.
10. For emergency operation of MV feeders and LV incomers, mechanical off switches shall be provided.
11. All the withdrawable units of the assemblies shall have the following positions:
    11.1. Service
    11.2. Disconnected-test
    11.3. Disconnected
    11.4. Removed
12. The MV switchgear shall be fixed pattern with SF6 as an insulating medium and equipped with vacuum circuit breakers.
13. The switchgear shall include integral fault making earth switches for circuit and busbar earthing.
14. The circuit breaker shall be of the fault making, fault breaking and load breaking type rated for the associated system maximum fault current and capable of carrying the maximum continuous load current.
15. The 400-690/230V switchgear shall incorporate air insulated circuit breakers, moulded case circuit breakers (MCCBs) and contactor units as necessary. The construction form shall be Form 4B as per the requirements of SANS 61439. Shutters shall be provided to cover each set of stationary contacts and shall be automatically operated on the withdrawal of the truck or part and shall include provision to lock the mechanism to prevent access to the contacts.
16. The LV switchboard shall have a short circuit withstand capability of not less than 50 kA for one second.
17. Control of the LV switchgear shall be of the conventional hard-wired type and connected to redundant gateways or remote I/O cubicles of the Plant SCADA system.
18. All AC and DC LV switchgear shall be designed as type tested assemblies (TTA).

4.3.10.2 MV Ring Main Unit

1. The MV Ring Main Unit (RMU) shall be compact, hermetically sealed SF6 type and shall be gas tight for life. A manometer shall be provided for monitoring SF6 gas pressure. A voltage presence indicating system to monitor the cable voltage during operating and maintenance phases shall be provided.
2. The RMU shall include:
    2.1. Switch disconnectors on cable feeder circuits
    2.2. breaker, IDMT, definite time overcurrent and earth fault protection on transformer feeder circuits
    2.3. LV phase rotation meter
    2.4. Voltage presence indicator
    2.5. Cable Clamping facilities
    2.6. Two (2) Incoming feeder functions for managing the energy that comes from the other inverter stations and optimally place into the internal MV network (depending on MV design)

3. At least One (1) gas insulated switchgear of circuit breaker protection function to protect the transformer on the MV side. The CB units shall have a suitable electronic relay with the capability to perform protection (overcurrent, earth fault, under-and –over voltage protection), fault recording and calculation functions, remote control and monitoring of the breakers.
4. At least One (1) gas insulated switchgear of circuit breaker protection function to protect the transformer on the MV side. The CB units shall have a suitable electronic relay with the capability to perform protection (overcurrent, earth fault, under-and –over voltage protection), fault recording and calculation functions, remote control and monitoring of the breakers.
5. The circuit breaker shall be designed for interrupting full rated fault current, and for making full fault current according to SANS 1874. The insulation medium shall be SF6 gas, and the interrupting medium may be either SF6 or vacuum.
6. The relay and all associated equipment offered should as far as possible be specified for use with AC power supplies.
7. The protection relay is installed for each circuit breaker forming part of the RMU and all necessary relays for control of the switchgear will be state-of-the-art and comply with relevant SANS standards.
8. Cable switch disconnectors and earth switches shall be load breaking and fault-making type and comply in all respects with SANS 1874. Switches shall be designed for interrupting full rated current, as well as small inductive or capacitive currents involved in disconnecting cables.
9. Each switch-disconnector, switch-fuse combination, circuit-breaker and earth switch shall be capable of being padlocked in the OFF and the EARTH positions.
10. Padlocking shall be provided to prevent the selection of the ON position while permitting operation from OFF to EARTH or from the EARTH to OFF positions.
11. All padlocking facilities shall be suitable for padlocks with 6 mm diameter shanks.
12. Circuit breaker disconnects switches and earth switches capable of being operated locally and remotely.
13. Be a modular unit, self-contained in a metallic enclosure with all equipment to perform a single function.
14. 162.301. Adequate mechanical interlock system (interlocking keys) designed (according to SANS 1874) for the circuit breakers, disconnect switches and the earth switches to prevent mal-operation and to ensure operator safety is required. The design of the interlock system shall prevent the operator from physically overriding the interlock controls.
15. All necessary metering devices
16. Earthing switches in each cubicle
17. Capacitive voltage detectors in each cubicle
18. The RMU consists of the following switchgear as a minimum:

    18.1. MV Circuit Breakers for transformer protection.

    18.2. Position indication of each RMU switching device shall be integrated to the plant SCADA system.

    18.3. Where RMU is not used, appropriately sized separable tee connectors shall be used to terminate cable to the transformer such that a failed transformer can be safely bypassed while keeping the rest of the radial circuit connected.

    18.4. It shall be appropriately rated such that a failed transformer can be safely bypassed while keeping the rest of the radial circuit connected. It shall not be close coupled to the transformers.

18.5. The LV auxiliary supplies shall be either of TN-S (separate PE and N conductors) or of the TN-C-S type with combined PE&N conductor (TN-C) from transformer to the main distribution, but separate PE and N conductors in the distribution and all connected consumers (TN-S).

19. The contractor considers a design where the RMUs are located within the in the inverter MV station/cabin.
20. The RMU complies with the minimum specific technical requirement set in Tender Technical Schedules.

4.3.11 Inverter MV Station

1. The Contractor shall at minimum house inverters and associated protection and control equipment and LV/LV auxiliary transformer in an enclosed MV station/cabins.
2. The LV auxiliary supply to the MV station/cabin is provided by an LV/LV transformer inside the MV station/cabin. This transformer taps off the output of the inverter and steps down to the applicable voltage level required by the auxiliary loads located in the field. Field loads are equipment such as HVAC systems, lighting, etc., and any other necessary equipment as shall be determined by the Contractor.
3. Where all equipment is enclosed in the cabin, the MV station/cabin is approved by the inverter, transformer and switchgear manufacturers and does not violate any warranties and guarantees for the equipment.
4. The MV station/cabin includes a cooling/ventilation system which allows the equipment enclosed to operate within the manufacturer's recommended operating range without deration of output (power, efficiency).
5. A fire protection detection assessment is undertaken by the Contractor to inform the measures for protection against fire hazards within and surrounding the MV station/cabin.
6. The MV station/cabin offered for the Project has already been deployed in utility scale PV projects with minimum capacity of 5 MW.
7. The MV station/cabin has a minimum of 10 years product guarantee against manufacturing defects.
8. The MV station/cabin is designed and protected to withstand outdoor conditions for a 25-year period.
9. The MV station/cabin is pad lockable to prevent unauthorised access.
10. The MV station/cabin selected for the Project complies with the minimum specific technical requirement set in Tender Technical Schedules.

4.3.12 Protection and Control

4.3.12.1 Plant Step Up (PSU) Transformer Protection

1. The MV transformers shall be provided with at least the following protection functions as per ANSI Standard Device Numbers (ANSI/IEEE Standard C37.2-2008):
   1.1. Restricted earth fault
   1.2. Overcurrent
   1.3. Buchholz Transformer Tank
   1.4. Pressure relief device tank
   1.5. Oil Temperature Alarm & Trip

1.6. Winding Temperature Alarm & Trip

1.7. Oil Level

4.3.12.2 Protection of Electrical Auxiliary Systems

1. All electrical circuits shall be adequately protected by relays and a suitably rated means of current interruption. The following electrical protection shall be provided as a minimum:
   1.1. Feeders shall be provided with Overcurrent Protection and Earth Fault (GFT) Protection
   1.2. Auxiliary transformers shall be installed in controlled environments and encased in naturally air ventilated enclosures.
   1.3. A winding temperature indicator shall be provide having contacts for temperature high alarm and trip functions.
   1.4. Medium voltage standby earth fault, (voltage displacement supervision) transformer Buchholz, transformer winding temperature, transformer oil temperature, transformer rate of rise of pressure and low level.
2. The above protection shall be realised with relays of the electronic digital type with facilities to enable testing of all functions during normal operation without imposing operational restrictions (i.e., leaving other protection functions active). The relays shall be capable of communicating with the SCADA so that alarms and trip conditions can be seen.
3. MV switchgear protection relays shall be of the electronic digital type with continuous self-supervision. Relays shall be capable of communicating with the SCADA so that alarms and trip conditions can be displayed.
4. LV protection relays shall have conventional relays/releases. Trip and alarm signals shall be hardwired to the SCADA system. Uncontrolled feeders up to 25 A shall be provided with MCB. For 25 A and up to 630 A, MCCBs shall be provided.

4.3.13 AC Cables and Installation

1. The MV cables shall be copper or aluminium and shall be screened, stranded single-core. Single-core cables shall be designed with individually screened cores. MV Cables shall comply with the following minimum criteria:
   1.1. XLPE or HEPR cables shall be used
   1.2. MV cables shall comply with the corresponding codes and standards
   1.3. MV cables shall be flame retardant as per SANS 60332-1 and SANS 60332-3
   1.4. MV cables shall withstand the expected maximum electrical voltages during the lifetime of the Plant
   1.5. All MV cables shall be permanent marked and properly identified
   1.6. AC cables shall be designed with a maximum operation temperature of:
   1.7. ≥90 ºC under normal operation
   1.8. ≥250 ºC under short circuit circumstances (five second maximum)
2. Instrument and data cables shall have conductors and insulation appropriate for their duty/location.
3. MV cable screen will be connected in both sides. In case only one side is grounded it should be justified that dangerous voltages do not appear in the non-grounded side (50 V).

4. Cable jointing shall be limited per circuit, and these shall be reviewed by the Employer, together with the joint specifications. Joints must be executed by trained personnel certified by the joint manufacturer. Topographical marking documentation of the position of MV/HV joints to be provided in as-built documents.
5. Suitable de-rating factors for current capacity of the cables shall be applied according to the applicable standards to prevent over heating under design conditions. MV and LV cables shall be sized based on current ampacity, voltage drop, and let through passing energy.
6. All power cables shall be suitable for service at maximum design load and minimum voltage conditions for the Site conditions and shall be capable of sustaining maximum through fault current without damage for the short time rating of the associated switchgear. Power cables with fuse/MCCB/MCB protection shall be capable of sustaining maximum prospective fault let-through current/time.
7. The following maximum voltage drop limits shall apply:

    7.1. Between main switchboards (i.e., supplied by a transformer) and sub switchboards: 2%

    7.2. Between main switchboards (i.e., supplied by a transformer) and static load terminals: 5%

    7.3. Between sub switchboards and lighting loads: 3%
8. Within buildings, cables shall be installed on hot dip galvanized cable trays or racking in a manner that shall prevent the cable being damaged and to minimise the occurrence and spread of fire. Power cables shall be adequately clamped to prevent movement under short-circuit conditions. Single core cables shall be clamped in trefoil formation considering phase cable swapping every 100 m.
9. Duplicated circuits, such as cables that service main distribution switchboards and those cables forming part of emergency/high integrity circuits shall follow different routes or be separated as far as is practicable.
10. Separation shall be achieved by laying cables neatly on trays. MV cables, 400/230 V power cables, and control cables shall be separated from each other. The MV cables shall be placed at the lowest level of the cable routes and in single layers only, followed by LV cables which shall be placed in the next higher levels and control cables placed at the top levels. 400-690/230 V and control cables may be laid to a maximum of two layers. Segregation levels will be according to SANS 10198. Out of the trays/racks and up to the equipment connection boxes, the cables shall be installed in galvanized steel conduits and metallic flexible conduits with external PVC insulation. All transitions from aerial to underground will be mechanically protected (conduit or cable tray with cover), extending 2 m above floor level.
11. LV cables shall be installed with thermal sleeve tape for a better and more durable installation.
12. For LV cables normal colour coding of cable cores as per SANS 1507 shall be used with:

    12.1. 2 cores: red – black.

    12.2. 3 cores: red - yellow – blue.

    12.3. 4 cores: red -yellow - blue – black (green/yellow).
13. All cables external to buildings shall be, as a minimum, laid in galvanized steel conduit or laid on tray or racks within reinforced concrete trenches or above ground on pipe racks. PVC conduits shall be used only for cables laid in ducts in the ground.
14. In all areas hot dip galvanized trays/racks or conduits shall be used and where any damage occurs, they shall be further protected with additional anticorrosion painting (such as cold galvanizing paint). No plastic, PVC, or similar trays and conduits shall be used. Trays/racks installed outdoors shall be provided with covers for protection of the cables against sun radiation.

15. All cable racking/trays shall be bonded to each other as well as to the plant earthing system. The cables trays shall be designed to allow for 20% spare space for future cables and shall have no more than 2 layers of cables in each cable tray.
16. Bottom entry power, C&I cabling shall be used for switchgear, other main Plant and C&I equipment. Cable access to enclosures shall be by compression type cable glands. Glands shall be of non-magnetic metal construction. Gland plates shall be of metal and shall be designed with sufficient inherent rigidity and strength to ensure no distortion with cables installed.
17. Cables and cable trays shall be clearly identified at both ends with a robust and weatherproof cable identification tag that carries the cable/tray number per the agreed identification system. Numbers shall be unique across the Plant and follow the KKS system. Cable rating shall be considered as per SANS 10198.
18. Electrical cables installed underground and/or in adequately meshed sized cable trays/cable ladders/welded wire mesh shall be designed to prevent faunal harm on cables and maintain the design lifetime.
19. Cable tray fixation shall be in accordance with Good Industry Practice, such as earthing, protection from the cutting angle of the structures, protection from UV, durable, regular fixation to prevent sagging, anchoring of the cable tray support to both cable tray and ground, such that the installation maintains the full performance of the electrical system.

4.3.14 Lighting and Small Power

1. The lighting and small power system includes the distribution boards (DBs), single and multi-core cables, conduits, wiring, luminaire brackets, luminaires, switch socket outlets and all other equipment as shall be required in the O&M building.
2. The Contractor installs lighting that is suitable for the area of application, readily accessible for maintenance, and standardized as much as possible, to keep the luminaires and lamp spares to a minimum.
3. The lighting is designed with personnel safety and functionality as the main criteria and shall provide adequate lighting to allow employees to perform their work safely and efficiently.
4. Small power circuits are protected with earth leakage and over current protection circuit breakers. Small power circuits are fed from circuit breakers, which are connected to the normal supply distribution board.
5. The Occupational Health and Safety Act (OHS Act) specifies minimum illumination levels for safety. The illumination level shall not fall below those recommendations. Degradation and environment shall be considered, along with maintenance in accordance with the supplier recommended maintenance plan.

4.3.15 400-690/230V AC and DC Sub-Distribution Boards

1. Sub-distribution boards shall be provided throughout the Plant for local lighting, small power, and welding supplies.
2. The distribution board design, installation, and testing are according to SANS 10142-1 and contains the following minimum equipment:

   2.1. Switch disconnector

   2.2. Overvoltage, overcurrent, short circuit protection
3. A change over switch with an emergency supply power source such as a generator socket shall be provided at the main distribution board and labelled according to SANS 10142-1.

4. Outdoor sub-distribution boards shall be of the weatherproof enclosure type, with IP65 rating. Indoor boards shall be IP54 rated. Additionally, all outdoor installed sub-distribution boards must be equipped with totally enclosed sun canopies.
5. Switchgear installed in electrical operating rooms shall be provided with a minimum ingress protection of IP54. They shall be capable of withstanding the associated fault current until the related protection operates.
6. DC sub-distribution boards shall be provided throughout the Plant for control supplies to switchgear, control panel, and emergency lighting as required.
7. The incoming breaker of all sub distribution boards shall be able to accommodate a lock-out device and be equipped with a remote signal protection tripping relay with adjustable current and time scales.
8. The AC sub-distribution boards shall be either single phase or three phase with a neutral and earth bar, and the DC sub distribution boards shall be of the two-pole type. All distribution boards shall be rated for the full load current of the incoming supply and equipped with an incomer isolating MCCB (4-pole for AC and 2-pole for DC) and with MCBs to provide over current protection to each sub circuit. All equipment installed inside the Sub distribution boards shall be designed and tested for the applicable voltage type (AC or DC).
9. All the space in the distribution boards shall not be fully utilised and shall contain 10% unused switch gear and an additional 20% space for future switchgear to be installed.

4.3.16 PV Plant Auxiliary Supplies

4.3.16.1 Field equipment

1. The LV auxiliary supply required for the PV plant field equipment is provided through a PV field auxiliary supply Distribution Board (DB) which is supplied from an LV/LV transformer which can be located inside the MV station/cabin. This transformer taps off the output of the inverter and steps down to the applicable LV required by the auxiliary loads. These loads can be localised loads such HVAC systems, UPSs, lighting, etc. Backup supplies for the auxiliaries are provided through a UPS system which is fed from the LV/LV transformer. The UPS and associated equipment are in the MV station/cabin.

4.3.16.2 O&M building backup supplies

1. Provision to be made for any new and/or re-purposed existing buildings to utilise back-up power for essential equipment, even during loss of Grid conditions, from either;
    1.1. PV Plant, taking Grid Code limitations into account or,
    1.2. Dedicated PV string for the purpose of providing power to the re-purposed existing buildings.
    1.3. Provision to be made for battery backed-up emergency power that is suitably sized to supply
        1.3.1. admin building lights,
        1.3.2. security camera's/alarms and related equipment required to monitor the plant,
        1.3.3. perimeter lights,
        1.3.4. (communication equipment (e.g. servers and related HVAC),
        1.3.5. Sub-station electrical protection equipment/devices, and
        1.3.6. Fire systems. Battery back-up time to be 24 hours.
2. These batteries can be recharged from the PV Plant or the Dedicated PV string.
3. The backup supply cables shall be provided with adequate protection at both ends.

4. The auxiliary supply wiring and circuit protection shall comply with SANS 10142-1 and SANS 556-1.

4.3.16.3 Construction Supply

1. The Contractor provides own construction power supply during the construction phase of the project.
2. All temporary installations shall comply to SANS 10142-1 and have certificates of compliance.

4.3.17 Earthing System Design, Bonding, and Lightning Protection

1. The earthing and lightning systems shall be designed according to SANS 725, IEC 50522, SANS 60364, SANS 62305 and SANS 61936-1, IEEE 665. All earthing connections will be secure and provided with bolt, nut, and stop washer for a reliable and durable connection. Anti-corrosion coating will be applied where applicable, and particular attention shall be paid to the following:
   1.1. Lightning ground potential rise (GPR) in the context of wire-line technology
   1.2. Lighting ground potential difference
   1.3. Step and touch voltages
   1.4. Electro-magnetic zoning
   1.5. Soil resistivity variation across the site
   1.6. Earth electrode resistance - resistance is a low frequency parameter whilst the assessment and analysis called for lightning with higher frequencies involved
   1.7. Large earth electrodes (example PV field)
   1.8. LEMP (All electromagnetic effects of lightning current via resistive, inductive, and capacitive coupling, which create surges and electromagnetic fields.)
   1.9. It will not be possible to use the structure steel piles as underground earthing electrodes. An independent buried earthing grid shall be installed to which the structure steel shall be connected
2. The Contractor shall be responsible for the design, installation, and testing of a single earth grid/mat for the whole Project which will act as an earth grid/mat for all the Plant equipment, including PV module structures, LV equipment, LV/MV power stations/cabins, MV equipment, HV equipment, buildings and structures. The earth grid/mat will consist of bare copper (Contractor can propose other suitable materials with relevant studies and supporting documentation for Employer´s approval) cable all along the LV and MV electrical cable trenches and along additional dedicated earth trenches in the solar field and the perimeter fence if required to achieve the necessary lightning protection and as per the earthing study. The final specification of the buried copper earth electrode will be according to SANS 60479, IEC 50522/IEEE 80 and recognised Good Industry Practice and the System Operator's approved design requirements. The earthing system shall achieve safe step and touch potentials according to the applicable international standard.
3. Each inverter will have a perimeter earthing grid constructed with bare copper cable and copper earthing rods, as required by the earthing study. The short time current withstand rating of the total earthing installation shall be at least equal to the system designed fault current and backup protection time. The loop impedance of the earthing system shall be such as to ensure that all protective devices operate within the short time rating of the system and such that prospective values of step and touch potential do not approach unsafe values. All underground joints shall be cad welded type.
4. All electrical equipment, metallic frames and supports, structural steel and in general all major metallic structures, fences, cable trays/racks shall be connected to the earthing system. Transformers and switchboards or assemblies containing switchgear equipment shall be provided with two or more earth terminals and each shall be connected to the secondary earthing system.

5. The copper strip sized to withstand the maximum system earth current for one (1) second and to provide suitable mechanical rigidity shall be used. Earthing cable sizes shall be designed according to the respective standards.
6. The Contractor shall also provide a lightning protection system for the PV plant which shall comply with SANS 62305 including the risk assessment and EM zoning as per the standard (EM Zones: SANS 61000-2-5, SANS 61000-4-5 and SANS 61000-4-9). Each lightning protection system shall be bonded to the main Plant earthing system. The Contractor shall ensure that equipment used in the different zones will be suitably rated for these EM zones.
7. The Contractor shall appoint an appropriately qualified 3rd party to conduct a lightning risk assessment that shall inform the design of the lightning protection system for all components of the Plant to minimise the cost to repair physical damage to the Facility due to lightning.
8. Surge protection devices shall be installed to protect the PV system against voltage surges. Surge protection devices shall also be installed at the combiner boxes, inverters' DC inputs and AC sides, distribution boards, and wherever else the Contractor deems necessary.
9. The following minimum requirements will apply:
    9.1. Main Distribution: Provide minimum Over Voltage Arrestors (SPD Type II) and lightning Current arrestors (SPD Type I or combination of Type I and Type II): peak current: 150 kA (10/350 µs), limited peak voltage 94 kV at 10 kA (8/20 µs)
    9.2. Sub Distribution (AC Boards): Overvoltage arrestors (SPD Type II) limited surge voltage: 4 kV at 10 kA (8/20 µs)
    9.3. Control and monitoring system (CMS): Overvoltage arrestors (SPD Type II) limited surge voltage: 1.5 kV
    9.4. DC Boards, PV Array: Overvoltage arrestors (SPD Type II) and Lightning Current arrestors (SPD Type I or combination of Type I and Type II), peak current: 50 kA (10/350 µs), limited surge voltage: 4 kV at 25 kA (8/20 µs)

4.3.18 Grid Connection

1. The Grid connection works is the responsibility of the EPC Contractor and the requirements are specified in Appendix F.

4.3.19 Grid Code Requirements

1. The PV system will be designed to meet the latest requirements of the Grid Connection Code for Renewable Power Plants (RPPs) Connected to the Electricity Transmission system (TS) or the Distribution System (DS) in South Africa, where compliance to this code will be assessed at the POC. A PV plant of 20 MVA or higher falls under Category C of the Grid Connection Code for RPPs, that is, a PV plant with rated power equal to or greater than 20 MVA connected at higher voltage network. Grid code compliance testing is done by the Contractor and witnessed by the Employer or a third party provided by the Employer.
2. The Contractor performs fault level studies to ensure proper sizing of PV Plant equipment (e.g., PV Switchgear, Cabling, DBs, earthmats, etc.).

4.4 Control Monitoring and Communication

4.4.1 Introduction

1. The site will be for most of the time manned, however, capability of remote monitoring via web access is required. There is one operator station for PV control and monitoring system.

4.4.2 General

1. The EPC Contractor shall be responsible for the modelling, design, supply, configuration, testing, installation, integration function testing of the whole works and compliance commissioning thereof.
2. The Tutuka Solar PV SCADA system shall perform all data acquisition, monitoring and control functions of the solar power plant.
3. All necessary information concerning process behaviour, instrumentation, and the integrity of controllers and alarm function shall be available at the Operator Control HMI. The HMI visualizes all process variables locally and in real-time, allowing for complete monitoring and control functions.
4. The Tutuka Solar PV system shall be highly available and reliable; this is achieved via a single fault-tolerant design for centralized communication networks, servers, PLC's/RTU's (both of Automation and SCADA servers), components and essential components, redundantly configured.
5. The PV SCADA systems shall be flexible in their system design, compatible with a wide range of communication protocols for interfacing.
6. The PV SCADA system shall connect to several types of inverters for control and monitoring purposes. The inverters can be Central or String Inverters or a combination of both types.
7. The SCADA system shall interface to multiple communication protocols (such as, but not limited to the following: Modbus Serial/TCP, IEC61850, DNP3, IEC-60870-5-101, IEC-60870-5-104, and as required per detailed interfaced requirements.
8. The Tutuka Solar PV SCADA system shall consist of the following main components:
    8.1. **Interfacing to the PV Inverters** – The automation controllers shall interface to the PV Inverters (either as Central Inverters or as String Inverters, depending on the detailed interfacing design). The automation controllers shall collect all monitoring and control data from the Inverters, MV Transformers, Protection and Measurements Panels, Weather Stations, or additional interfaces as detailed design requirements. Interfacing shall either be with analogue, digital input/outputs or communication protocol.
    8.2. **Interfacing to Weather Stations** – The PV SCADA system shall interface to Weather Stations to acquire meteorological information for performance evaluation and prediction of the Generation of the PV plant.
    8.3. **Operator Control** – The Automation Controllers, SCADA Servers, and associated networks shall be redundantly configured and perform all data processing, storage of historical data, and monitoring and control functions. The Operating Stations (or HMI) shall support the plant operator in performing all monitoring and control functions of the Tutuka Solar PV Plant.
    8.4. **Plant Historian** – The Plant Historian shall be the central repository of all process data. The Plant Historian Server shall provide a long-term archiving function of process data. The plant historian shall allow for reporting, where the report can be built, graphs using historical content can be configured and reported (e.g. exported in commonly used data formats, such as Excel). Export and download of reports to local computer (Microsoft Excel format or pdf format).

8.5. **Engineering Station** – The PV Plant SCADA system shall provide an engineering station where engineering applications for building, configuring, and maintaining the Tutuka Solar PV Plant SCADA system.

8.6. **GPS** – A centralized GPS shall be provided, based upon NTP Time Protocol, and as required per detailed electrical equipment time interfacing requirements. Time Synchronization shall be provided for all equipment forming part of the PV SCADA System.

8.7. **Interfacing to Electrical Systems** – The PV Plant SCADA system shall interface to all electrical systems, substations (such as IED's, whether hardwired or networked). This shall be defined during the Detailed Design stages of the project. The PV SCADA system shall collect measurement data (Voltage, Current, Active and Reactive Power) at the point of interface for the electrical system (e.g., Measurements and Metering Panels) and provide this data to the SCADA system.

8.8. **Interfaces for Grid Control** – The SCADA system shall integrate with National Control (NCC), Standby National Control, and the Regional Control Centre). The SCADA / NCC gateway shall interface for generation control and signal exchange for remote monitoring and control purposes.

8.9. **Interfacing to Ancillary Systems** - The Tutuka Solar PV SCADA system shall interface several auxiliary systems, such as the Fire Detection System, HVAC Systems, and other systems where specified as part of detailed design interfacing requirements.

8.10. Selected Software Related functions of the SCADA System:

8.10.1. HMI Application– The HMI display shall provide as minimum display diagrams, monitoring, event and alarming, supervisory control, trending, tagging, data entry and communication monitoring.

8.10.2. Web-Based Monitoring – The SCADA system and applications shall allow external users to retrieve real-time and historical data. The system shall ensure reliability and security. It shall allow for multiple users to connect at the same time. Historical data shall be available for display, tabular, graphic, chart and gauges.

9. The Contractor will remotely monitor the SCADA /CMS and Inverter systems during the O&M period.
10. It is required that the Employer's staff will be trained to operate and maintain the plant during the O&M period. The Contractor will utilise the local control room on-site during the O&M period for any control and changes.
11. A control room in the O&M building will be utilised for the local control and monitoring of the PV plant. The O&M building will have a server and equipment room for the plant operations and additional required IT infrastructure or servers for site security purposes.
12. Web-based client will grant access to authorised remote users to the PV installation historical and near real-time data.
13. All the Contractor's designs are to follow best engineering practices. Designs and specifications are to comply with International and National standards, specifications, and guidelines. The specification may reference specific standards throughout the section but is not limited to these.
14. The Contractor to design and comply with all Eskom specifications, standards and best practices as stipulated under the Codes and Standards Section.
15. The Contractor to conduct and submit a Reliability, Availability and Maintainability (RAM) study to identify and address single points of failure. The RAM study to consider O&M personnel response time of one (1) hour.

4.4.3 Control and Monitoring System Overview

1. This technical specification document describes the Tutuka Solar PV SCADA plant control and monitoring system. The PV SCADA, control and monitoring system shall comply with the requirements of interfacing to the Grid (Grid Code) and shall provide a modern, intuitive operator interface with a plant historian, trends, and reports.

   1.1. The Scope of Supply shall consist of:

   1.1.1. SCADA Servers, PLC/RTU hardware and software.

   1.1.2. Controls and Monitors hardware and software.

   1.1.3. Network Panels, switches, and fibre communication technologies.

   1.1.4. Configuration, Installation and Commissioning of Systems.

   1.1.5. Factory Acceptance Tests.

   1.1.6. Compliance and Acceptance Tests.

   1.1.7. Grid Code Model development, testing and validation. Modelling shall be performed in compliance with the grid code requirements.

   1.1.8. The Contractor shall perform SCADA and control systems engineering.

   1.1.9. The PV SCADA solution shall comply with cyber-security requirements.

   1.1.10. Operator and Maintenance Training and Documentation supply.

4.4.4 Architecture

1. The SCADA system shall consist of an integrated Human Machine Interface (HMI), Input/output (IO) modules, media converters, remote terminal units, communication infrastructure, inverters, energy meters, and weather monitoring equipment, servers, printers and software (Tutuka Solar PV SCADA Conceptual Architecture).
2. The SCADA systems shall continuously monitor, control, perform storage of information functions and reporting of alarms and events.
3. The SCADA system controls and monitors all grid control requirements applicable to the Tutuka Solar PV Plant and is based on two systems, namely, the Automation Controllers and the Local Plant SCADA systems.

4.4.5 Operating and Control Philosophy

1. Operating Philosophy

The Tutuka Solar PV Plant shall be modelled and designed to operate in an automatic mode producing electrical power for evacuation into the electrical grid/network whenever sufficient sunlight is available, while not exceeding the Maximum Export Capacity (MEC) at the grid nterconnection point. In the event that tracking systems are used, tracking drive units shall be capable of moving all the trackers to the stow position from any position in the event of power outages or when the maximum operating wind speed threshold is exceeded. The system shall be able to automatically revert to tracking mode once the power outage or wind event has passed.

2. Control Philosophy

The solar PV system shall be designed to comply with all legal, safety and technical requirements to achieve the set maximum power evacuation limit from the Tutuka PV plant.

4.4.6 Local Plant SCADA

1. The Local Plant SCADA shall be based on an established supervision and data acquisition platform, and shall provide real-time control and monitoring functions, and shall be designed to record all relevant process data of the PV modules, strings, combiners, of the weather stations, of the electrical substation and grid connection data.
2. Data shall be locally stored on a localized plant historian for long term archive and shall be forwarded to remote centres or enterprise historians for further processing.
3. Standard ergonomic HMI graphics shall be used to display acquired process data.

4.4.7 Plant Process Network and Automation

1. The Process Network shall be redundantly configured, connecting both the Plant Controller and/or Local Plant SCADA.
2. The Process Network shall be based upon Ethernet TCP/IP, with optical fibre as the preferred physical medium (although standard Ethernet Cable (copper) is also acceptable).
3. The automation network shall be a ring network, with a master switch with ring management capability (e.g. redundancy standard protocol). This network connects all systems (such as inverters, electrical substation, grid connection (NCC)).

4.4.8 Alarms

1. The Contractor to provide an Alarm Philosophy for the Alarm Management System. In addition, the Contractor to comply with the 240-56355728 Human Machine Interface Design Requirements Standard.
2. The Contractor to provide alarms as per the alarm Response Procedure and Philosophy to the Regional Control Centre and Employer's local and remote-control room.
3. The Contractor to provide the required alarm and fault reporting to operators and O&M personnel by means of communication platforms such as Short Message Service (SMS), email, and others.
4. The Contractor to ensure alarms relating to the safety of the plant, generated by systems such as the Fire Detection, to be reported to the local and remote Operator Control Room. In addition, these alarms are to be integrated into the site Security System where 24-hour surveillance of the site is maintained in the remote Security Control Room or Regional Control Centre These alarms are also reported to the site response personnel by means of other communication platforms such as SMS and email.
5. All redundant equipment shall be alarmed if a failure occurs in order to return the functional redundant system to service as soon as possible.

4.4.9 Operational Control and Monitoring

1. The Contractor utilises the Control Room of the existing wind plant's O&M building. The Contractor evaluates the viable option for the new server room in the vicinity of the existing covered parking area or on the PV Plant Environmental Approved Area, taking into consideration existing cables and routes, piping, and ducting.
2. As a minimum, the Server Rooms comply with the 32-894 Eskom Server Rooms and Data Systems Standard.
3. The Contractor provides one (1) operator stations in the local Control Room for plant operators.

4. The Contractor to provide the required equipment and works for the Employer to achieve off-site monitoring of the plant. The off-site operator location will have monitoring, alarm, and fault reporting functionality.
5. The Employer provides spacing for a Control Room at their offices for remote monitoring. The Contractor to provide all required equipment, 3rd party interfaces and systems to achieve operational capability remotely.
6. The Contractor provides a 19” rack for a server cabinet in the remote-control room. The single cubicle has active cooling to ensure equipment operate in a controlled environment and complies to Eskom standard, 240-56355731 Environmental Conditions for Process Control Equipment Used at Power Stations. The cabinet has access control to ensure unauthorised accessibility to the server.
7. Remote monitoring is required at the Contractor’s identified offices during the first O&M period of commercial operation. The Contractor to work closely with the Employer to address the detailed design of the IT architecture and required topology, as well as the Cyber Security designs and requirements.
8. The Contractor provides a web-server as part of the Control and Monitoring System (SCADA/CMS) network. The web server securely communicates near real-time and historical plant data to remote web-clients. The web-clients are remotely based users (off-site) with authorised access to monitor the plant in near real time via web browsers such as Mozilla Firefox, Google Chrome, and Safari.
9. The Contractor provides interface communication between the SCADA/CMS network and 3rd party Employer’s networks. Furthermore, the Contractor provides interface communication between the SCADA/CMS network and other systems not listed in this specification report that the Employer sees necessary during the detailed designs, construction, and commissioning phases.
10. The Contractor ensures that the IT/OT interface at a minimum comply to the following standards:
    10.1. 240-55410927 Cyber Security Standard for Operational Technology
    10.2. 240-79669677 DMZ Designs for OT Systems
    10.3. 32-373 Information Security – IT and OT Third Party and Remote Access Standard
11. A workstation to display the CCTV to be installed in the Control Room.

4.4.9.1 Codes, Standards, and Guidelines

The Contractor complies with the latest revisions of the standards as per Appendix C.

4.4.10 Control and Monitoring System (CMS) Servers

1. The Contractor provides an onsite supervisory Control and Monitoring System (CMS), otherwise known as the Supervisory Control and Data Acquisition (SCADA) system, that is responsible for data acquisition and monitoring of instruments and electronic sub-systems of the PV installations. These include, but are not limited to:
    1.1. PV inverter systems
    1.2. PV string combiner boxes
    1.3. Electrical MV switchgear
    1.4. Electrical MV and LV transformers
    1.5. Electrical protection relays
    1.6. Electrical energy measurement and metering
    1.7. Electrical battery tripping units (BTU)

1.8. Uninterruptable power supplies (UPS)

1.9. Internal environmental sensors of equipment panels, network cabinets, inverter stations/cabins

1.10. PV meteorological system (weather station)

1.11. Balance of plant (BoP) potable water and sewage tank levels

1.12. BoP Fire detection system (FDS)

1.13. BoP Heating, ventilation, and air-conditioning (HVAC) system

2. The Contractor designs, procures, installs, tests, and commissions the entire CMS scope as specified in this Works.
3. The Contractor provides a CMS that achieves 98% availability in accordance with the plant availability.
4. The Contractor provides one pair of redundantly configured CMS servers (i.e., 2 server machines) for the PV system. The servers operate as a primary-standby configuration and rated for continuous operation. Switchover from the primary server to the standby server, and vice versa, is seamless and instant upon detecting failure, without interrupting data acquisition, processing of data and operations and monitoring functions of the CMS. The standby server continues full operations if the primary server fails to operate.
5. The Contractor ensures that redundant equipment and servers are split over across two cabinets.
6. The Contractor provides the following hardware for each server machine of the redundant pair:

   6.1. redundant central processing units (CPU)

   6.2. redundant array of independent disks (RAID) configuration

   6.3. redundant power supplies with dual power input ports

   6.4. redundant case fans

   6.5. two (2) 19” (inch.) rack-mountable type enclosure for the servers and power supplies installed in the plant server room

   6.6. all redundant equipment is split across two (2) cabinets

   6.7. on-board database to continuously process and store all real time plant data for the lifespan of the plant

   6.8. removable media such as optical drives or local online media storage and front accessible universal serial bus (USB) ports
7. The Contractor provides the CMS servers that accomplish multiple functions, including:

   7.1. hosting the Microsoft Windows operating system suitable for industrial process plant applications

   7.2. hosting the CMS application software for operating and monitoring of all equipment

   7.3. hosting the anti-virus software

   7.4. performing comprehensive operating and monitoring functionality of the plant in real time via the thin clients

   7.5. performing network configuration, logic development, mimic development, antivirus, and software updates

   7.6. storing and processing of plant data via the redundant information servers’ database

   7.7. storing of all engineering logic and CMS network configuration settings

   7.8. performing of online engineering and diagnostics of the plant via the thin clients

7.9. hosting a web application that makes available, multiple pages or mimics of real time plant data for monitoring and alarming to authorised remote clients connected to the Eskom network

7.10. running the OPC protocol software to communicate between multi-vendor systems on the plant and to remotely transmit data to the PDS in MWP via the PDS network (OP UA)

7.11. running the back-up and recovery application in an event of a disaster to the CMS network

7.12. copying of data automatically from the information servers onto the removable media at pre-configured intervals

7.13. automatic shutdown of the CMS servers and thin clients in a safe sequence after detecting the loss of the input power to the UPS system. The sequence includes automatic saving of plant and system data, closing of all running applications, and providing the plant operator with adequate warning of the shutdown.

4.4.10.1 Codes, Standards, and Guidelines

The Contractor complies with the latest revisions of the standards as per Appendix C.

4.4.11 Control and Monitoring System (CMS) Network

1. The Contractor provides a SCADA/CMS network that operates using full duplex data communication.
2. The Contractor provides a SCADA/CMS that is single fault tolerant. In an event of a single fault, be it physical or functional, at a power supply or at a networking level, there is no loss of data communication, plant operations, and monitoring of the remaining areas of the plant via the Human Machine interface (HMI) located in the local and remote-control rooms.
3. The Contractor ensures that all SCADA/CMS equipment installed in uncontrolled environmental conditions is rated to operate safely within the ambient environmental conditions it will be exposed to during the life of the plant; Eskom standard, 240-56355731 Environmental Conditions for Process Control Equipment Used at Power Stations.
4. The Contractor designs the SCADA/CMS with lightning protection, surge protection, earthing, grounding and shielding in accordance to Eskom standards, international standards and best industry practices.
5. The Contractor provides industrial Ethernet network switches with the following requirements:
   5.1. managed type with online management and configuration via the thin clients using a network management software installed on the SCADA/CMS servers
   5.2. compatibility with Simple network management protocol version 3 (SNMP v3) and Internet protocol version 6 (IPv6)
   5.3. online monitoring of the port connections, communication link status, bandwidth, and device heath status indicating alarms and faults to the server and remote users
   5.4. power supply from dual redundant power sources (230 Vac or 24 Vdc)
   5.5. dual power input ports
   5.6. mounted on a Deutsche Industry Norm (DIN) rail in field equipment panels, or, mounted on a 19” network cabinet for redundant master switches located in the server room
   5.7. optical fibre and Ethernet ports
   5.8. 10% unused ports (rounded up)
   5.9. wide operating temperature range

5.10. auto negotiation capability

5.11. auto crossover (MDIX) capability

5.12. full duplex communication capability

6. The Contractor provides the following information regarding the network switches to be monitored and alarmed on the SCADA/CMS thin clients and remote users:

   6.1. device state

   6.2. link and connection state of each connection

   6.3. bandwidth utilization of each connection

   6.4. network performance and traffic statistics (latency, throughput, errors, dropped packets)

   6.5. network loads, malfunctions and failures of the network components are detected and alarmed promptly, and countermeasures are initiated automatically in due time using the network management software.

7. The Contractor provides a colour laser printer for the SCADA/CMS network. The printer prints A4 and A3 size documents. The Contractor installs the printer onto a printer desk inside the local Control Room.

4.4.11.1 Codes, Standards, and Guidelines

The Contractor complies with the latest revisions of the standards as per Appendix C.

4.4.12 Building Management Systems (BMS)

1. The Contractor provides a fully functional BMS network that monitors the potable and sewage tank levels, the Fire Detection System, the HVAC System, and the environmental sensors inside the server room network cabinets.
2. The Contractor provides continuous level monitoring of the potable water tank levels, and sewage tank levels. Alarms and warnings are indicated to the control room operator if the tank levels are reaching its lower or upper limits. (i.e. ‘low = 30%’, ‘low-low = 15%’, ‘high = 70%’ and ‘high-high = 85%’). Alarms are to be communicated to off-site personnel via SMS and email service.
3. The Contractor conducts a detailed fire protection detection assessment and provides a fire management and evacuation plan.
4. The Contractor provides a Fire Detection System (FDS) for the site. The alarm response from the FDS is informed by the Fire Protection Detection Assessment and Alarm Response Procedure. The design to comply with:

   4.1. SANS 10139 Fire detection and alarm systems for buildings — System design, installation, or an accepted equivalent standard

   4.2. Eskom 240-56737448 Fire Detection and Life Safety Design Standard

5. The Contractor provides an HVAC system to control the operating temperature and humidity levels within the server room in accordance with 32-894 Eskom Server Rooms and Data Systems Standard. The Contractor provides positive pressurisation of the server rooms to prevent dust ingress.

   5.1. The Contractor provides monitoring of all HVAC panels on the plant in real time at the operator HMI in the control room. Alarms and warnings are indicated immediately to the control room operators if the HVAC system is operating abnormally. Alarms and faults are to be communicated to off-site personnel via SMS and email service.

   5.2. The Contractor provides a dedicated network switch to communicate with the BMS equipment.

5.3. The Contractor provides the BMS server to host the application software and the information database to monitor the equipment.

5.4. The Contractor provides a local thin client for the BMS network.

5.5. The Contractor provides two (2) LCD monitors (minimum 19”), one (1) keyboard, and one (1) mouse to form the HMI for the BMS at the local control room. Connection to the thin client sever in the server room is achieved via KVM extenders.

5.6. The Contractor provides a dedicated 19” floor standing network cabinet for the BMS equipment.

5.7. The Contractor ensures that redundant equipment and servers are split over across two cabinets.

5.8. The Contractor ensures that all data of the subsystems is stored at 1 min intervals, and where required, an average of the values over the period is stored.

4.4.12.1 Codes, Standards, and Guidelines

The Contractor complies with the latest revisions of the standards as per Appendix C.

4.4.13 Fire detection System

1. The Contractor conducts a detailed fire protection detection assessment according to Eskom Standard 240-54937439 - Fire Protection/Detection Assessment Standard and provides a fire management and evacuation plan.
2. The Contractor provides a fully functional fire detection and monitoring system for the site in accordance with the fire detection and protection standards:
3. SANS 10139 Fire detection and alarm systems for buildings — System design, installation, or an accepted equivalent standard.
4. Eskom 240-56737448 Fire Detection and Life Safety Design Standard.
5. The Contractor ensures the alarm response from the FDS is informed by the Fire protection detection Assessment and Alarm Response Procedure. The Contractor ensures that alarms generated from the FDS are monitored and reported to the Employer’s personnel where 24-hour surveillance is mandated, such as the remote or regional Security Control Room.
6. The Contractor to interface the FDS with the site Security System, i.e. enabling video-based fire detection from the CCTV equipment or reporting of alarms and plant status.
7. The Contractor provides fire panels with on-board display for local monitoring and testing. The fire panels interface to the building management system (BMS). Monitoring of the FDS at the local control room is via the dedicated BMS communication network. Acknowledgement of fire alarms is not allowed via the BMS.
8. The Contractor provides all fire sensors, alarms, panels, cabling, and supporting equipment in accordance with the fire detection and protection standards referenced in this specification.
9. The Contractor provides power to the fire detection system from an uninterruptable power source (i.e., the battery tripping units or UPSs with battery back-up as stipulated by SANS 10139).
10. All power supply cables are fire resistant for 120 minutes from the source to destination.
11. The Contractor designs the fire detection system to ensure that any failure of the FDS network, failure of the FDS power supply, or failure to monitor the FDS at the control room HMI do not prevent each fire panel from operating normally on its own.

12. By virtue of the DOL mandate to South African Qualification & Certification Committee (SAQCC), any person installing, commissioning, or maintaining Fire Detection Systems needs to be registered with SAQCC according to SAQCC rules.
13. The Contractor provides one hardwired signal per zone informing the HVAC system in that zone of the present fire dampers as well as stopping/starting extraction and supply fans.
14. The FDS monitors and alarms the activation of any fire protection systems e.g. sprinkler or deluge systems.

4.4.13.1 Codes, Standards, and Guidelines

The Contractor complies with the latest revisions of the standards as per Appendix C.

4.4.14 Third Party Network Access into the CMS Network

4.4.14.1 Eskom Corporate IT Network

1. The Contractor provides the network interface to Eskom's corporate IT network. Eskom IT equipment will be installed inside a network cabinet in the existing Wind Farm Server Equipment Room to enable the interface between the SCADA/CMS network and the Eskom IT network.
2. The Contractor Provides OPC UA protocol. Real time data is required to be stored on the Eskom plant data system (PDS) where it can be accessed from Megawatt Park (MWP)
3. The Contractor provides support to the Employer (Eskom IT) throughout the installation, testing, commissioning, and configuration of the interface for the duration of the Contract (incl. O&M period).

4.4.14.2 Remote Access to the SCADA/CMS Network

1. Remote monitoring may be required at the Contractor's identified offices during the defined O&M period. The Contractor to work closely with the Employer to address the detailed design of the IT architecture and required topology, as well as the Cyber Security designs and requirements.
2. The Contractor to provide the required equipment and works for the Employer to achieve off-site monitoring of the plant.
3. The Contractor installs a webserver on the SCADA/CMS network to serve web pages to Employer's remote clients. The authorised clients make use of a standard web browser such as Mozilla Firefox, Google Chrome and Safari to login to the SCADA/CMS server and visualise the operation and alarms of the PV installations and BMS in near real time
4. The Contractor provides a web-based SCADA/CMS application for the remote monitoring. The web pages are similar to the pages displayed on the HMI at the control room. Thin client software that is required to be installed onto the remote client PCs are downloaded from the onsite SCADA/CMS web server via the secured remote interface. A log activity schedule of each remote user is saved on the SCADA/CMS web server for the lifespan of the plant. Daily, weekly, monthly and yearly graphical trends and reports of specific parameters are generated from the web page. Comprehensive reports of all plant data are saved on .CSV or .XLS file formats for further analysis.
5. As a minimum, the following reports are to be generated by the system for each PV installation and collectively:

    5.1. Availability of each inverter

    5.2. Energy produced per inverter

    5.3. Energy sent out at the point of connection

5.4. Auxiliary power consumed

5.5. Performance ratio of the plant

5.6. Average Irradiance (GHI and DNI)

5.7. Capacity factor

5.8. Specific Yield

5.9. Alarms, faults, and trips

6. The Contractor provides a gateway firewall for the remote interface. The Contractor complies to the firewall, IT/OT interface and Cyber Security standards and specifications:

6.1. 240-55410927 Cyber Security Standard for Operational Technology

6.2. 32-373 Information Security – IT and OT Third Party and Remote Access Standard

6.3. 240-79669677 DMZ Designs for OT Systems

4.4.14.3 Codes, Standards, and Guidelines

The Contractor complies with the latest revisions of the standards as per Appendix C.

4.4.15 Operator System Thin Clients

1. The Contractor provides two (2) thin client machines per control room, e.g. local and remote, that comprise of the Human machine interface (HMI) between the plant operator and the SCADA/CMS servers.
2. The Contractor ensures compliance to Eskom standard 240-56355728 Human Machine Interface Design Requirements Standard
3. The Contractor to follow guidelines as prescribed by Eskom 240-56355808 Ergonomic Design of Power Station Control Suite Guideline
4. The Contractor provides 100% plant operational and monitoring availability of each thin client. Therefore, each thin client offers its operator, the complete operating and monitoring functionality of the entire plant.
5. The Contractor provides the following peripherals to thin client:

5.1. 3 x 24”(minimum) liquid crystal display monitors (LCD)

5.2. 1 x 40”(minimum) LCD monitor

5.3. Built-in optical drive/BU-ray writer (online backup system)

5.4. 1 x USB type keyboard and mouse

5.5. 2 x front USB ports

6. The Contractor installs the thin clients inside the SCADA/CMS network cabinets of the server room.
7. The Contractor provides the keyboard, video, mouse (KVM) extenders to interface the HMI peripherals in the control room, to the thin clients in the server room. The KVM extenders do not degrade the video quality as displayed on the monitors. The KVM extender does not introduce any operating delay or lower refresh rate as required. The KVM extenders are installed securely at each operator’s desk to prevent physical interference.

4.4.16 Thin Client Operational and Graphical Display Requirements

The Contractor provides the functional requirements described in sections the below:

1. Graphical display requirements: -

1.1. Alphanumeric characters:

1.1.1. Text, except for labels, is presented using upper- and lower-case characters.

1.1.2. Capitalization is used to start sentences, and to indicate proper nouns and acronyms.

1.1.3. Labels are displayed in upper case.

1.1.4. A sans-serif font is used. An example of a sans-serif font is Arial. Sans-serif fonts are more legible on electronic displays than serif fonts.

1.1.5. For the selected font, it must be possible to clearly distinguish between X and K, T and Y, I and L, I and 1, O and Q, O and 0, S and 5, and U and V

1.1.6. Text, numbers, and symbols are readable from the normal operating position be it seated or standing at the plant operator's desk or remote client's desk.

1.2. Numeric data:

1.2.1. Numeric values are displayed using the decimal number system.

1.2.2. Leading zeros for whole numbers are not displayed. For example, the number fifty-two must be displayed as 52, rather than 0052. A leading zero is only provided if the number is a decimal with no preceding integer. For example, the decimal number of a half should be displayed as 0.5, rather than .5.

1.2.3. Numbers are displayed at the number of significant digits required by the users to perform their tasks. The number of significant digits must be supported by the accuracy of the underlying instruments and SCADA/CMS hardware.

1.2.4. Each numeric display must be able to accommodate all the values in the range of its variable.

1.2.5. All numeric data is oriented upright.

1.3. Abbreviations and acronyms:

1.3.1. Abbreviations are avoided, except when terms are commonly referred to by their initials or abbreviations.

1.3.2. Abbreviations and acronyms do not include punctuations. For example, CMS is preferred over C.M.S.

1.3.3. The use of the letters O and I in arbitrary codes is avoided, since they are easily confused with the numbers 0 (zero) and 1(one), respectively.

1.3.4. When arbitrary codes use both letters and numbers, the letters are grouped together, and numbers grouped together rather than interspersing letters with numbers.

1.4. Labels:

1.4.1. Label formats are consistent across and within displays.

1.4.2. Labels are worded consistently, so that the same item is given the same label wherever it appears.

1.4.3. Labels are separated from one another by at least two standard character spaces.

1.4.4. Labels are oriented horizontally.

1.5. Icons and symbols:

1.5.1. Icons in graphic displays are primarily used to represent actual objects or actions.

1.5.2. Icons and symbols are used consistently throughout the displays for all plant areas.

1.5.3. Icons are designed to look like the objects, processes, or operations they represent, by use of literal, functional, or operational representations.

1.5.4. Icons must be closed i.e.; they must have a continuous outside border

1.5.5. The symbols used on displays are consistent with those of other information sources used in the work area, such as SLDs and logic diagrams, or based on the outline or physical structure of the plant device if ergonomically appropriate.

1.5.6. Each icon and symbol represent a single object or action and is easily distinguished by their external geometric configuration from all other icons and symbols.

1.5.7. Icons and symbols are oriented upright.

1.5.8. Icons and symbols are large enough for the user to perceive the representation and discriminate it from other icons and symbols.

1.5.9. An icon or symbol is highlighted when it is selected by a user.

1.5.10. Icons are accompanied by a text label, except when the icon has an unambiguous meaning to the user, e.g., standard SLD or Logic symbology. The text label is incorporated into the icon itself, provided it does not clutter or cause distortion of the icon.

1.6. Colour:

1.6.1. The colours used for coding is readily distinguishable from each other.

1.6.2. The number of colours used for coding is kept to the minimum needed for providing sufficient information. Once colours are assigned a specific use or meaning, no other colour is used for the same purpose.

1.7. Highlighting:

1.7.1. Highlighting methods (e.g., flashing, and brightness) associated with emergency conditions is not used in association with normal conditions.

1.8. Flashing:

1.8.1. Flashing is used only for the highlighting of information that requires immediate attention (e.g., warning messages, hazardous conditions). The only exception to this is the convention of blinking the cursor as an aid in locating it quickly.

1.8.2. When a single flash rate is used, the rate is at least 2 Hz and not more than 3 Hz. The percentage of time that an item is ‘on’ must be equal to the time that it is ‘off’ i.e., a 50% duty cycle is used.

1.8.3. Flash suppression or event acknowledgement keys are provided.

1.9. Pointing cursors:

1.9.1. The pointing cursor is always visible to the user.

1.9.2. The pointing cursor does not blink.

1.9.3. The position of the pointing cursor is clearly visible during movement from one screen position to another.

1.9.4. The pointing cursor maintains its size across all screens and display locations.

1.9.5. The pointing cursor does not move in the absence of any input from the user.

1.10. Display pages:

1.10.1. Displays are configured in a clear and unambiguous manner to provide the operator with information relevant to the task.

1.10.2. Every display contains a title positioned suitably at the top, which briefly describes the contents or purpose of the display.

1.10.3. Displayed information, which temporarily overlays and obscures other display data, must not erase the overlaid data.

1.10.4. In a multi-page display, each page must be labelled to show its relation to the others.

1.10.5. A comprehensive method of display access across all types of display is provided, while always providing the operator with an overview of high-level plant status

1.10.6. Selection of any display should not require more than two keystrokes. In alarm or abnormal conditions only one keystroke is required to access the relevant display

1.11. Menus:

1.11.1. Navigation is clear, simple, and unambiguous.

1.11.2. All menu items are visible to the user without scrolling.

1.11.3. Menu options is ordered and grouped logically. If no logical structure is apparent, the menu options must be ordered alphabetically.

1.11.4. The order of the menu options is fixed.

1.11.5. Menus clearly indicate which options are selectable.

1.11.6. When the same options appear on several different menus, consistency of wording and ordering on all the menus is maintained.

1.11.7. When menu selection is to be made from a long list, and not all options can be displayed at once, a hierarchic sequence of menu selections is provided rather than one long multi-page menu.

1.11.8. When hierarchic menus are used, the user must have some indication of current position in the menu structure.

1.11.9. Users are able to return to the highest-level menu in the hierarchic menu structure by a single key action.

1.12. Windows:

1.12.1. Windows are identifiable by a label consistently located at the top of the window’s border.

1.12.2. Users are able to select separate windows that share a single display screen.

1.12.3. When multiple windows are opened simultaneously, the user has the capability to tile, layer, or sequentially view the windows. Tiling refers to a configuration in which windows are positioned beside one another. Layering refers to moving one window, so it appears to be positioned on top of another one.

1.12.4. The system keeps track of the windows that are open and provide a means of displaying the list of open windows to the user.

1.12.5. Caution and warning windows are positioned front most on the display.

1.12.6. User control of windows is consistent from one display to another for each type of window.

1.12.7. Users must be able to close windows with a single action.

1.12.8. The users must be able to move windows to different areas of the display.

1.12.9. It is not possible to position windows such that they obscure menu bars, access to the command area, or caution and warning messages.

1.12.10. The action that opens a window automatically makes that window active.

1.12.11. Windows have a default location on the display screen.

1.12.12. Users must be able to change the horizontal and vertical dimensions of a window independently and together.

1.12.13. The user must be able to scroll through the contents of a window both horizontally and vertically.

1.12.14. Display data that is temporarily obscured by a window object reappears when the object is removed.

1.12.15. There is a maximum limit to the number of windows allowed to be open at one time.

1.13. Display efficiency:

1.13.1. Response time for acknowledgement of any display control command is no longer than 2 seconds.

1.13.2. Any display selected or requested by the operator, including trend displays and dynamic data, is completed within 2 seconds.

1.13.3. Feedback that any command issued by the operator to change the status of a plant device, such as closing a breaker has been received by the switchgear is displayed within 2 seconds and feedback that the breaker has reached its desired position is displayed within 2 seconds of the event.

1.13.4. The response time for the update of variables in displays (i.e., running time of signal from signal change on the binary or analogue device up to the change of the appropriate dynamic value on the plant mimic) do not exceed 5 seconds.

1.14. Operational requirements:

1.14.1. General:

1.14.1.1. The operator control interface presents an integrated and standardised set of displays and facilities which is designed to conform to ergonomic principles and modern power plant practice.

1.14.1.2. The design approach of the operating interfaces, and the underlying functionality of the SCADA/CMS behind the interfaces, is consistent across all sub-systems and functional areas covered by the SCADA/CMS

1.14.1.3. Uniformed signal descriptions and abbreviations are used through-out the entire SCADA/CMS and physical plant interface.

1.14.2. Errors:

1.14.2.1. No set or sequence of keystrokes causes the operator systems and SCADA/CMS servers to fail or freeze.

1.14.2.2. Any incorrect operation is indicated to the operator by audible signal or suitable text message.

1.14.2.3. In all cases a standardised back track facility is available so that the operator can escape from a display. True system errors are fully indicated as to type, cause, and remedial action.

1.14.3. Alarms:

1.14.3.1. A comprehensive and integrated alarm handing system is employed, which clearly distinguishes between different alarm types.

1.14.3.2. Alarm information is not lost or inaccessible whilst navigating through displays, and dynamic alarm presentation is provided the operator with information matched to the current situation and its criticality.

1.14.3.3. Faults or operational failure detected on each individual string, or the network raises an alarm to the control room operator.

1.14.3.4. Alarm handling and management system is designed in accordance with international standards, Eskom's standards and guidelines, and best engineering practice.

4.4.17 SCADA/CMS Plant Information Server (PIS) Requirements

The Contractor provides the following requirements:

1. General:

1.1. The on-site, redundant plant information server is a central database repository built into the redundant SCADA/CMS servers for the long-term storage of all plant data produced by the PV installations. This includes all plant information generated by the sub systems of the plant as well as calculated or processed data.

1.2. The SCADA/CMS servers contains a software application and database that stores all plant data and include tools for the analysis of all the plant data including:

1.2.1. Alarm data

1.2.2. Sequence of Events (SoE)

1.2.3. Field and other system's readings (inputs and outputs)

1.2.4. Calculated variables

1.2.5. Control variables

1.2.6. SCADA/CMS system settings

1.2.7. Operator inputs (key logging)

1.3. The software application stores all analogue tags and events at a resolution of one (1) second or better. All data is time stamped using the GPS time server.

1.4. The software application stores each analogue tag according to the amount of change in the tag value, where the amount of change is specified by the user.

1.5. Data on these servers is accessible by an OPC client and all applications are OPC compliant for external interfacing. Web server application is available on the SCADA/CMS web server to be able to serve web pages containing real time data and historical data to remote clients via the Eskom network.

1.6. The software application stores historical plant information on-line for the lifespan of the plant at maximum resolution.

1.7. The software application automatically copies the historical plant information stored on the historian to an external hot-swappable hard disk drive, while on-line and without any loss of availability and functionality of the software application. The external hot-swappable hard disk drives serve as a backup of the historical plant information. Furthermore, the software application automatically copies the data onto the local online storage device or DVD/blu-ray in the SCADA/CMS servers at pre-defined intervals. The intervals are set on the software application.

Data is stored on .CSV files then copied onto the local online storage device or DVD/ blu-ray. Each file contains data for a pre-defined period.

1.8. The SCADA/CMS thin clients (full functionality) and remote client users (limited functions), with the appropriate user rights, are able to select and view all the near real-time and historical plant data from plant information servers, in the form of:

1.9. Trends

1.9.1. Chronological lists

1.9.2. Reports

1.9.3. Process graphics

1.9.4. Performance calculations and analysis

1.9.5. Event history and analysis

1.9.6. Importing/exporting of information from/to Microsoft Excel®, and via SQL and OPC

1.9.7. Data stored in the Historian database are appropriately time stamped.

1.10. Comprehensive prioritising, grouping, filtering and database sorting is provided from the SCADA/CMS servers.

1.11. The historian databases are open to queries from OPC Clients

1.12. Any changes made to the database is made in real-time and on-line via the CMS servers, and all changes come into effect without restarting any part of the CMS server or thin clients.

2. Trends:

2.1. From the SCADA/CMS thin clients, trends are configurable. The user, as a minimum, is able to configure the following:

2.1.1. Select the tags to view.

2.1.2. Specify the start and stop date of each trend.

2.1.3. Specify the start and stop time of each trend.

2.2. From the SCADA/CMS thin clients, the user views a minimum of six (6) trends in the same display window. Remote user views two (2) trends per window

3. Chronological Lists:

3.1. Binary Events:

3.1.1. From the SCADA/CMS thin clients, the user views binary events in the form of a chronological list. The chronological list includes:

3.1.1.1. event date

3.1.1.2. event time

3.1.1.3. tag name

3.1.1.4. tag description

3.1.1.5. tag value

3.1.2. The user filters the binary events, as a minimum, according to:

3.1.2.1. unit

3.1.2.2. tag name

3.1.2.3. tag description

3.1.2.4. time period

3.1.3. The user saves the binary event history as a .CSV or .XLS file type.

3.2. Alarm Events:

3.2.1. From the SCADA/CMS thin clients and remote clients, the users' views alarm events in the form of a chronological list. The chronological list includes:

3.2.1.1. event time

3.2.1.2. tag name

3.2.1.3. tag description

3.2.1.4. tag value

3.2.2. The users filter the alarm events, as a minimum, according to:

3.2.2.1. unit

3.2.2.2. tag name

3.2.2.3. tag description

3.2.2.4. priority

3.2.2.5. entry/exit

3.2.3. The users save the alarm event history as a .CSV or .XLS file type.

3.2.3.1. Operator Events:

3.2.4. From the SCADA/CMS thin clients, the user views all operator event history in the form of a chronological list. The user filters the operator events, as a minimum, according to:

3.2.4.1. unit

3.2.4.2. operator system

3.2.4.3. time period

3.2.4.4. event type

3.2.5. The user saves the Operator event as a CSV or .XLS file type.

3.3. Reports:

3.3.1. A report generator that builds and schedules reports is provided at the SCADA/CMS thin clients

3.3.2. From the SCADA/CMS thin clients, the users, as a minimum, are able to configure the following:

3.3.2.1. create, edit, and store reports.

3.3.2.2. create, edit, and store report formats.

3.3.2.3. Schedule the automatic creation of reports at periodic intervals, elapsed times or on the occurrence of an event (e.g., alarm or event message)

3.3.3. The following reports are to be generated by the system for each PV installation and collectively:

3.3.3.1. Availability of each inverter

3.3.3.2. Energy produced per inverter.

3.3.3.3. Energy sent out at the Point of Connection

3.3.3.4. Auxiliary power consumed

3.3.3.5. Performance ratio of the plant

3.3.3.6. Average irradiance (GHI and DNI)

3.3.3.7. Capacity factor

3.3.3.8. Specific yield

3.3.3.9. Alarms, faults, and trips

3.3.4. Remote client users create and save a report of selectable parameters via a standard web browser in .CSV or .XLS file formats.

3.3.5. The users create reports and report formats without any software programming. The report generator provides total control over report format similar to spreadsheet packages.

3.3.6. The users include both near real-time and historical plant information.

3.3.7. Users produce lists of totals and averages and apply arithmetic functions to plant information.

3.3.8. The types/classes of data used by the report generator includes the following:

3.3.8.1. analogue variables

3.3.8.2. status of multi-state variables

3.3.8.3. alarm and event messages

3.3.8.4. calculated variables

3.3.8.5. batch-end information for sequence control

3.3.8.6. historical data values and status

3.3.8.7. any other retrievable tagged items

3.3.9. Users are provided data in the form of:

3.3.9.1. current values

3.3.9.2. batch values

3.3.9.3. database query value

3.3.9.4. operator entry values

3.3.10. Users save reports CSV, .XLS and HTML files.

3.3.11. The report generated includes one parameter per column. Time stamp intervals are displayed on the rows. Under default setting, all parameters are generated onto a single file for selectable period of time period. Reports containing user selectable parameters are produced. Daily, weekly, and monthly report templates are producible

3.4. Process Graphics:

3.4.1. The process graphics are configurable by a user at the SCADA/CMS thin clients. The user, as a minimum, configures the following:

3.4.1.1. create, edit, and store graphical displays

3.4.1.2. select the tags to be displayed in the process graphic displays

3.4.2. The user is able to include both near real-time and historical plant information in the displays.

3.4.3. The user is able to save the process graphic as .JPEG file HTML file.

4.4.18 Network Time Synchronisation

1. The Contractor provides a clock synchronisation system to synchronise the time of the system clock of each network device on the SCADA/CMS network, to a common time source. Common clock synchronisation assures consistent stamping of data onto the SCADA/CMS servers which simplifies data analysis and troubleshooting during an investigation.
2. The Contractor provides a clock synchronisation system that includes the following requirements:
   2.1. Have a global positioning system (GPS) antenna and a time server
   2.2. Implement the network time protocol (NTP) via an Ethernet connection to the SCADA/CMS network switch.
   2.3. Provide time stamping with an accuracy of 10 milliseconds (UTC+2)
   2.4. On loss of the GPS signal, the accuracy of the GPS clock, i.e.: deviation from UTC is less than 1 minute per day.
   2.5. Determine its installation position automatically by self-calibrating.
   2.6. Retains critical data (by means of non-volatile memory or battery back-up) in the event of power supply failure.
   2.7. Have automatic time synchronisation to the plant, after recovery from any GPS time sync system failure or power supply failure
   2.8. Have a GPS antenna and receiver system provided are highly resistant to electrical surges from sources such as lightning.
   2.9. Have an on-board display and function keys
   2.10. Provide for monitoring and alarming of the time server at the SCADA/CMS thin clients
   2.11. Have a 19” rack or DIN rail enclosure
   2.12. Be powered from a 230 Vac or 24 Vdc source

4.4.19 Miscellaneous Network Equipment

1. The Contractor provides the following equipment as required by the design:
   1.1. network protocol convertors
   1.2. network medium convertors
   1.3. digital or analogue input and output (IO) modules
   1.4. programmable logic controllers (PLC) with on-board IO cards, communication processors and protocol convertors
   1.5. dc power supplies (12 V or 24 V)
   1.6. splice trays and path panels for fibre optic cables
2. The equipment described in (1) is installed in the CMS field equipment panels or 19” network cabinets. If installed in an uncontrolled environment, the equipment is rated to operate between a wide temperature range.

4.4.20 SCADA/CMS Field Equipment Panels

1. The Contractor provides SCADA/CMS equipment panels inside Inverter stations/cabins and switchgear rooms. The equipment panels contain CMS network equipment as required by each area of the plant. This includes the network switch and associated equipment.
2. The Contractor designs the SCADA/CMS equipment panels to include physical separation of the power supply equipment, networking devices and splice tray and patch panels into their own compartments within the panel. Cable channels are installed to route the cabling between compartments or section within the panel.
3. The Contractor provides field equipment panels for string combiner boxes (SCB) and weather stations (WS) that is rated IP65 for outdoor installation.

4.4.21 Server Room Network Cabinets

1. The Contractor provides nineteen-inch type (19”) network cabinets to install SCADA/CMS servers, thin clients, redundant network switches and UPSs. All connectors on rack mounted components are rear facing in the cabinet for easier cable management. Network and power cabling are bottom entry with cable entry from raised false flooring in the server room.
2. The Contractor provides network cabinets that include the following characteristics:
   2.1. grommets are installed where panels are cut for communication and power cable entry.
   2.2. Internal cable channels or traces to neatly route cables inside the cabinet.
   2.3. Removable blanking panels on all unused slots or sections
   2.4. Adequate depth (> 200 mm free space) to allow air circulation around cables in the rear.
   2.5. Perforated front and rear door and side panels to allow circulation of air.
   2.6. Flexible brushes to be used to prevent air leakage via cable entries or cut-out.
   2.7. Include 19” racks and DIN rails to mount equipment.
   2.8. Removable perforated front and rear door panels
   2.9. Doors with manual locking mechanism and automatic open/close detection
   2.10. Internal lights for illumination
   2.11. 10% uninstalled space on the racks and DIN slots to install spare equipment.
   2.12. blanking panels on un-used slots
   2.13. Air condition system for temperature conditioning preferably direct Expansion or window mounted
   2.14. internal air temperature and relative humidity sensors monitored on the network cabinet (local) and the SCADA/CMS (operator HMI). Internal temperature to be controlled at 22 ˚C ±2 ˚C.

4.4.22 SCADA/CMS Power Supply and Power Distribution

1. The Contractor provides dual redundantly configured, 230 Vac uninterruptable power supply (UPS) system with a battery bank to provide uninterruptable source of power to the SCADA/CMS equipment in the server and control rooms of the PV Plant.
2. The Contractor provides sealed-type, deep cycle battery banks to support the redundant UPSs. In the event of hydrogen discharge from the batteries, the Contractor to ensure the necessary safety regulations are adhered to. Sealed type Nickel Cadmium, Lithium Ion or Valve regulated lead acid batteries are preferred. It is preferred that the Contractor install the UPS system inside 19” floor

standing cabinets inside the PV Plant server room. Alternatively, the Contractor installs the UPS and batteries in a dedicated battery room with ventilation if the batteries are of the type that will discharge hydrogen.

3. The Contractor designs the UPS and battery bank system to provide a standby time of one (1) hour under full load immediately after the main 230 Vac supply to the UPS system is isolated. The UPS provides a regulated power source for sensitive CMS equipment and ensures a safe shutdown sequence of the SCADA/CMS servers and thin clients when the UPS battery source reaches a reserve capacity of 25 percent (%).
4. The Contractor provides 230 Vac distribution boards (DB) containing miniature circuit breakers (MCBs) for the CMS power distribution. The DBs are installed to distribute the power from UPSs to the loads. The Contractor provides earth leakage protection system for CMS loads.
5. The Contractor designs the SCADA/CMS network and its power supply distribution to ensure that loss of power to a single CMS equipment panel in a specific inverter cabin or switchgear room does not result in the failure of operation of the remaining SCADA/CMS equipment panels. The remaining CMS panels continue communicating over the SCADA/CMS network to the SCADA/CMS servers and operator HMI.
6. The Contractor provides suitably rated DC power source for all SCADA/CMS equipment requiring dc power.
7. The Contractor provides a detailed SCADA/CMS load schedule by using the high-level load list shown in Table 4-3 as a guide to size the SCADA/CMS power supplies.

Table 4-3: Power source to SCADA/CMS equipment

Control system equipment	Equipment room / location	Power source per device
SCADA/CMS network switches	Inverter stations/cabins	Uninterruptable power source (AC or DC)
String combiner boxes (Monitoring)	PV field array	230 Vac from Aux. DB per station/cabin
Weather stations (Instrumentation)	Field	230 Vac from Aux. DB per station/cabin
Fire panels (FDS)	Inverter stations/cabins	DC power provided in the inverter stations/cabins
19” UPS cabinet	PV Plant server room	230 Vac from PV Aux DBs located in the O&M building
19” network/server cabinet - Redundant CMS and plant information servers - Redundant master switches - Common switch - GPS clock - Web server - Firewall & internet modem	PV Plant server room	230 Vac (redundant UPSs) in plant server room
19” BMS cabinet - BMS server - BMS switch - BMS thin client	PV plant server room	230 Vac (redundant UPSs) in plant server room
SCADA/CMS thin clients	PV Plant control room / server room	230 Vac (redundant UPSs) in plant server room

Control system equipment	Equipment room / location	Power source per device
KVM extenders	PV Plant server room and control room	230 Vac (redundant UPSs) in plant server room
Monitors	PV Plant control room	230 Vac (redundant UPSs)
3rd party equipment		
Local security system cabinet (provision)	PV Plant server room	230 Vac (redundant UPSs) in plant server room
IT/IM cabinet (provision)	PV Plant server room	230 Vac (redundant UPSs) in plant server room
19" OT PPC and Gateway equipment cabinet	Dx Plant relay/control room	230Vac redundant UPS in Dx substation plant relay room

4.4.23 Field Equipment, Cabling, and Installation Requirements

1. Contractor provides all SCADA/CMS field equipment enclosures and structures, instruments, field power and communication cabling and cable infrastructure (conduit and racks) in accordance with the relevant standards and guidelines as specified under the codes and standards section of this specification.
2. The Contractor provides SCADA/CMS enclosures that is rated IP65 for outdoor installation.
3. The Contractor provides adequate earthing, lightning protection, grounding, bonding, shielding and surge protection on all SCADA/CMS equipment and cabling.
4. The Contractor installs data communication and control cables into a separate cable trench (raceway or rack) from power cables to prevent noise interference.

4.4.24 CMS Control Room, Server Room, Equipment Rooms

1. The Contractor provides the PV Plant control and server room in accordance with the Eskom standards for process control and ergonomic control suite design, as specified under codes and standards section of this specification.
2. The Contractor provides a suitable operating environment (controlled or uncontrolled) for all SCADA/CMS equipment in accordance to the relevant standards and guidelines as specified under codes and standards section of this specification.
3. Monitoring Technology must be used to monitor fluid, humidity, vibration, smoke, temperature, and incorporate camera and CCTV in the server room.
4. The Contractor installs the SCADA/CMS equipment panels and fire panels inside the inverter stations/cabins and switchgear rooms as required.
5. The Contractor provides sufficient lighting inside the server and control room.
6. The Contractor designs the server room with sufficient walking space of at least one (1) meter between the cabinets for operations and maintenance staff. The dimensions and layout inside the server room are ergonomically friendly such that removal of a network cabinet or piece of equipment at the far end of the room does not require switching off and removal of any other equipment inside the server room and control room.
7. The Contractor installs raised floors (0.3 meter) inside the server room to allow for adequate cable access into the network cabinets.
8. The Contractor designs the server room to house the following network cabinets, as a minimum:

   8.1. CMS network cabinet/s (servers, thin clients, switches, splice trays, etc.)

8.2. Building management system (BMS) network cabinet

8.3. Redundantly configured CMS UPS system cabinet/s

8.4. Plant security system network cabinet/s

8.5. 1 x 19" IT network cabinet

8.6. 1 x Network cabinet for Eskom gateway/RTU (Information Exchange Code of the SA Grid Code)

4.4.25 Plant Parameters

1. The Contractor provides a SCADA/CMS that stores and displays all parameters from plant instruments and equipment onto the SCADA/CMS servers, thin clients, and remote clients. Furthermore, network communication faults and statuses are monitored and logged onto the SCADA/CMS servers.
2. The Contractor populates a signal list with the number of system parameters, signals, or calculated parameters that the Employer requires during the detailed design and commissioning phase of the project.

4.4.26 Software Management

1. The Contractor provides all application and antivirus software used on the SCADA/CMS network.
2. The Contractor provides all software to the Employer which remains the property of the Employer. The Employer's O&M representative is in possession of all plant software.
3. The Contractor provides software that requires minimal or no updates over the lifespan of 25 years. If the software expires, a warning is displayed on the SCADA/CMS server and the SCADA/CMS continue operating normally (for the life of the plant) without shutting down the SCADA/CMS system or any plant sub-system.
4. During the O&M period, if software version updates are required, the Contractor conducts the exercise together with the Employer's representative. All SCADA/CMS modifications and updates are logged into the maintenance manual and signed off. One copy of the maintenance manual remains the property of the Employer while the other copy remains with the Contractor.
5. The Contractor provides a list of all SCADA/CMS software.
6. All passwords of the SCADA/CMS servers and thin clients remain the property of the Employer. In this way, both the Employer and Contractor are required in order conduct modifications to the SCADA/CMS.

4.4.27 Labelling and Codification

1. The Contractor provides a suitable labelling and codification system in accordance with the KKS standard for the entire SCADA/CMS works. This helps identify all instruments, cables, cable cores, equipment enclosures, network hardware, power supply systems, signals, OPC tags, etc.
2. The Contractor provides warning labels on all equipment that pose a risk of electric shock.

4.4.28 Vendor Document Submittal Schedule (VDSS)

1. The Contractor provides the list of SCADA/CMS documents to the Employer. During handover, the as-built design documents are handed over as softcopy (2 x electronic media) and hardcopy (2 x files). All file formats are compatible with Microsoft office and Adobe reader software.

2. List of deviations from the scope and recommendations or proposals to meet the scope requirements with reasons, advantages, and disadvantages. The Contractor provides this list as part of the tender submission.
    2.1. Detailed CMS network single line diagram of the complete CMS works.
    2.2. Detailed field wiring schematics
    2.3. Site specific equipment locations and cable route diagrams
    2.4. Instrument and equipment list
    2.5. Cable schedule and cable specifications (power and communication)
    2.6. Comprehensive CMS design report (Operating and engineering description, logic diagrams and formulas used to calculate data, HMI mimics, graphical user interface screen dumps, data analysis and information storage description, operations, and troubleshooting, etc.)
    2.7. CMS signal list
    2.8. All instrument and equipment datasheets, manuals, specifications
    2.9. CMS load list (Power supply and distribution SLD including design calculations, battery sizing, etc.)
    2.10. Server room network cabinet and CMS equipment panel specifications and general arrangement diagrams (2D and 3D)
    2.11. Control and server room specifications and general arrangement diagrams (2D and 3D)
    2.12. Calibration and Factory acceptance test certificates
    2.13. Site acceptance test (SAT) procedure and check sheet.
    2.14. Site integration test (SIT) procedure and check sheet.
    2.15. Commissioning procedure and check sheet.
    2.16. Operations and maintenance manual for the SCADA/CMS during the O&M period. SCADA/CMS fault finding and troubleshooting guide to be included in comprehensive O&M manual
    2.17. Training material on SCADA/CMS and subsystems. This includes training material for operators, engineers and technicians. The training material provided is required to be on the level of a system engineer to fully configure the CMS after the O&M period.

4.4.29 Codes, Standards, and Guidelines

The Contractor complies with the latest revisions of the standards as per Appendix C.

4.5 Information Management

1. The Contractor supports the Eskom IM (Information Management) team and provides access to all parts in the Plant for installation, communication, and information management as required by the IM team.
2. The Contractor interfaces with the IT infrastructure provided by the Employer for full functionality of the works.
3. Desktop, computing and printing equipment requirements are as follows:
    3.1. Any computing devices that are required for any LAN, CCTV or infrastructure shall be provided by the project as per sections 4.4.10, 4.4.11, 4.4.12, 4.4.13 and 4.4.14.

4.5.0 Codes, Standards, and Guidelines

The Contractor complies with the latest revisions of the standards as per Appendix C.

4.6 THE SECURITY SYSTEM

1. The objective of the physical security system shall be to prevent or delay unauthorised access to, or control over the power plant through a set of security control measures.
2. The principal methodology of protection is to deter/deny, detect, delay and to defeat unauthorised access or control of the power plant. Each of these principles compliments each other and consists of several physical and electronic security systems.
3. Deter/Deny – This involves measures and actions to prevent an unauthorised person from entering the facility (such as Access Control and Perimeter Fencing). Deterrence shall be achieved by physical barriers.
4. Detect – This is achieved by means of security systems, alarms, and continuous surveillance.
5. Delay – The Security System shall be designed as to ensure maximum intruder delay.

4.6.0 General Requirements for the Security System

1. The Tutuka Solar PV power plant shall provide a security solution to protect the PV Plant from any security breach (such as theft of PV modules).

1. Security shall be provided by a combination of physical barrier systems and shall be designed to prevent, detect, and delay unauthorized access and continuously monitored.
2. All sensitive areas shall be protected by physical barriers (openings and doors shall be secured, protected, and alarmed).
3. Alarms shall be centrally enunciated (within the Admin Building Control Room and Security Building or remotely communicated).
4. Access Points and barriers shall be monitored with CCTV surveillance. CCTV monitoring stations to be installed in the Control Room and the Security Access Building.
5. Therefore, it is essential to protect the PV infrastructure, and precautions shall be taken to protect the power plant's safety and security.
6. Security measures may include anti-theft bolts, CCTV Cameras, alarms, and security fencing. These measures shall be designed to reduce the risk of security breach, theft or tampering with Tutuka Solar PV systems and equipment.
7. The EPC Contractor shall be responsible for the supply, design, installation, and commissioning of the security solution and shall provide a detailed security solution with an associated risk or threat assessment.
8. A robust security plan shall be provided as part of the risk assessment. Typical breakdown of key deliverables shall include the following as a minimum:
    8.1. The protection and security systems shall be operating at greater than 95% availability.
    8.2. The security system shall provide support to the security personnel should any potential risk or threat materialize.
    8.3. The security solution shall be designed in such a manner that no single failure of a component in the system shall disable the security system.
    8.4. The security system shall be an integrated solution.

9. Security planning undertaking with all relevant security stakeholders and shall not be undertaking in isolation (planning with Eskom's Group Security).
10. The EPC Contractor shall be responsible for the supply, design, installation, and commissioning of all power supplies for the electronic security systems.
11. The EPC Contractor shall be responsible for the supply, design, installation, and commissioning of all communication systems within and externally connected to the PV plant, monitoring and security system.
12. The security system shall be in line with the latest security standards and shall be accepted by the insurance provider.
13. The security systems shall satisfy as a minimum several of the following security elements:
    - 13.1. Permanent Security Fencing
    - 13.2. Permanent Security System
    - 13.3. Temporary onsite security during construction
    - 13.4. CCTV Cameras
    - 13.5. Access Control
    - 13.6. Video Analytics Software and Digital Video Recorder
    - 13.7. Security Sensors
    - 13.8. Warning Devices (such as warning signs or use of CCTV cameras and site monitoring to dissuade intrusion).
    - 13.9. Security Staff
    - 13.10. Remote Alarming
    - 13.11. Interfacing between the security systems, SCADA, CCTV, Building Management Systems, Access Control, and monitoring centres where applicable.

4.6.1 Codes, Standards, and Guidelines

The Contractor complies with the latest revisions of the standards as per Appendix C.

4.7 Heating Ventilation and Air Conditioning

1. The Contractor performs the design, drawings, procurement, manufacture, quality control & assurance, supply, delivery, installation, commissioning, testing, training, and maintenance and handing over of HVAC works based on the Employer's outlined functional specification.
2. The HVAC Works include the following:
    - 2.1. Direct expansions air conditioning units, air handling units, ductwork, pipework, condensers, evaporators, and its associated subsystems with new energy efficient systems.
    - 2.2. Mechanical ventilation system, complete with fans, grilles, louvres, and ducting.
    - 2.3. Associated electrical works and related controls & monitoring of complete HVAC system.
    - 2.4. Complete HVAC related building and civil works.
    - 2.5. Interfacing with SCADA/CMS for monitoring of complete HVAC system.
    - 2.6. Provision of painting and corrosion protection for complete Works.
    - 2.7. Provision of training, operation & maintenance manuals.

2.8. Plant codification and labelling for the complete works.

3. The Contractor makes provision for spares and maintenance support during the Operation and Maintenance period.
4. The complete HVAC system is to be designed to accommodate 10% future growth.
5. The complete HVAC performance figures obtained during testing and commissioning must be within a range of ±5% of the specified figures given during Contractor's design, plant and material selection phase.

4.7.1 Design Conditions

1. The required indoor conditions for the buildings and rooms are listed in Table 4-4.

Table 4-4: Required indoor conditions

Area/Building	Indoor Temperatures	Relative Humidity
Server and Equipment Room	22 °C ±2 °C	50% ± 10%
Security Access building	22 °C ±2 °C	Not Controlled

2. The following outdoor design conditions are provided for information. The Contractor shall treat the information provided as a guide and perform detailed design according to verified environmental conditions that the Contractor will source.

   2.1. Summer: 43,2°C DB

   2.2. Winter: 0°C DB

   2.3. Altitude:1600 m

4.7.2 HVAC System Description

1. The O&M Control room and office are to be serviced by a dedicated direct expansion split unit, complete with evaporator and matching air-cooled condensing units. The cooling and heating plant is to be based on air cooled outdoor unit(s) which are connected to indoor unit(s) via a single refrigerant circuit, comprising suction and liquid refrigerant pipework. Both the indoor and outdoor units are to be inverter type units which provide space cooling or heating depending on the individual space requirements.
2. The Contractor shall ensure that the risk of the unit being left on for extended periods of time or the unit automatically switching on after a power interruption is mitigated with the use of sensors, auto-control cards, or other means that are suitable for the application.
3. The O&M Server Room is to be equipped with running and standby under ceiling type indoor units together with air cooled outdoor units. The HVAC equipment is to be configured to operate on running and standby mode for redundancy, including automatic change over between the units in case of failure of any one unit and at pre-set intervals to allow equal running time between the units. The units must have a cooling only mode of operation and will provide cooling 24 hours a day, seven day a week throughout the year.
4. The HVAC units are to be controlled by wall mounted controllers which allow the occupants to set the room temperature, fan speed, and turn the units on and off. The room temperatures are to be sensed at wall mounted thermostats which will automatically adjust its cooling or heating to maintain the room set point. The O&M Server Room HVAC system is to be programmed such that should the temperatures within the respective rooms rise above 26°C or should a fault occur on the running unit, the controller will automatically start the standby unit.

5. Outdoor filtered air is to be provided by means of fresh air units which are connected to an external insulated galvanized sheet metal ductwork. Air is to be introduced into the space by means of constant air volume (CAV) diffusers/grilles.
6. Ablution and O&M Workshop and Spares storeroom ventilation is provided by a ducted extraction system and window extractor fans discharging contaminated air to outside with make-up air supplied from the surrounding areas via door grilles and ducted fresh air supply.

4.7.3 HVAC System Commissioning

1. The complete HVAC system is to be commissioned in accordance with the following SANS 10147 an and codes or such other recognized commissioning procedure or code accepted by the Employer:
   a. SANS 10173: Code of Practice for the Installation, Testing and Balancing of Air Conditioning Ductwork, or
   b. CIBS Commissioning Code A: 1996 or latest revision.
   c. Automatic controls: CIBS Commissioning Code C: 2001 or latest revision.
   d. Refrigerating Systems: CIBS Commissioning Code R: 2002 or latest revision.

4.7.4 Codes, Standards, and Guidelines

The Contractor complies with the latest revisions of the standards as per Appendix C.

4.8 Fire Protection

1. The Contractor performs the design, drawings, procurement, manufacture, quality control and assurance, supply, delivery, installation, commissioning, testing, training, and maintenance and handing over of Fire Protection System works based on the Employer's outlined functional specification.
2. A Fire Protection/Detection Assessment shall be performed early in the design process to inform the engineering, procurement, and construction of the Works. The Fire Protection/Detection Assessment shall be performed according to Eskom Standard 240-54937439 - Fire Protection/Detection Assessment Standard. The Fire Protection/Detection Assessment shall be reviewed and accepted by the Employer before the Contractor implements the outcomes of the assessment. The Contractor shall implement the outcomes of the reviewed and accepted assessment. The Fire Protection/Detection Assessment shall determine the fire protection and fire detection approach followed.
3. The fire detection system design shall be performed in accordance with Eskom Standard 240-56737448 - Fire Detection and Life Safety Design Standard.
4. The fire protection system design shall be performed in accordance with Eskom Standard 240-56737448 - Fire Protection and Life Safety Design Standard.
5. The Fire Protection System works include the following:
   5.1. Portable fire extinguishing equipment to service the inverter stations/cabins and O&M buildings in accordance with SANS 10400-T, SANS 10105, and Eskom Standard 240-56737448 - Fire Protection and Life Safety Design Standard.
   5.2. SABS symbolic signs are to be installed to clearly indicate all firefighting equipment, fire escape routes, and exit doors in accordance with SANS 1186.

5.3. Provision of training, operation, and maintenance manuals.

5.4. Plant codification and labelling for the complete works.

5.5. The Contractor makes provision for spares and maintenance support for the Operation and Maintenance period.

6. The complete fire protection system is to be designed, constructed, and equipped to satisfy the requirements of SANS 10400 - National Building Regulations, Building Standard Act No. 103 of 1977, and Eskom Standard 240-54937450 - Fire Protection and Life Safety Design Standard, in order to ensure the following requirements are met:

   6.1. Ensure protection of occupants (life safety)

   6.2. Minimize the spread and intensity of fire

   6.3. Minimize and control the generation of fire and spread of smoke

   6.4. Ensure sufficient building stability is retained in a fire

   6.5. Provide adequate fire detection and fire extinguishing equipment, and access for fire brigade services

7. Fire risks shall be minimised where practical by the use of non-combustible materials, by separation and/or compartmentalisation of individual fire hazards, and by separation from sources of ignition.

8. Fire protection measures for oil filled transformers (if installed) shall comply with requirements indicated in 240-54937450 - Fire Protection & Life Safety Design Standard. All oil filled transformers shall be bunded. Cable entries into the bund shall be piped up above the bund level using non-combustible materials. All bund drains shall be fitted with fire traps.

9. Door sets to all enclosed fire risk areas shall have a minimum two-hour fire rating and shall be fitted with self-closing devices.

10. The Contractor shall be responsible for fire protection on the entire site in the Contractor's scope during the construction period.

4.8.0 Codes, Standards, and Guidelines

The Contractor complies with the latest revisions of the standards as per Appendix C.

4.9 Sewage and Waste Disposal

1. The Contractor performs the design, drawings, procurement, manufacture, quality control and assurance, supply, delivery, installation, commissioning, testing, training, and maintenance and handing over of Sewage and Waste disposal works based on the Employer's outlined functional specification.

2. The sewage system is required to service of five (5) Security Staff stationed at the Security Access Building and a minimum of 10 staff situated in other offices

3. The Contractor shall evaluate the option for installing a sewage conservancy tank system and infrastructure for a minimum of 15 personnel.

4. The Contractor submits the design calculations/drawings of the sewage conservancy tank which is within this scope of work for review, acceptance, and comments by the Employer.

5. The sewage handling system shall be connected with the pipes from the kitchen and toilets in the Security Access Building. The kitchen waste passes through a grease trap before entering the drain. This grease trap requires regular cleaning and maintenance that should not be neglected.

6. The sewage handling system shall be designed such that blockage by the scum layer is prevented.

4.9.0 General

If a sewage conservancy tank system is installed:

1. The tank shall have a level monitoring system (monitored by the Plant CMS) installed in order to protect public health by preventing backup of sewage and subsequent discharge into the environment. An alarm is triggered at 85% capacity in order to give sufficient warning for Operation and Maintenance team to address the issue.
2. The sewage conservancy tank is connected with pipes from the kitchen and toilets in the Security Access Building. The kitchen waste passes through a grease trap before entering the drain. This grease trap requires regular cleaning and maintenance that should not be neglected.
3. The sewage conservancy tank is situated where it is accessible to vacuum tankers, for sludge and scum removal, noting that no erection of building is permitted over the tank. The vacuum tanker bay to be designed and constructed adjacent to the conservancy tank and to include a hose with potable water for flushing.
4. The tank shall be constructed and designed in accordance with the information contained within SANS 10400-P: The Application of the National Building Regulations.
5. The tank shall be designed such that all requirements of the Occupational Health and Safety Act (Act No. 85 of 1993) and its regulations are adhered to.
6. The tank shall be designed with two compartments to allow for periodic desludging. The tank is easily accessible.
7. The tank shall always be watertight and shall not allow for any storm water inflow. The tank is constructed of materials which are not susceptible to corrosion, corrosion protection as per 240-101712128 and 240-106365693. The interior is plastered with a waterproof material.
8. Water supply for cleaning shall always be available within the vicinity of the conservancy tank. The design includes a water connection point.

4.9.1 Design Phase

1. The Contractor engages a competent qualified Professional Engineer experienced (minimum 5 years' experience) in the design of similar work to be fully responsible for the design.
2. The Services performed by the Contractor in the design phase include:
   2.1. Complete design in accordance with the requirements of this specification.
   2.2. Sizing and optimizing of the different components.
   2.3. Design of the sewage conservancy tank and all other associated supporting structures.
   2.4. The Contractor ensures the sewage conservancy tank is functionally and efficiently located and that it is sized for optimum space usage.

4.9.2 Construction Specifications

1. The tank is constructed and designed in accordance with the information contained within SANS 10400-P: The Application of the National Building Regulations.
2. The tank is designed such that all requirements of the Occupational Health and Safety Act (Act No. 85 of 1993) and its regulations are adhered to.
3. The inlet is designed such that blockage by the scum layer is prevented.

4. The tank is designed with two compartments to allow for periodic desludging. The tank is easily accessible.
5. The tank is watertight at all times and does not allow for any storm water inflow. The tank is constructed of materials which are not susceptible to corrosion, corrosion protection as per 240-101712128 and 240-106365693. The interior is plastered with a waterproof material.
6. Water supply for cleaning is always available within the vicinity of the conservancy tank. The design includes a water connection point.

4.9.3 Codes, Standards, and Guidelines

The Contractor complies with the latest revisions of the standards as per Appendix C.

4.10 Monitoring and Meteorological Equipment and Instrumentation

1. The Plant monitoring and meteorological measurement system shall comply with requirements for Class A of the most recent IEC 61724-1 Photovoltaic system performance. Part 1: Monitoring standard.
2. The Contractor shall install the required number of monitoring and measurement sensors, instruments, and equipment as indicated in IEC 61724-1, taking note of the following:

    2.1. Irradiance:

        2.1.1. Minimum of two (2) horizontally mounted and completely unshaded, calibrated pyranometers to measure the global horizontal irradiation, and minimum of two (2) in-plane (POA) irradiance sensors according to Secondary Standard as stipulated in ISO 9060.

        2.1.2. For bifacial modules, minimum of two (2) horizontally mounted albedometers installed away from the solar array in an unobstructed area to measure the horizontal albedo and optionally diffuse irradiance, and use in an optical model, such as a view-factor or ray-tracing model, to estimate rear-side irradiance; or

        2.1.3. For bifacial modules, minimum of six (6) in-plane rear-side irradiance or, optionally, spectrally matched in-plane rear-side irradiance albedometers.

    2.2. PV module temperature:

        2.2.1. Minimum of six (6) thermal sensors (according to IEC 61724-1) to measure module surface temperature with a measurement resolution ≤ 0.1°C and uncertainty of ± 1°C at the PV module back sheet.

        2.2.2. Module temperature can vary across each PV module and across the PV array. Temperature sensors shall be placed in representative locations to capture the range of variation an allow determination of an effective average.

    2.3. Ambient air temperature:

        2.3.1. Minimum of two (2) shielded ventilated thermocouples, appropriately distributed around the PV Plant, to measure the ambient temperature with a measurement resolution of ≤ 0.1°C and uncertainty of ± 1°C (according to IEC 61724-1).

    2.4. Soiling:

        2.4.1. Minimum two (2) soiling measurement instruments installed on the PV module plane of array (POA) to approximate the impact of soiling on the performance of the PV Plant (according to IEC 61724-1).

    2.5. Wind speed and direction:

2.5.1. Minimum of two (2) wind speed and wind direction anemometers, appropriately distributed around the PV Plant, mounted at height and location which are representative of the PV array conditions (according to IEC 61724-1).

2.5.2. Wind measurement equipment should not shade the PV system at any time of day or year and should be located at a point that is sufficiently far from obstructions.

2.6. Rainfall:

2.6.1. Minimum of two (2) rainfall measurement sensors, appropriately distributed around the PV Plant.

2.7. Humidity:

2.7.1. Minimum of one (1) relative humidity measuring sensor.

2.8. Tracker system:

2.8.1. For single-axis trackers, measurement of the real-time tracker tilt angle shall be performed (according to IEC 61724-1).

3. The meteorological station specification, installation, operation, and maintenance shall comply the manufacturer's guidelines and requirements set forth in World Meteorological Organisation best practices.
4. The meteorological station must be powered by UPS with at least 12 hours of uninterrupted power supply capacity. The status of the UPS devices (battery level, UPS temperature, etc.) must be monitored at all times by the monitoring system and alarms must be triggered in case of values exceeding specific ranges.
5. The design of the meteorological stations shall be such that 100% of all maintenance work can be accomplished while the equipment remains in operation.
6. The measurement equipment will be provided with the necessary protection against the site conditions. However, it must be easily accessible for maintenance and inspection purposes.
7. The stations shall be connected to the Plant monitoring and control system.
8. The final location of the meteorological stations and instruments shall be reviewed by the Employer.
9. All instruments and equipment shall be supplied with calibration certificates not older than six months. All sensors shall be calibrated and recalibrated in accordance with the manufacturer's specifications and as a minimum on a yearly basis.

4.11 Inspection Testing and Commissioning

1. This section describes the type of inspections, tests, and performance verification that the Contractor demonstrates during the execution of the Project. These tests are defined as:
    1.1. Tests before Installation;
    1.2. Tests after Installation;
    1.3. Tests after Completion; and
    1.4. Tests after Operational Acceptance.

4.11.1 General Requirements

1. The Contractor:
    1.1. Refers and complies with the following Standards:
        1.1.1. IEC 62446 - Grid connected photovoltaic systems - Minimum requirements for System documentation, commissioning tests & Inspections" to complete the minimum requirements for a PV Plant commissioning.
        1.1.2. IEC 60364-6 - Low Voltage Electrical installations.
        1.1.3. IEC 62337 - Commissioning of Electrical, Instrumentation and Control systems.
        1.1.4. Grid Connection Code for Renewable Power Plants (RPPs) connected to the Electricity Transmission System (TS) or the Distribution System (DS) in South Africa.
        1.1.5. SANS 10173 Code of Practice for the Installation, Testing and Balancing of Air Conditioning Ductwork, or CIBS Commissioning Code A: 1996 or latest revision.
        1.1.6. Automatic Controls: CIBS Commissioning Code B: 1996 or latest revision.
        1.1.7. Refrigerating Systems: CIBS Commissioning Code R: 2002 or latest revision.
    1.2. Uses Commissioning best practice methods and any other relevant standards.
2. Personnel and Facilities:-
    2.1. Inspects, tests, commissions, and performs all relevant tests of the PV component and system at manufacturing facilities, independent laboratories and on site, as per requirements set in this document, to demonstrate compliance with the Contract, as built (design) documents and standards.
    2.2. Provides facilities necessary to enable the inspection, testing, commissioning, and performance testing of the Project to be satisfactorily completed including labour, equipment, materials, instruments, consumable materials, electrical power, fuel, lubricants, water etc.
    2.3. Provides staff with the relevant skills and competence for the inspection, testing, commissioning, performance testing and witnessing required.
    2.4. Provides an ECSA registered professional engineer to declare the installation complies with all standards & requirements.
    2.5. Ensures that the supervising commissioning engineer has a minimum of 3 years' experience in the commissioning and performance testing of utility scale PV installations.
    2.6. Is responsible for all Health & Safety requirements during commissioning. Provides a Safety Briefing for all personnel who will carry out or witness the tests and ensures that such personnel always comply with all applicable Health & Safety procedures during the tests. Ceases any testing if any unsafe conditions rise.

2.7. Provides the opportunity to the Employer and Employer's representatives to witness all commissioning tests. The Employer provide reasonable and adequate notice to the Contractor that other parties have been invited to witness the tests and the Contractor provides all facilities and support that are reasonably required by the Employer for such parties to witness the tests.

2.8. Co-operates and co-ordinates with the Employer, Employer's representatives, and Site Managers in the best way to ensure the commissioning activities are performed respecting all Employers' requirements.

2.9. Commences commissioning activities respecting all legal, environmental, and administrative requirements.

2.10. Co-operates with the respective authorities for verification of their requirement during project installation, commissioning, and operation.

2.11. Executes all commissioning activities at any time in the most diligent manner, at highest level of professionalism, and considering the best practice and in good workmanship established in the PV industry.

3. Instruments:-

3.1. Provides any instruments or other equipment for the Employer and Employer's representatives to review the accuracy, quality, and performance of the PV Plant.

3.2. Provides any assistance required by Employer and Employer's representatives in the use of instruments and measuring equipment.

3.3. Ensures that instruments used for inspection, testing, commissioning, and performance monitoring are correctly calibrated and up to date, according to their relevant standards. Submits valid calibration certificates with method statements and test records.

3.4. Provides temporary communication equipment as necessary to enable the commissioning team to carry out their tasks safely and effectively. Ensure temporary communication equipment does not cause interference with equipment owned or operated by any other parties.

4. Defects and Delays:-

4.1. Submits without delay any record indicating that any part of the PV Plant inspected or tested does not comply with the Contract Documents and Test Protocols along with a method statement for the proposed remedial works including measures to be taken to prevent any delay to the programme for the PV Plant.

4.2. Rectifies any defects that become apparent during inspection, testing, commissioning, and performance testing. Re-test defective parts of the PV Plant, and any associated interdependent systems, and demonstrate that the PV Plant operates in accordance with the Contract Documents.

5. Test Protocols and Reports:-

5.1. Provides to the Project Manager, at least three (3) weeks prior to start of any tests, detailed test protocols including information regarding test schedules, testing methodology, equipment to be used, evaluation method, and the criteria of acceptance of each test type. The Project Manager must accept the test protocol before the commencement of any tests. The test protocol includes, but not limited to:

5.1.1. Definition of each test type and test methods

5.1.2. List of equipment to be used for each test along with technical specification, measurement uncertainties and relevant certificates

5.1.3. Duration of each test

5.1.4. Test evaluation method (including equations – wherever applicable)

5.1.5. Acceptance/Rejection criteria for each test type

5.2. Provides the report to the Project Manager upon the successful commencement of any tests during commissioning. The report includes, but not limited to:

5.2.1. Final test protocol

5.2.2. Raw data (un-processed)

5.2.3. Evaluation of raw data (processed data)

5.2.4. Final result indicating the acceptance/rejection of each test type

4.11.2 Tests before Installation

1. Tests before installation refers to the following tests for all components to be used for the Project:- Quality Control Plans or Inspection & Test Plans shall be accompanied by objective acceptance criteria which shall be subject to review and acceptance and any test where in a witness or Hold point populated by the employer shall be subject to witnessing

   1.1. Factory Acceptance Test

   1.2. Independent Laboratory Test

   1.3. Site Acceptance Test

2. Factory Acceptance Tests are done only for major Plant components: PV module, Inverter, Transformer, Switchgear, and CMS Equipment. The tests/inspections are performed in the respective components manufacturers' premises prior to the shipment of components.

3. The Contractor to submit for review and acceptance to the Employer the test program for Plant at least three (3) weeks prior to the Factory Acceptance Test date for local supplied equipment and at least nine (9) weeks for equipment not locally supplied. The test program includes but is not limited to::-

   3.1. Date of commencement of each test type

   3.2. Detailed description of inspections/test types

   3.3. Component certificates, technical data sheets

   3.4. Manufacturer's quality certificates

   3.5. Standards to be followed during testing/inspection

   3.6. Test results of former inspections/tests, if available

4. The Employer and the Employer's representatives reserve the right to attend and witness any Factory Acceptance Test at its own cost. The Contractor is notified of the Employer's intent to attend the test not later than one (1) week prior to the test.

5. Upon the successful completion of the Factory Acceptance Test, the Contractor submits the test report along with the relevant documents. All test reports are prepared by the Contractor and contains, but not limited to:-

   5.1. Definition of each test type and test methods

   5.2. Technical data along with the component certificate of the tested components

   5.3. Test evaluation and technical data of tested components, including relevant certificates

   5.4. Compliance with the requirements for the Project and/or Industry practice

   5.5. Summary and conclusion with regard to acceptance or rejection of equipment

6. The test reports are reviewed and accepted by the Employer prior to shipment of the tested components to the Project site. The test reports, and its supporting documents, must be signed by the Contractor and the Employer prior to shipment of tested components.
7. The Contractor is responsible for management and any additional expenses that are caused due to the requirement for any repetition of Factory Acceptance Tests.
8. PV Module:-

8.1. The Contractor verifies that all PV modules that are delivered for the Project have been quality checked and complies with the Employer's requirement.

8.2. Quality acceptance test for PV modules is performed during the Tests before Installation (prior to delivery of PV modules on site). The goal of the quality acceptance tests for PV modules is to verify the power of the delivered PV modules according to the manufacturer power guarantee levels and requirements set in this document, and that the PV modules are free from any manufacturing defects. For this purpose, the following two tests are performed:

8.2.1. Nominal vs. Manufacturer Flash Test Power Comparison

8.2.2. Independent Laboratory Test – Counter Check

8.3. Nominal vs. Manufacturer Flash Test Power Comparison:

8.3.1. The Contractor provides to the Employer the module supplier's/manufacturer's measurement data on major electrical parameters (Isc, Voc, Impp, Vmpp, Pmpp, and Fill Factor) for every individual PV module to be delivered to the Project site, in PDF and Excel table format. The common term for such kind of measured data is called flash test data.

8.3.2. The Contractor is responsible to verify that all the modules to be supplied are within guaranteed nominal power and within the provided tolerances on power. For this purpose, the power at MPP in the flash test data sheet is checked against the nominal power and power tolerances. Those modules of which power is beyond the specified rating and the respective tolerance are rejected for the Project. The flash test data and results are reviewed and accepted by the Employer.

8.4. Independent Laboratory Test – Counter Test:-

8.4.1. A second quality check on PV modules is performed to cross check the module quality and the nominal power of modules to be delivered for the Project. This is an independent laboratory verification of compliance with the respective design qualification and type approval of the module stipulated in the required standards (i.e. IEC 61215). Since this test aims to verify the manufacturer's compliance with the type certification and factory testing, it is also called Counter Test.

8.4.2. The Contractor ensures that the independent testing laboratory for the counter test is certified according to ISO/IEC 17025. The scope of the accreditation certificate of the laboratory must cover the test standards required for certification of PV modules.

8.4.3. The counter test consists of two major inspections: Visual inspection and Power measurement.

8.4.4. Visual inspection on sample modules is carried out according to IEC 61215 standards. This clause aims to check if there is some material defect, broken cells, or faulty connections in the module.

8.4.5. Power measurement is done by measuring the I-V curve and the electrical parameters under Standard Test Condition (STC). The measurement must be performed according to the requirements defined in IEC 60904-1 and IEC 60904-3. The measurement uncertainty of MPP power of modules does not exceed ±3% (for c-Si modules). The measurements are carried out with AAA class sun simulator according to IEC 60904-9.

8.4.6. The modules to be measured belong to the samples from shipment lot or batch of modules that are going to be delivered to the Site. Upon the receipt of flash test data and result on power comparison, the Employer randomly selects the samples which the Contractor tests in the independent laboratory. The sampling procedure is in accordance with ISO 2859-1. Special inspection level S4 with Acceptance Quality Level (AQL) 4.0 is used. Table 4-5 shows the sample size to be considered for the counter test and the acceptance and rejection size. If the number of rejected modules within the sample (inspection level S4) of a certain lot is equal to or greater than the rejection threshold AQL 4.0 according to ISO 2859, all modules of this lot are not considered for the Project and are rejected and replaced.

Table 4-5: Sample size and rejection threshold for counter test

Lot Size [units]	Sample Size (inspection level S4) [units]	Admissible faults (AQL 4.0) [units]	Rejection threshold (AQL 4.0) [units]
1,000 – 1,200	20	2	3
1,201 – 10,000	32	3	4
10,001 – 35,000	50	5	6
35,001 – 500,000	80	7	8

8.4.7. The modules are to be completely sealed from any exposure to light during packing and transport from the factory until the time that the counter test is performed. It is part of the laboratory work order to maintain the modules in a dark storage environment such that no light exposure can take place and induce any degradation or other effect prior to the Counter Test.

8.4.8. The Counter Test is performed within fifteen (15) days after receipt of the PV modules by the laboratory. The Contractor is responsible for delivery of the modules to, and returns the modules from, the laboratory. All costs and expenses connected and related to the Counter Test (including the transportation of the modules and the fees for the laboratory) is the responsibility of the Contractor.

8.5. Upon the completion of power comparison test and counter test, PV modules fulfil the following conditions for delivery for the Project.

8.5.1. Manufacturer flash test data confirm that every module to be delivered for the Project has MPP power within the provided tolerance ranges

8.5.2. Visual inspection carried out on sample module according to IEC 61215 does not detect any damages or abnormalities; and

8.5.3. Counter Test on nominal power of sample modules confirm that modules are supplied with guaranteed power ratings and the module power is within the manufacturer tolerances limit.

8.6. The Contractor delivers PV Modules to the site with all relevant documents (test reports, technical data sheet, relevant certificates, warranty, installation manuals etc.).

9. Inverter:

9.1. The Contractor provides to the Employer all type test and serial test results performed by the respective inverter manufacturer/supplier for the inverters to be delivered for the Project. The tests include all certificates according to valid IEC and South African Grid Code standard as described in Table 4-6.

Table 4-6: Inverter certificate standards

Standard	Description
Minimum required standards	
IEC 62109	Safety of Static Inverters
IEC 61727	Characteristics of the Utility Interface
IEC 62116	Testing procedure of Islanding Prevention Methods for Utility-Interactive Photovoltaic Inverters
IEC 62103	Electronic equipment for use in power installations
IEC 61000-6-3/4	EMC Emission
IEC 61000-6-1/2	EMC Immunity
Others	South African Grid Code for Renewables

9.2. The Contractor provides to the Employer the following minimum serial test result for the inverters to be delivered to the Project site. The minimum tests are:

9.2.1. Visual inspection

9.2.2. Cabling checks

9.2.3. Protective conductor test

9.2.4. High Voltage test

9.2.5. Configuration of assembly components

9.2.6. Functional test

9.2.7. Long term test

9.2.8. Safety and protection test

9.3. The Contractor only delivers the inverters to site upon submission and acceptance of its factory acceptance test results.

9.4. The Contractor delivers inverters to the site with all relevant documents (test reports, relevant certificates, technical data sheet, warranty, installation manuals etc.).

10. Transformer:

10.1. Before being fitted to the transformers, all components are subjected to routine tests required by the relevant standards at the suppliers or sub-supplier's factory. A detailed test report, proving the successful passing of such tests, is to be provided.

10.2. Unless otherwise specified, the tests are carried out in accordance with IEC standards. The following tests are performed and witnessed by the Employer/Employer's representative at the manufacturer's factory prior to shipment:

10.2.1. Transformer Ratio Test

10.2.2. Insulation Resistance Test

10.2.3. DC Winding Resistance Test

10.2.4. Temperature Rise Test

10.2.5. Load Loss Measurement

10.2.6. Power Frequency Voltage Withstand Test

10.2.7. Lightning Impulse Test

10.3. Transformer Ratio Test:

10.3.1. This test is carried out with the use of a Turns Ratio Test set, the ratio of the transformer is to be proven on all the tap positions and using the same test equipment the voltage vector relationship is also checked.

10.3.2. The measurement of voltage ratio and check of voltage vector relationship are carried out in accordance with the applicable procedure laid out in IEC 60076.

10.3.3. The results are recorded on a test sheet.

10.4. Insulation Resistance Test:

10.4.1. This test is carried out with all cables disconnected; a 5kV insulation resistance test is to be applied:

10.4.1.1. between primary winding and earth.

10.4.1.2. between secondary winding and earth.

10.4.1.3. between primary and secondary winding.

10.4.1.4. The results are recorded on a test sheet.

10.5. DC Winding Resistance Test:

10.5.1. The winding resistance is checked on all taps of the tap charger to verify there is no high resistance on the tap charger and windings. A DC winding resistance test set is used for this test. This test is carried out in accordance with IEC 60076-1.

10.5.2. The results are recorded on a test sheet.

10.6. Temperature Rise Test:

10.6.1. To be carried out in accordance with IEC 60076-2, at rated voltage, rated frequency and with rated power of the secondary winding.

10.6.2. The winding temperature is ascertained by using the resistance method. The hot spot temperatures rise is performed in accordance with the SANS 60354.

10.6.3. Full details of the test arrangements, procedures and conditions are supplied with the test certificates.

10.7. Load Loss Measurement:

10.7.1. The Employer does not allow any tolerances on load losses above those stated in IEC 60076-1.

10.7.2. The load losses on every transformer is measured on the principal tapping position and corrected to the reference temperature specified in IEC 60076-11.

10.8. Power Frequency Voltage Withstand Test:

10.8.1. Both a separate-source AC withstand voltage test and an induced AC withstand voltage test are performed in accordance with IEC 60076-11.

10.8.2. The basic insulation levels and corresponding test voltages will be in accordance with IEC 60076-3.

10.9. Lightning Impulse Test:

10.9.1. This test is carried out in accordance with IEC 60076-11.

10.9.2. The basic insulation levels and corresponding test voltages will be in accordance with IEC 60076-3.

11. Switchgear and Ring Main Units:

11.1. The Contractor proves the ability of the ring main unit (RMU) to pass the mandatory type tests in accordance with SANS 62271-200 and SANS 1874.

11.2. Routine tests for RMUs are according to the requirements in SANS 62271-200.

11.3. Internal arc classification test for RMUs are according to the requirements in SANS 1874.

11.4. All RMUs fitted within a metal enclosure for outdoor applications shall be tested in accordance with SANS/IEC 62271-202. The following requirements for these tests shall apply:

11.4.1. The tests shall be performed on each RMU manufacturer type offered, and each RMU shall be tested inside the exact RMU enclosure design offered (i.e., same material, dimensions, manufacturing method, manufacturer, manufacturing location, etc.),

11.4.2. All the related SANS/IEC 62271-200 and SANS/IEC 62271-202 compliant type test reports and type test videos applicable for the selection of tests on HV switchgear for the proof of class IAC-A and IAC-B in accordance with SANS/IEC 62271-202, shall be submitted to the Employer for safety review and technical evaluation. This shall include the applicable type test reports and videos for each RMU enclosure manufacturer design and RMU manufacturer option offered. These type test reports and videos will be reviewed and evaluated to ensure safe installation and operating procedures are implemented by the Employer for the internal arc venting behaviour observed as part of the Eskom Zero harm values,

11.4.3. All type test reports and videos for all applicable IAC AB tests performed in accordance with SANS/IEC 62271-202 and SANS/IEC 62271-200 for the RMU and metal enclosure combinations offered is supplied to the Employer for safety review.

11.4.4. RMUs for indoor applications shall be tested in accordance with SANS/IEC 62271-200. The following requirements for these tests shall apply:

11.4.4.1. The tests shall be performed on each RMU manufacturer type and design offered (i.e., same material, dimensions, manufacturing method, manufacturer, manufacturing location, etc.),

11.4.4.2. All the related SANS/IEC 62271-200 compliant type test reports and type test videos shall be submitted to the Employer for safety review and technical evaluation.

11.5. The Factory Tests are performed in accordance with SANS 1874, including the MV test. For the individual switchgear apparatus (i.e., circuit breaker, load break switch, etc.), type and routine test certificates of the manufacturer must be supplied.

11.6. The following Site Tests are performed:

11.6.1. Visual Inspection

11.6.2. Timing and Contact Resistance Tests on Circuit Breaker

11.6.3. Insulation winding resistance and Ratio test on voltage/current transformers

11.7. Visual Inspection:

11.7.1. Visual Inspection is made prior to any measurements/tests. The inspection follows the manufacturer’s checklist/procedures and confirms that the component is free from any defects.

11.8. Circuit Breaker:

11.8.1. The circuit breakers offered are to be fully type tested in accordance with IEC 60056 and IEC 60694 to be witnessed by Employer and Employer’s representatives. The Contractor agrees to perform the type test on one independent test station.

11.8.2. Timing Test: The circuit breaker is to be electrically operated and verified that the opening and closing times fall within the designed parameters.

11.8.3. Contact Resistance Test: A 100 Amps micro-ohm meter is used to conduct this test. The CB is closed, and 100 Amps is passed through the breaker closed contacts from the 3 phase incoming terminals to the outgoing terminals. A voltage is detected across the contacts through the voltage detection leads connected to the same terminal pads. The test must provide a resistance in micro-ohms signifying low contact resistance.

11.9. Voltage and Current Transformers:

11.9.1. The voltage transformers for metering and protection offered are to be fully type tested in accordance with SANS 61869-3/IEC 61869-3. Full type test certificate are submitted. The current transformers are to be fully type tested in accordance with SANS 61869-2/IEC 61869-2. The following tests are performed as minimum:

11.9.1.1. Insulation Winding Resistance Test

11.9.1.2. Ratio Test

11.9.1.3. Type Test

12. The Contractor complies with the following mandatory type tests as per SANS 62271-200:

12.1. Test to verify the insulation level of the equipment

12.2. Test to prove the temperature rise of any part of the equipment and measurement of the resistance of circuits

12.3. Prove the capability of the main and earthing circuits to be subjected to the rated peak and the rated short time withstand currents

12.4. Tests to prove the making and breaking capacity of the included switching devices

12.5. Tests to prove the satisfactory operation of the included switching devices and removable parts

12.6. Tests to verify the IP protection code

12.7. Tests to verify auxiliary and control circuits

13. SCADA/CMS Test:

13.1. The SCADA/CMS Factory Acceptance Test is to be performed at the C&I Contractor's/Supplier's facility where the equipment is installed into its enclosures, connected, powered up and tested with the software application.

13.2. The Contractor provides the following factory acceptance tests for SCADA/CMS equipment, but not limited to:

13.2.1. Physical inspections of all SCADA/CMS hardware components, cabinets and enclosures. Network cabinets and field equipment panels will be inspected at the Factory with components fully installed and functional.

13.2.2. Redundancy and single fault tolerance checks will be performed on network equipment, servers, thin clients, switches, power supplies, etc.

13.2.3. Application software checks will be performed as required.

14. Low Voltage Installations:

14.1. All low voltage installations including distribution boards are tested in accordance with SANS 10142-1.

15. Site Acceptance Test:
    15.1. Site Acceptance Test refers to the inspections and document verification of all components immediately after the delivery of components on site.
    15.2. The Contractor verifies that all components delivered to the site are free from any defects and all documents (technical data sheet, certificates, warranty documents, Factory Test reports, and component manuals) are available.
    15.3. The Site Acceptance Test are witnessed and accepted by the Project Manager.

4.11.3 Tests after Installation

1. Tests after Installation refer to “Mechanical Completion Test" and "Electrical Completion Test”. These tests are the inspections and tests that are performed on site after mechanical and electrical installation work has been completed. These tests are related to document verification, visual inspections on site, electrical measurements, and safety checks.
2. The test after Installation must demonstrate:
    2.1. Completeness of the mechanical and electrical construction works
    2.2. Correctness of the assembly and installation
    2.3. Safety and reliability of the works under all operating conditions
    2.4. Inspection and functional tests
    2.5. Proper functioning of the components and system under all operating conditions
3. Tests after Installation are considered successful if the Plant complies with the requirements defined for each type of inspections described in this specification.
4. Copies of all tests and data are provided to the Employer for review and acceptance.
5. Test Pre-Requisite – Minimum System Documentation Requirement:
    5.1. Upon giving notice on readiness for Tests after Installation and prior to the commencement of Mechanical and Electrical Completion Inspection, the Contractor provides As Built Drawings as well as the Operation and Maintenance Manuals of the Plant to the Employer and Employer’s representative.
    5.2. The completeness of the documentation is reviewed and accepted by the Employer before commencement of the tests.
6. The following non-exclusive list of Plant sections are documented and checked during the Tests after Installation:
    6.1. Basic system information:
        6.1.1. Project location and installation date
        6.1.2. Rated system capacity (DC and AC)
        6.1.3. PV modules and inverter – manufacturer, model, and quantity
        6.1.4. Installation date
        6.1.5. Commissioning date (to be updated later if time schedule of tests not met)
    6.2. System designer’s information (name, affiliate, contact details)
    6.3. System installer/Contractor information (name, affiliate, contact details)

6.4. Detailed single line diagram of the DC, LV/MV AC part, and transmission line including detailed connection and wiring diagrams for array DC junction boxes and inverter stations/cabins.

6.5. General specifications of array:

6.5.1. Module type

6.5.2. Module number

6.5.3. Number of modules per string

6.5.4. Number of strings

6.6. PV string information:

6.6.1. String cable type, size, and length

6.6.2. Specification (current and voltage rating) of overvoltage protection device

6.7. Electrical characteristics of array:

6.7.1. Array junction box location

6.7.2. Array main cable specification

6.7.3. Location, type, and rating of over voltage protective devices

6.8. Earthing and over voltage protections including a single line diagram showing the details of all earthing, lightning protection systems, and details of surge protection devices

6.9. A single line diagram including DC and AC isolators location, type and rating along with similar information for AC over-current protection device

6.10. Plant safety regulation following all MCB's, MCCB's, Isolators employed in the AC electrical boards with a padlocking facility

6.11. Technical data sheet of all components

6.12. Full documentation of the SCADA

6.13. Description and documentation of all mechanical structures including details such as material type, structure mounting solution, foundation design, and geotechnical study

6.14. Warranty documentation for all strategic parts such as PV modules, inverters, structure, switchgear with the information of starting date of warranty and period of warranty

6.15. Documentation of all required legal and administrative permits, if any

6.16. Confirmation on project design and installation compliance with all permits (Environmental, Water Use license and grid code)

6.17. Documentation of module flash test data

6.18. The complete C&I design, network diagram, test certificates and test results.

7. Mechanical Completion Test:

7.1. Upon completion of the actual installation works, an inspection is conducted. The purpose is to verify that the Contractor has executed all installation works in accordance with the Contract and as built design and is compliant with applicable norms and standards. At this inspection it is tested that the works prove to be of good workmanship established in the PV industry and are free from any material/construction defects. During the inspection, the correctness of the documentation of the works in the As-Built Drawings is checked and verified.

7.2. Prior to the Inspection, the Contractor conducts an internal inspection that verifies the compliance of the works with the design and the Employer's Requirements. The minor deviations on execution

of work are recorded under the Punch-List. The Punch-List does not contain any outstanding issue which has an effect on safe operation, monitoring, Plant performance, and administrative/legal requirements. The Punch-List must be reviewed and accepted by the Employer before the Mechanical Completion Test.

7.3. The Contractor undertake the following, but not limited to, to verify the physical installation is completed according to the design:

7.3.1. General:

7.3.1.1. Verify all parts of the PV Plant are in line with the Final Design

7.3.1.2. Verify the PV Plant construction is according to the provisions of the Contract

7.3.1.3. Verify all equipment and parts have been installed according to their manufacturer's installation manuals

7.3.2. PV Modules:

7.3.2.1. Inspect Modules as installed and verify absence of any breakages, scratches, damage on back sheet, junction box, frame distortions, and bending or any other signs of incorrect or incomplete installation

7.3.2.2. Verify that Modules have been sorted according to their Flash Test Data

7.3.2.3. Verify that serial number of each module is documented according to installation location on site

7.3.2.4. Verify that the installation was done according to manufacturer’s recommendation and/or requirements

7.3.3. PV String Combiners:

7.3.3.1. Verify that PV String cables have been permanently marked and numbered

7.3.3.2. Check cable Pulling Test records

7.3.3.3. Inspect DC cabling between modules and verify that cable types, sizes and lengths as well as cable connector types are in accordance with the design

7.3.3.4. Verify the integrity of Surge Protection Devices and all Earthing connections

7.3.3.5. Verify the installation according to design and manufacturer’s recommendation

7.3.3.6. Verify that the string monitoring system have been installed according to design and requirement for communication to SCADA/CMS system

7.3.4. PV Mounting Structures:

7.3.4.1. Verify correct Orientation and Inclination angles for the PV Modules

7.3.4.2. Verify that the installation is free from any corrosion

7.3.4.3. Verify fastening with recommended torque, overall set-out distances, surfacing, alignment and completeness of the assembly

7.3.5. Foundation and Civil works:

7.3.5.1. Verify all civil works (O&M building, foundation, security systems, internal roads) are completed according to design and according to permits for the Project

7.3.5.2. Verify that security system (fences, video surveillance) are installed according to Employer’s requirement

7.3.5.3. Verify HVAC, drainage and sewage systems installed according to as built design

7.3.6. PV Inverters:

7.3.6.1. Verify that all cables and switches have been marked and numbered permanently

7.3.6.2. Inspect all DC & AC cabling and verify that cable types, sizes and lengths are in accordance with the design

7.3.6.3. Verify all inverter parameters are set up within Manufacturer's recommendations, grid requirements and local regulations

7.3.6.4. Verify the ventilation of inverter cabin is installed according to design and inverter manufacturer's recommendation (if any) for operation in project location

7.3.7. Inverter stations/cabins containing inverters, transformers, and switchgear:

7.3.7.1. Verify that all cables and switches have been marked and numbered permanently

7.3.7.2. Inspect AC cabling and switches and verify that types, sizes and lengths are in accordance with the design

7.3.7.3. Verify Voltage Controls

7.3.7.4. Inspect Insulation Test records on all cables and circuits

7.3.7.5. Proper Installation and safety during operation

7.3.7.6. Verify the physical installation of energy meters, protections, earthing and lightning

7.3.8. Control and Monitoring System:

7.3.8.1. Verify all system components and respective electrical and data connections are according to design

7.3.8.2. Verify all Calibration Certificates are available

7.3.8.3. Verify broadband equipment and connections

7.3.9. Labelling and Identification:

7.3.9.1. Verify all circuits, protective devices, switches and terminals are suitably labelled

7.3.9.2. Verify all DC junction boxes (PV generator and PV array boxes) carry a warning label indicating that active parts inside the boxes are fed from a PV array and may still be alive after isolation from the PV inverter and public supply

7.3.9.3. Verify the main AC isolating switch is clearly labelled

7.3.9.4. Verify dual supply warning labels are fitted at point of interconnection

7.3.9.5. Verify a single line wiring diagram is displayed on site

7.3.9.6. Verify the inverter protection settings and installer details are displayed on site

7.3.9.7. Verify the emergency shutdown procedures are displayed on site

7.3.9.8. Verify all signs and labels are suitably affixed and durable

7.3.10. HVAC System: The complete HVAC system is to be commissioned in accordance with the following SANS and Chartered Institution of Building Services Engineers (CIBSE) codes or such other recognized commissioning procedure or code accepted by the Employer:

7.3.10.1. Air distribution systems: SANS 10173: Code of Practice for the Installation, Testing and Balancing of Air Conditioning Ductwork, or CIBS Commissioning Code A: 1996 or latest revision

7.3.10.2. Automatic controls: CIBS Commissioning Code C: 2001 or latest revision

7.3.10.3. Refrigerating Systems: CIBS Commissioning Code R: 2002 or latest revision

7.4. Upon the successful completion of Mechanical Completion Test, the Mechanical Completion Certificate will be issued by the Employer.

8. Electrical Completion Test:

8.1. The Electrical Completion Test is performed to verify the proper functionality, configuration, and installation of the PV Plant. The electrical configuration tests are considered as minimum requirement and are performed according to IEC 62446, IEC 60364-6, Grid Connection Code for Renewable Power Plants (RPPs) Connected to the Electricity Transmission System (TS) or the Distribution System (DS) in South Africa and current best practice. The tests are witnessed by the Employer and Employer's representative.

8.2. The Contractor undertake the following, but not limited to:

8.2.1. Tests on AC circuits in accordance with IEC 60364-6:

8.2.1.1. Continuity of conductors

8.2.1.2. An electrical continuity test be made on protective conductors, including main and supplementary equipotential bonding conductors, and live conductors in the case of ring final circuits

8.2.1.3. Insulation resistance of the electrical installation

8.2.1.4. The insulation resistance is measured between live conductors and the protective conductor connected to the Earthing arrangement

8.2.1.5. Protection by SELV, PELV or by electrical separation

8.2.1.6. Insulation resistance/impedance of floors and walls

8.2.1.7. Protection by automatic disconnection of the supply

8.2.1.8. Polarity test

8.2.1.9. Check of phase sequence

8.2.1.10. Functional tests

8.2.1.11. Verification of voltage drop

8.2.2. Tests on DC circuits in accordance with IEC 62446-1:

8.2.2.1. Continuity of protective Earthing and/or equipotential bonding conductors, where fitted. Where protective or bonding conductors are fitted on the DC side, such as bonding of the array frame, an electrical continuity test is made on all such conductors. The connection to the main Earthing terminal should also be verified

8.2.2.2. The polarity of all DC cables is verified using suitable test apparatus. Once polarity is confirmed, cables be checked to ensure they are correctly identified and correctly connected into system devices such as switching devices or inverters

8.2.2.3. I-V curve measurement on all strings – The nominal power of strings is measured and their respective power to be verified against the sum of name plate power of modules connected to string. Open circuit voltage and PV current also to be verified according to IEC 62446-1

8.2.3. The following functional tests be performed:

8.2.3.1. Switchgear and other control apparatus to be tested to ensure correct operation and that they are properly mounted and connected

8.2.3.2. A loss of mains test to be performed: With the system operating, the main AC isolator is opened – it should be observed (e.g., on a display meter) that the PV Plant immediately ceases to generate. Following this, the AC isolator should be re-closed, and it should be observed that the system reverts to normal operation

8.2.3.3. PV array Insulation resistance test. All inverters forming part of the PV Plant be tested to ensure correct operation. The test procedure should be the procedure defined by the inverter manufacturer/supplier. During electrical completion test, the Contractor provide proof of inverter commissioning test report/certificate which verify that all the inverters installed on site fulfils the requirements defined by manufacturer for the safe and efficient long-term operation

8.2.3.4. The Contractor pays special attention to the operating temperature of the inverter and inverter cabin. For this purpose, the Contractor measures the operating temperature of inverter/inverter cabin for at least seven consecutive days and verifies that the operation of inverter (without derating) is within the manufacturer's recommended range

8.3. Certificate of Compliance

8.3.1. Certificate of Compliance (CoCs) are issued for all single phase, three phase or DC type electrical installations within the O&M Building(s) including the control room, offices and work stations, server and equipment room, kitchen and ablution facilities, spares storeroom, and security access building. This is also applicable for all internal and external lighting areas of the O&M building(s).

8.3.2. Work on an electrical installation shall be carried out under the control of a registered person who shall issue a CoC after inspection and tests are conducted on the installation. Registered person may not issue CoC where faults exist

8.3.3. When issuing CoC, it is important to make sure that it extends as far as where the installation ends (point of consumption or supply terminals) and that it does not extend into the machinery connected to the installation

8.3.4. The Contractor submits test reports of all electrical installations as per the sample test report (Certificate of Compliance) in SANS 10142-1

8.3.5. CoC and test report is issued only by electrical tester, installation electrician or master electrician for single phase installation

8.3.6. CoC and test report is issued only by installation electrician or master installation electrician for three phase and DC installations

8.3.7. The CoC is also accompanied by as-built design package documentation

8.4. Functional Test of Meteorological System and C&I system:

8.4.1. Functional test procedure and check sheets are provided to ensure that the SCADA/CMS meets the requirements as specified in the Scope of work

8.4.2. All meteorological stations signal be working properly, and the data are being recorded into the monitoring system

8.4.3. Commissioning of C&I system is according to IEC 62337 - Commissioning of Electrical, Instrumentation and Control systems

8.4.4. Test communications with string combiner boxes and inverters

8.4.5. Verify format and handling of acquired data set

8.4.6. Check threshold alarm controls

8.4.7. Inspect all system displays, event recording and timing synchronization regime and data storage and upload from local to remote

8.4.8. Inspect the site communication systems - broadband cable distribution and GSM (backup, if provided)

8.4.9. Inspect operation of display and data-processing software and check visualization from local to remote

8.4.10. Control of remote system access and data downloading

8.4.11. Handover of access rights and passwords

8.5. Infrared Thermography:

8.5.1. Infrared scanning on all PV modules as well as electrical connections is performed in order to verify that modules are free from any hot spots and electrical connections are properly made. Infrared scanning is done when irradiation on module plane is greater than 500 W/m^2.

8.6. Grid Code connection test:

8.6.1. The Contractor performs the Grid Connection test according to Grid Connection Code for Renewable Power Plants (RPPs) Connected to the Electricity Transmission System (TS) or the Distribution System (DS) in South Africa and provides a test report. In any case the Grid Connection Test is witnessed by the Employer and the Employer's representative. The test is approved by a third party provided by the Employer

8.6.2. The Contractor provides an ECSA registered professional engineer or technologist to declare the installation complies with all standards and requirements

8.6.3. Upon the successful completion of Grid code test, the Contractor provide a Certificate of Compliance (COC) of the PV Plant certified by the ECSA registered professional engineer or technologist and the responsible person

8.7. Reporting:

8.7.1. Once the Electrical Completion tests are successfully performed, the Contractor provide the report to the Employer, for review and acceptance, including the following:

8.7.1.1. A report, signed by the Contractor, summarizing each test performed and their acceptance or rejection according to the test protocol, relevant standards and requirements

8.7.1.2. Test raw data and processed data

8.7.1.3. Final Test protocol along with list of measurement equipment considered during testing and their specification

8.7.1.4. Certificate of Compliance (COC) for all electrical installations

8.7.1.5. Plant safety clearance certificate accompanied by the relevant as-built design package documentation, equipment type test certificate, calibration certificates for test equipment, routine test results

8.7.2. Upon the successful completion of Electrical Completion Test, the Employer issue Completion Certificate to the Contractor.

4.11.4 Tests after Completion

1. Tests after Completion refer to the "Provisional Acceptance Test (PAT)" which verifies both performance ratio and availability of the Plant against the Contractor's guarantee.
2. The following is to be completed before the start of PAT:

2.1. Mechanical Completion Certificate, Certificate of Compliance (COC) for electrical installations, safety clearance certificates for Plant installations, Completion Certificate have been issued

2.2. Training on Construction and Commissioning to the Employer's representative and Employer's staff have been completed

3. The Contractor has provided O&M Manual to the Employer and the Employer' representative, which include, but not limited to:

3.1. Procedures for verifying correct system operation (Start-up / Shut down of PV Plant , HMI operation, Single line diagram, Regular Maintenance on Modules, Inverter first line maintenance, transformer, switchgear, UPS, etc.)

3.2. Safety Guidelines including emergency shutdown/isolation procedures

3.3. Preventive and corrective maintenance procedures including site inspection checklist for each component including power evacuation line and security systems

3.4. Scheduling of routine maintenance

3.5. A checklist of what to do in case of system failure

3.6. Documentation on stock of spare parts and spare parts management including contact information and procedures for replacement of defective components

3.7. Inverter O&M Manual (troubleshooting for error codes, repair, software for inverter, Fault finding on the DC Plant)

3.8. Data Acquisition System and CMS O&M Manual (troubleshooting, equipment descriptions, repair, metering equipment downloading, weather station)

3.9. Method of PV module cleaning

3.10. Operation and maintenance manual for inverter, transformer and module from respective manufacturers

3.11. Performance monitoring and reporting procedures

4. The Provisional Acceptance Test (PAT):

4.1. The Contractor executes the PAT and is witnessed by the Employer and the Employer's representative.

4.2. The Contractor prepares a detailed test program and test protocol based on requirements described in this document and submits to the Employer for approval.

4.3. The Test program and the test protocol must be accepted by the Employer/Employer's representative before the commencement of the test.

4.4. The SCADA system must be available at all times during the test period and the verification of Performance Ratio and Availability must be made through the data recorded in SCADA system.

4.5. The Contractor is allowed to run Performance Ratio and Availability test simultaneously or separately. In each case, the test period must be 15 consecutive valid days.

4.6. A valid day during the test period is defined as a day during which a daily average solar irradiation on module plane is greater than 2.0 kWh/m^2, measured by POA irradiance sensors or reference cells installed on the site. During the measurement period (15 consecutive days) if any day does not represent a valid day(s), the period of measurement will be extended consecutively with the same number of those days.

4.7. Such extension can be done up to a limit up to the Contractor's guaranteed operational acceptance date. If despite this extension, the required number of valid days are not achieved, then evaluation is be made only for available valid days.

5. The PAT Procedure:

5.1. Parameters and Instrumentation:

5.1.1. The following technical parameters are required to be measured on site by the Contractor in order to perform and verify the performance tests for both, Performance Ratio Test and Availability Test:

5.1.1.1. AC Energy output at the Point of Connection (PoC): [kWh]

5.1.1.2. Global solar irradiation on plane of array: [kWh/m^2]

5.1.1.3. Global solar irradiation on horizontal surface (GHI): [kWh/m^2]

5.1.1.4. Module temperature: [°C]

5.1.1.5. AC Energy output from each inverter: [kWh]

5.1.1.6. Ambient air temperature: [°C]

5.1.2. The first two technical parameters (major parameters) mentioned above are used directly to verify the performance of the Plant. The later four parameters are used as back up to verify consistency of measurement of major parameters. These parameters are to be stored in 15-minute intervals. The logged data is to be checked for consistency and validity and has to be found free from obvious anomalies or irregularities.

5.2. PAT Stopping and Restarting Procedure:

5.2.1. The PAT is stopped and restarted:

5.2.1.1. If the Plant, wholly or in part, ceases to operate at any time during PAT due to causes beyond the control of the Contractor, then the PAT is suspended during that time and resumes following restoration of operation, until the total PAT duration has reached the required length of valid days.

5.2.1.2. In the event of any disruptions due to Force Majeure, grid failure and caused by the Employer for a period longer than the Contractor's guaranteed operational acceptance date.

5.2.2. The Contractor maintains a log of any such event, including the cause, the duration and the times at which PAT was suspended and resumed. The Contractor provides written notice to the Employer within eight (8) hours following each such PAT suspension and resumption. All pre-requisites specified must remain satisfied on any such PAT resumption.

5.2.3. If at any point during PAT the Contractor deems that it is unlikely to pass the PAT, then the Contractor notifies the Employer and may discontinue the PAT. The Contractor may subsequently commence a new PAT, subject to compliance with all provisions and procedures within this Section.

5.3. Performance Ratio (PR) Evaluation Procedure during PAT:

5.3.1. The Plant Performance Ratio (PR) is evaluated according to equations below:

$$[PR_{measured}]_{PAT} = \frac{[E_{prod}]_{PAT}}{[E_{PV}]_{PAT}}$$

Where:-

$[PR_{measured}]_{PAT} =$ Average measured PR during the Provisional Acceptance Test period, expressed in %

$[E_{prod}]_{PAT}$ = Sum of energy measured in energy meters installed at point of connection during the Provisional Acceptance Test period, expressed in kWh

$[E_{PV}]_{PAT}$ = Theoretical energy that could have been produced by PV modules during the Provisional Acceptance Test period, expressed in kWh

$$[E_{PV}]_{PAT} = P_{Nom} \times \frac{[Irr_{POA-measured}]_{PAT}}{[Irr_{STC}]}$$

Where:

P_{Nom} = Nominal Peak Power of the PV Modules, sum of nameplate power of modules installed in the Plant, expressed in kWp

$[Irr_{POA-measured}]_{PAT}$ = Average solar irradiation measured on Plane of Array during the complete Provisional Acceptance Test period when the Plant was available, expressed in kWh/m^2

$[Irr_{STC}]$ = Solar irradiation at Standard Test Conditions (STC) condition, 1 kW/m^2 (constant)

5.4. Plant Availability Evaluation Procedure during PAT:

5.4.1. The Plant Availability is measured for a consecutive 15-day period, for the PAT.

5.4.2. The Plant Availability is evaluated based on technical availability of the inverter. The Plant must deliver energy to the meter at the point of connection during the period when the Plant is considered as available. Otherwise, the Plant is considered as unavailable.

5.4.3. The evaluation of Plant Availability is done only for the periods during which the global solar irradiation on module plane is higher than threshold level of solar irradiation. The threshold value of solar irradiation on module plane for Plant availability is 100 W/m2. This level of irradiation is considered as the minimum level of irradiation required to overcome the inverter's threshold power.

5.4.4. The stoppage of the Plant due to events caused by the following is not considered while evaluating the Plant availability:

5.4.4.1. events caused by faults that are not attributed to the Contractor (e.g., manual shut-down, inspections not attributable to the Contractor)

5.4.4.2. required by third parties (e.g., insurance companies, authorities)

5.4.4.3. attributable to the grid operator/the Employer

5.4.4.4. the result of Force Majeure events

5.4.5. The Plant Availability $[AV]$ is defined as average of individual inverter availability, as shown in the equations below:

$$[AV] = \frac{\sum_{i=1}^{i=n}[AV]_i}{n}$$

Where:-

i = Number of each individual inverter

n = Total number of inverters in the Plant

The individual technical availability of the inverter (i) is calculated by using the equation shown below:

$$[AV]_i = \frac{T_{op}}{T_{tot} - T_{grid} - T_p - T_{fm}} \times 100\%$$

Where:-

$T_{op} =$ Total time during the measurement period where the inverter was producing energy and energy was supplied to the grid, expressed in 15 minutes interval

$T_{tot} =$ Total time during the measurement period where the irradiation on module plane was higher than 100 W/m^2, expressed in 15 minutes interval

$T_{grid} =$ Time period during which the grid was not available (although the inverter is available), expressed in 15 minutes interval. The Contractor shall provide written proof from the grid operator including hours during which there was a failure from grid and the Plant could not feed energy to the grid.

$T_p =$ Time period that the inverter was not in operation (the inverter is not available) because of stoppages ordered by the Employer / third parties (insurance or authority) requirement, expressed in 15 minutes interval

$T_{fm} =$ Time period that the Plant did not operate because of Force Majeure events, expressed in 15 minutes interval

All technical parameters mentioned in equations above are calculated for the period during which the solar irradiation on module plane is higher than the threshold level (i.e. 100 W/m^2).

5.5. Criteria for PAT Acceptance:

5.5.1. The provisional Acceptance Test is considered successful if:

5.5.1.1. Measured Performance Ratio (PR) is greater than or equal to Guaranteed Performance Ratio during PAT, and

5.5.1.2. Measured Plant Availability is greater than or equal to Guaranteed Plant Availability during PAT

5.6. Criteria for Issuance of Operational Acceptance Certificate:

5.6.1. The Operational Acceptance Certificate is issued by the Employer, if:

5.6.1.1. PAT requirements are successfully completed

5.6.1.2. The complete O&M manual is provided by the Contractor and accepted by the Employer

5.6.1.3. Punch List is reviewed and accepted by the Employer

5.6.1.4. All Guarantees and Warranties are successfully transferred to the Project Manager and the Plant is substantially handed over to the Employer

5.6.1.5. The Contractor has stored on-site the minimum required spare parts for the Project

5.6.1.6. The site is free from any wastes, residues from site establishment and construction

5.6.1.7. If applicable, any delay liquidated damage payable, (see Appendix E), to the Employer by the Contractor is completed.

4.11.5 Tests after Operational Acceptance

1. Tests after Operational Acceptance refer to "Intermediate Acceptance Tests" (IATs) and "Final Acceptance Tests (FATs)". The IATs and FATs are performed during the O&M period and are described further in Table 4-7.

Table 4-7: Summary of Tests after Operational Acceptance

Test	Test Type and Timing
Year 1 Intermediate Acceptance Tests	Performance ratio test during year 1 of operation (month 1 to month 12 - after issuance of Substantial Completion Certificate)
	Plant availability test during year 1 of operation (month 1 to month 12 - after issuance of Substantial Completion Certificate)
Year 2 Final Acceptance Tests	Performance ratio test during year 2 of operation (month 13 to month 24)
	Plant availability test during year 2 of operation (month 13 to month 24)

2. Performance Ratio (PR) Test during IATs and FATs:

2.1. The Contractor performs annual performance ratio tests for the plant operation during the O&M period. There are five performance ratio tests during the O&M period; Performance Ratio Test for IATs (year 1) and Performance Ratio Test for FAT (year2).

2.2. Performance Ratio test is performed for the operational Plant parameters measured during one complete year period.

2.3. There are no irradiation threshold and valid day's criteria for performance ratio evaluation during the O&M period.

2.4. The Performance Ratio is only evaluated for the period during which the Plant is available.

2.5. Performance Ratio (PR) Evaluation Procedure during IATs and FATs:

2.6. The Plant Performance Ratio (PR) of the Plant for IATs and FATs (for year n being years 1 or 2) is evaluated according to equations below:

$$[PR_{measured}]_{year\ n} = \frac{[E_{prod}]_{year\ n}}{[E_{PV}]_{year\ n}}$$

Where:

$[PR_{measured}]_{year\ n}$ = Year n annual average measured PR when the Plant was available during year n operational period, expressed in %

$[E_{prod}]_{year\ n}$ = Sum of energy measured at energy meters installed at point of connection during complete year n operational period, expressed in kWh

$[E_{PV}]_{year\ n}$ = Theoretical energy that could have been produced by PV modules during complete year n operational period, expressed in kWh

$$[E_{PV}]_{year\ n} = P_{Nom} \times \frac{[Irr_{POA-measured}]_{year\ n}}{[Irr_{STC}]}$$

Where:

P_{Nom} = Nominal Peak Power of the PV Modules, sum of nameplate power of modules installed in the Plant, expressed in kWp

$[Irr_{POA-measured}]_{year\ n}$ = Annual average solar irradiation measured on Plane of Array during the complete year n period when the Plant was available, expressed in kWh/m^2

$[Irr_{STC}]$ = Solar irradiation at Standard Test Conditions (STC) condition, 1 kW/m^2 (constant)

2.7. The annual average solar irradiation ($[Irr_{POA-measured}]_{year\ n}$ in above equation) is calculated based on arithmetic average of the measurements from the Site POA irradiance sensors or reference cells installed on module plane. In the case, where POA irradiance sensor(s) or reference cell(s) were not recording data and/or not working properly during the measurement period, the irradiation value is the average of the POA irradiance sensors or reference cells which are working properly.

2.8. In the case where all POA irradiance sensors or reference cells were not working (or SCADA system were not recording data) for some period, the irradiation value to be considered for those periods in the performance ratio test shall be based on the solar irradiation on module plane estimated by the Contractor (as indicated in Table 4-9).

2.9. The Performance Ratio tests during the O&M period is considered successful if:

2.10. The performance ratio evaluated for the year of operation is equal to or greater than the performance ratio guaranteed by the Contractor for the corresponding year period (The Contractor is required to provide Performance Guaranteed Values as indicated in Table 4-8).

2.11. The Contractor is subjected to the Performance Liquidated damage if the measured performance ratio is less than respective guaranteed performance ratio during the O&M period, according Appendix E.

3. Plant Availability Test during IATs and FATs:

3.1. The Contractor performs annual availability tests for the plant operation during the O&M period. There are five availability tests during the O&M period; Availability Test for IATs (year 1) and Availability Test for FATs (year 2).

3.2. Availability test is performed for complete one year period during each availability test.

3.3. The evaluation of Plant Availability is done only for the periods during which the global solar irradiation on module plane is higher than threshold level of solar irradiation. The threshold value of solar irradiation on module plane for Plant availability is 100 W/m2. This level of irradiation is considered as the minimum level of irradiation required to overcome inverter's threshold power.

3.4. Plant Availability Evaluation Procedure during IATs and FATs:

3.4.1. The Plant Availability is evaluated based on technical availability of the inverter. The Plant must deliver energy to the meter at the point of connection during the period when the Plant is considered as available. Otherwise, the Plant is considered as unavailable.

3.4.2. The stoppage of the Plant due to events caused by the following is not considered while evaluating the Plant availability:

3.4.2.1. events caused by faults that are not attributed to the Contractor (e.g., manual shut-down, inspections not attributable to the Contractor)

3.4.2.2. required by third parties (e.g., insurance companies, authorities)

3.4.2.3. attributable to the grid operator/the Employer

3.4.2.4. the result of Force Majeure events

3.5. The Plant Availability $[AV]$ is defined as average of individual inverter availability, as shown in the equations below:

$$[AV] = \frac{\sum_{i=1}^{i=n}[AV]_i}{n}$$

Where:-

$i =$ Number of each individual inverter

$n =$ Total number of inverters in the Plant

The individual technical availability of the inverter (i) is calculated by using the equation shown below:

$$[AV]_i = \frac{T_{op}}{T_{tot} - T_{grid} - T_p - T_{fm}} \times 100\%$$

Where:-

$T_{op} =$ Total time during the measurement period where the inverter was producing energy and energy was supplied to the grid, expressed in 15 minutes interval

$T_{tot} =$ Total time during the measurement period where the irradiation on module plane was higher than 100 W/m^2, expressed in 15 minutes interval

$T_{grid} =$ Time period during which the grid was not available (although the inverter is available), expressed in 15 minutes interval. The Contractor shall provide written proof from the grid operator including hours during which there was a failure from grid and the Plant could not feed energy to the grid.

$T_p =$ Time period that the inverter was not in operation (the inverter is not available) because of stoppages ordered by the Employer / third parties (insurance or authority) requirement, expressed in 15 minutes interval

$T_{fm} =$ Time period that the Plant did not operate because of Force Majeure events, expressed in 15 minutes interval

3.6. All technical parameters mentioned in equations above are calculated for the period during which the solar irradiation on module plane is higher than the threshold level (i.e. 100 W/m2).

3.7. The solar irradiation is calculated based on arithmetic average of the measurements from the Site POA irradiance sensors or reference cells installed on module plane. In the case where POA irradiance sensor(s) or reference cell(s) were not recording data and/or not working properly, the irradiation value is the average of the POA irradiance sensors or reference cells which are working properly.

3.8. In the case where all POA irradiance sensors or reference cells are not working (or SCADA system are not recording data) for some period but the inverter is producing energy and energy being fed into the meter/grid, those periods are considered as available, and those periods are counted in availability evaluation equation.

3.9. In the case where all POA irradiance sensors or reference cells are not working (or SCADA system are not recording data) for some period and the inverter is not producing energy, those periods are considered as unavailable, and those periods are counted in availability evaluation equation.

3.10. The Availability tests during the O&M period will be considered successful if:

3.10.1. The annual availability evaluated for the year of operation is equal to or greater than the annual average availability guaranteed by the Contractor for the corresponding year period (The Contractor is required to provide Performance Guaranteed Values as indicated in Table 4-8).

3.11. The Contractor is subjected to Performance Liquidated damage if the measured availability is less than respective guaranteed availability during the O&M period, according to Appendix E.

4. Visual Inspection:

4.1. Visual Inspection of the Plant is performed in order to verify correct installation and functioning.

4.2. The visual inspection is performed for following major components but not limited to:

4.2.1. PV Module,

4.2.2. Foundation and Mounting structure

4.2.3. Security System and Civil structures (O&M building, etc.)

4.2.4. DC Cables, cable routing, electrical connections,

4.2.5. Junction boxes, fuses, isolation switches, protection device

4.2.6. Inverter and Inverter station/cabin

4.2.7. Transformer and Switch gear

4.2.8. Power evacuation line and point of connection

4.2.9. Energy meter

4.2.10. Meteorological Stations

4.2.11. Monitoring and C&I system

4.2.12. Remote communication

4.2.13. Security system

4.2.14. And any other Plant components

4.3. The Contractor verifies that the Plant is free from any defects and the Plant does not pose any risk for safe operation.

4.4. The Contractor verifies that the site is free from any wastes, residues from construction, operation, and maintenance.

4.5. The Contractor verifies that the minimum level of spare parts is available on site according to the Employer's requirement.

5. Electrical Measurements:

5.1. The Contractor performs:

5.1.1. Continuity test, polarity test, protective earthing test, insulation resistance test, fire protection system, protection device test and verify the proper functioning of all electrical equipment.

5.1.2. Infrared scanning on all (100%) PV modules as well as in electrical connections are performed to verify that modules are free from any hot spots and electrical connections are

properly made. Infrared scanning is done when irradiation on module plane is greater than 500 W/m2.

6. Criteria for Acceptance of IATs:

6.1. The Intermediate Acceptance Tests are considered successful if:

6.1.1. Measured performance ratio during the year of operation is equal to or greater than the respective performance ratio guaranteed by the Contractor.

6.1.2. Measured Plant availability during the year of operation is equal to or greater than the respective availability guaranteed by the Contractor.

6.1.3. Any applicable liquidated damage payable to the Employer by the Contractor is completed.

6.1.4. The O&M training is successfully completed.

6.1.5. The complete Plant O&M manual and component O&M manual are delivered to the Employer.

6.1.6. The minimum level of spare parts have been stored on site and transferred to the Employer.

6.1.7. All guarantees and warranties of components are successfully transferred to the Employer.

7. Criteria for Acceptance of FATs:

7.1. The Final Acceptance Tests are considered successful if:

7.1.1. Measured performance ratio during the year of operation is equal to or greater than respective performance ratio guaranteed by the Contractor.

7.1.2. Measured Plant availability during the year of operation period is equal to or greater than respective availability guaranteed by the Contractor.

7.1.3. Any applicable liquidated damage payable to the Employer by the Contractor is completed.

7.1.4. The visual inspection is successfully completed, and the Plant is free from any defects.

7.1.5. Electrical measurements are successfully completed.

7.1.6. The O&M training is successfully completed.

7.1.7. The complete Plant O&M manual and component O&M manual are delivered to the Employer.

7.1.8. The minimum level of spare parts have been stored on site and transferred to the Employer.

7.1.9. All guarantees and warranties of components are successfully transferred to the Employer.

4.12 Contractor's Guarantee on Performance and Availability

1. The Contractor provides the following guaranteed values for PAT, IATs, and FATs:

1.1. Performance Ratio (PR)

1.2. Plant Availability

2. These Performance Guaranteed Values for the PV Facility are verified during the Provisional Acceptance Test, Intermediate Acceptance Tests, and Final Acceptance Tests.

3. The guaranteed Performance Ratio shall be evaluated at 100% Plant availability. The actual Plant Availability is guaranteed and evaluated separately.

4. The Contractor is required to provide Performance Guaranteed Values as indicated in Table 4-8.

Table 4-8: Plant Performance Guarantees from the Contractor

Year	Parameter	Minimum required by Employer	Guaranteed by Contractor
1	Guaranteed annual average Performance Ratio for year 1 of operation - for Year 1 Intermediate Acceptance Test	78.0 %	
	Guaranteed annual average Plant Availability for year 1 of operation - for Year 1 Intermediate Acceptance Test	98 %	
2	Guaranteed annual average Performance Ratio for year 2 of operation - for Year 2 Final Acceptance Test	77.5 %	
	Guaranteed annual average Plant Availability for year 2 of operation - for Year 2 Final Acceptance Test	98 %	

5. With regards to the “Guaranteed annual average Performance Ratio for year 1 of operation - for Intermediate Acceptance Test” provided in Table 4-8, the Contractor is required to provide a monthly breakdown of this year 1 Performance Ratio guarantee, along with estimation of solar irradiation on module plane, in a tabular format as shown in Table 4-9.

Table 4-9: Monthly breakdown of Guaranteed Performance Ratio for first year

Month	Breakdown of first year annual guaranteed PR (%)	Estimated Solar Irradiation on Module Plane (kWh/m^2)
January		
February		
March		
April		
May		
June		
July		
August		
September		
October		
November		
December		
Annual Average		

6. The PR guaranteed for the Provisional Acceptance Test will be the corresponding monthly average PR (shown in Table 4-9) during which the PAT is performed. If the PAT duration covers a period of two consecutive months, then the guaranteed PR during PAT is calculated based on weighted average PR of the two respective months.

4.13 Equipment Warranty

1. The Contractor provides equipment warranty according to minimum requirement set in Table 4-10.
2. In addition (and without prejudice) to the defects liability, the Contractor releases warranty on equipment, including, but not limited to, strategic part warranty. No equipment warranty shall limit another warranty or otherwise.
3. The Contractor transfers the ownership of all manufacturer equipment warranties to the Employer during the Operational Acceptance of the Project.

Table 4-10: Equipment warranty

Equipment	Minimum Warranty Period in Years
PV Module - Product Warranty against Manufacturing defects	10
PV Modules – Performance	25
Mounting structures Duration of warranty (materials)	10
Mounting structures Lifetime design warranty	25
Inverter	10
LV/MV Step Up Transformer	5
MV/LV Step Down Transformer LV/0.4kV	5
Ring Main Unit	5
MV Switchgear	5
HVAC Equipment	2
Fire Protection Equipment	2
Water supply and reticulation Equipment Duration of warranty (materials)	10

4.14 Spare Parts and Tools

1. The Contractor provides a list of spare parts and tools recommended by equipment manufacturers for operation and maintenance for 25-year lifetime period to the Employer for acceptance. The Contractor considers such list as minimum required spare parts and tools for the Project.
2. The Contractor provides spare parts and tools for the operation and maintenance period of the project.
3. The Contractor supplies all required tools, equipment, and facilities which are necessary for carrying out the operation and maintenance of the PV Plant.
4. The Contractor recommends any additional spare parts and tools if the minimum requirement on spare parts and tools provided by the equipment manufacturers is considered as not sufficient for operation and maintenance for 25-year lifetime period.
5. The Employer, at its option, may decide to purchase such additional spare parts and tools subject to schedule of delivery to be agreed with the Contractor.
6. Spare parts can be classified into the following categories:-
   6.1. Maintenance spares and consumables: These are items for which the Contractor anticipates that demands will arise in normal operation of the Plant.

6.2. Strategic spares: These are items for which the Contractor anticipates that demands may arise through breakdowns which could jeopardise the performance, availability, or safety of the Plant.

7. Based on the Plant performance during the Defect Liability Period, the Contractor shall define the minimum stock of spare parts taking into account the location of the site which can increase the lead time of certain spare equipment and therefore could impact the replenishment of the spare parts inventory.

8. A minimum level of Strategic spares shall be held on site for each component at all times. The following list outlines the expected minimum level of spares for key equipment, includes, but is not limited to, the following:

   8.1. PV modules – Minimum of 0.2% of the total installed PV modules per Plant.

   8.2. Inverter – For the case of central inverters, the Contractor shall request from the manufacturer a recommended list of spares / bill of quantities that shall take into consideration the number of inverters per Plant and Project's location. This recommended spare part list by the manufacturer shall specify proper equipment information, such as manufacturer's unit code, name, description, and total quantity per Plant to be considered. For the case of string inverter, the Contractor shall request from the manufacturer a recommended number of spare inverters to the held onsite.

   8.3. Trackers – The Contractor shall request from the manufacturer a recommended list of spares / bill of quantities that shall take into consideration the number of trackers per Plant and Project's location.

   8.4. String DC Cable – Minimum 500 m.

   8.5. Main DC Cable – Minimum 500 m.

   8.6. AC Power cables – Minimum 500 m.

   8.7. Communication cables – Minimum 500 m.

   8.8. MV transformers – Minimum one (1) unit.

   8.9. MV switchgear / RMU – Minimum one (1) unit.

   8.10. Aux. Transformer - Minimum one (1) unit.

9. Meteorological station equipment and instrumentation - The Contractor shall request from the manufacturer a recommended list of spares / bill of quantities that shall take into consideration the number of meteorological stations per Plant and Project's location.

10. A minimum level of maintenance spares and consumables shall consider the different system and equipment of the Plant, such as, DC Combiner Boxes, AC Junction Boxes, LV cabinets, communication system, CCTV system, etc.

4.14.0 Spares Cataloguing Requirements

1. On the recommended spares list the Contractor provides sufficient information as required by the Employer to facilitate the efficient and accurate cataloguing (naming, classification and numbering) of the Plant and Material, including the manufacturer's/vendor's part number (MPN) for the works. The Contractor furthermore provides all mandatory attributes and variables required by the Employer to suitably describe and categorise the relevant commodity. For completeness the Contractor considers any items for cataloguing contained in the O&M manuals.

2. The Contractor labels the Plant and Materials strictly in accordance with the Employer's prescribed cataloguing requirements, which includes the label format and content. If the Contractor considers that Plant and Material are too small to be separately labelled or are otherwise not capable of being separately labelled, the Contractor obtains the Project Manager's acceptance accordingly. Upon

acceptance by the Project Manager the box or other packaging material containing such Plant and Material may be labelled instead of the items themselves.

3. If information shown on a Plant and Material label is changed at any time after delivery, the Contractor notifies the Project Manager and supplies a substitute label for the relevant items.
4. The Contractor establishes and maintains a data base of the Plant and Material which matches the Employer's records and meets its future ordering requirements.

4.15 Operation and Maintenance

The Operation and Maintenance requirements are captured in Appendix D of this document.

5. DOCUMENTATION REQUIREMENTS

1. The Contractor is the Design Authority as defined in [8] 240-53113685 Design Review Procedure.
2. The Contractor is responsible for following, and conducts all the reviews as specified in [8], including:
   2.1. Design Freeze Review
   2.2. Integrated Design Review
   2.3. Construction Completion Review
   2.4. Acceptance Testing Review
3. The following process is followed during submission of documents:
   3.1. The Contractor submits the documents/drawings to the Employer.
   3.2. The Employer's Document Controller registers the documents.
   3.3. The Employer's Document Controller will supply the documents/drawings to all relevant parties within the Employer's project team.
   3.4. The Employer's project team reviews the documents/drawings and submits all comments or inputs to the Employer, and the Employer submits to the Contractor for consideration.
   3.5. If the Employer finds major deficiencies in the submitted documents/drawings, the Contractor addresses these major deficiencies, revises the documents/drawings, and resubmits to the Employer.
   3.6. The Employer reviews the documents/drawings and if no major deficiencies are found, the Contractor organises a Design Review session.
   3.7. The Contractor conducts the Design Review session and invites the Employer to attend/participate.
   3.8. If any fundamental errors are identified during the Design Review session, or further actions are required, the Contractor record all concerns raised and revises the designs.
   3.9. The Contractor organises a Design Review session once all designs were revised according to the concerns raised by the Employer.
   3.10. If no fundamental errors were found in the designs during the Design Review session, the Contractor compiles the Design Review minutes or report and submits it to the Employer.
   3.11. The Employer's project team reviews the Contractor's report/minutes. If the report/minutes are not acceptable, the Contractor revises the report/minutes and resubmits to the Employer.
   3.12. The Employer accepts the Contractor's design once the report/minutes are accepted by the Employer's project team

5.1 General Requirements

1. The Contractor will compose and submit all Documentation and Technical Information required throughout the project including the information listed in this document.
2. All Documentation shall be written in English.
3. All Documentation shall be composed in accordance with International Standard IEC 62446, Grid connected photovoltaic systems – Minimum requirements for system documentation, commissioning tests and inspection.
4. All Documentation shall be produced in accordance with the Eskom Supplier Contract Requirements Specification at all stages throughout the project life.
5. Metric/SI units shall be used throughout the Contractors' Documentation.
6. The Contractor is to submit the Documentation in a timely manner to avoid peaks in information flow, as agreed with the Employer.
7. The Contractor shall provide a document referencing system for version control and Quality Assurance purposes.
8. The Contractor shall provide a Quality Plan for all stages of the project including Detailed Design, Procurement, Construction, Commissioning, Performance Testing and Operation and Maintenance.
9. The Contractor shall co-ordinate their Drawings with relevant Drawings prepared by others, to ensure drawings are compatible, correctly annotated and cross-referenced at their interfaces and the Master List of all drawings with the latest Revisions shall be maintained by Contractor.
10. The Contractor shall ensure that the 'originator' and 'approver' have signed each of the Contractor's Documents before submission to confirm that the Work:
    10.1. Complies with the Functional Specification Document.
    10.2. Has been checked and dated.
    10.3. Has been co-ordinated in sequence and physical relationship with the work of others.
    10.4. Does not contain any unauthorised Changes under the Contract.
11. The Contractor shall ensure that submissions are complete to avoid any delay resulting from the need to re-submit information for review.
12. Consistent symbols, legends, equipment references, and terminology shall be used in the Contractor's Documentation in line with appropriate standards and all coding systems will be finalised with Employer's concerned officials.
13. The Contractor shall clearly annotate, describe, and date each revision to the Contractor's Documents after initial submission. Revisions shall be marked sequentially and to an agreed format.
14. The Contractor shall retain a dated record copy of revisions to the Contractor's Documents. Archived copies of the Documentation shall be resubmitted when requested by the Engineer.
15. Any discrepancies identified in the Contractor's Documents shall be submitted in a timely manner.
16. Electronic Format of Submission
    16.1. The Contractor shall use the latest versions of application software.
    16.2. The Contractor shall provide all information in an electronic format as shown Table 5-1, or otherwise compatible with the project electronic data management system, as agreed.

Table 5-1: Electronic Format of Submission

Item	Electronic Format
Information in narrative form	Microsoft Word
Information in numerical or schedule form	Microsoft Excel
Programmes	Microsoft Project
Information in database form	Microsoft Access
Drawings	AutoCAD
Scanned information	Windows Compatible (e.g., Adobe Acrobat)
Manufacturers' literature	Windows Compatible

17. Format & Copies of Submissions

    17.1. All Documents shall be equipped with an index where applicable. Such index shall be hyperlinked in electronic formats of the Documents.

    17.2. The Contractor shall submit the Documentation in electronic format and on paper copies as shown in Table 5-2.

Table 5-2: Format & Copies of Submissions

Item	Paper Copies		Electronic Copies
	Number	Size	Number
Documents	3	A4/A3	3
Reports, Calculations and Technical Documents	3	A4	3
Programmes and Work Plans	3	A3/A4	3
Method Statements	3	A4	3
Technical Data	3	A4	3
Drawings	3	A0/A1	3
Manufacturer's Information	3	A4	3
Controls & Wiring Diagrams	3	A3/A4	3
SCADA Software	-	-	3
Antivirus Software	-	-	3
Test Certificates	3	A4	3
Commissioning Records	3	A4	3
Draft O&M Manuals	3	A4	3
O&M Manuals	3	A4	3
Guarantees & Warranties	3	A4	3
Reference Codes, Standards and Guides	3	-	3

18. The Contractor shall employ all appropriate project electronic document handling systems for the transmission of the Documentation.

19. Any or all of the Contractor's Documents may be reviewed by the Employer to verify compliance with the Functional Specification Document and accordance with the Design Intent.

20. All Contractor's Documents selected for review will be given a status mark as shown in Table 5-3

Table 5-3: Review status mark

Status Mark	Review Comment	Meaning
A	No comment	The Contractor may proceed.
B	Comments as noted	The Contractor may proceed at their own risk, incorporating the comments in a timely manner, and resubmit.
C	Re-submit before proceeding	The Contractor must resubmit before proceeding.

21. Any incomplete or substandard submissions will automatically be given 'C' status.
22. Comments given by the Employer do not relieve the Contractor of their responsibilities and obligations regarding the execution of the works and compliance with the Contract Documentation and the Functional Specification Document. Comments given by the Engineer do not constitute a Change under the Contract.

5.2 Design Phase

1. The Contractor submits all design, documents, and drawings in compliance with the requirements indicated in the Functional Specification Document.
2. All design, equipment, materials, fabrication and tests conforms to the latest applicable standards indicated in the Functional Specification Document.
3. All design and equipment are entirely suitable for the use under the site conditions.
4. The design of Plant including, but not limited to PV array layout, civil infrastructures, Plant footprint, interconnection route, design and layout comply with the Environmental permit and Water Use License Permit.
5. The Contractor provides, but not limited to, documents, drawings, design information in the time manner indicated in Table 5-4 to ensure the finalization of design within agreed timelines.

Table 5-4: Documents related to design phase

No.	Document / Drawing	Review Type
Within 1 week after issue of *Contract* Date		
1	Project handbook	I
2	Project schedule with minimum level 3 activities	A
3	Design and Drawing list (schedule) with submission dates	A
4	Project Quality Plan, Environment and Waste Management Plan	A
Within 2 weeks after issue of *Contract* Date		
5	List of Permits, Approvals required for the Project	I/A
Within 3 weeks after issue of *Contract* Date (Draft Design)		
6	A brief and straight-forward description of the design and Plant layout	I
7	PV Array Layout showing details on module orientation, total PV footprint, installation location of civil infrastructure (O&M building, PV Plant substation, Inverter cabin, parking area)	A
8	Civil Design • Road: Internal Road, perimeter road and access to inverter cabin, O&M building, PV Plant substation, meteorological station, and any other civil infrastructures • Foundation: type, layout, design, and material	A

No.	Document / Drawing	Review Type
	• O&M building: layout, design, and material • PV Plant Substation: layout, design, and material • Parking Area: layout, design, and material • Drainage and Sewage System: layout, design, and material • Concrete mix design • Method statement for civil engineering works	
9	Cable routing layout: • DC: String Configuration, String to Combiner box and to Inverter Cabin • AC: Inverter Cabin to 22kV switching station • MV Cables (underground and overhead)	A
10	Electrical Single Line Diagram: DC system, AC system including point of connection, security, and Communication system	A
11	Protection, Earthing and Lightning systems	A
12	Security Design according to specification: • Fencing • Perimeter lighting and security systems according to specification • Construction method	A
13	C&I System according to specification: • Detailed CMS network single line diagram of the complete CMS works • Detailed field wiring schematics Site specific equipment locations and cable route diagrams • Instrument and equipment list • Cable schedule and cable specifications (power and communication) • Comprehensive CMS design report (Operating and engineering description, logic diagrams and formulas used to calculate data, HMI mimics, graphical user interface screen dumps, data analysis and information storage description, operations, and troubleshooting, etc.) • CMS signal list • All instrument and equipment datasheets, manuals, specifications • CMS load list (Power supply and distribution SLD including design calculations, battery sizing, etc.) • Server room network cabinet and CMS equipment panel specifications and general arrangement diagrams (2D and 3D) Control and server room specifications and general arrangement diagrams (2D and 3D) Software relevant to CMS system	A
14	Detailed Construction method including no. of employees working on site, site establishment, employee management: how employees will be accommodated and transported to site, sanitation services, waste management	I/A
15	Site survey report (Geotechnical Investigation report)	A
16	Shipping and Delivery schedule of the components of the PV-Plant	I
17	Technical specifications, relevant certificates according to specifications and warranty documents and installation manuals of all PV components including but not limited to followings: • PV module • Mounting structure • DC, AC and Communication Cables	A

No.	Document / Drawing	Review Type
	• Combiner Boxes • Inverter and MV Cabins • LV/MV Transformer, Auxiliary transformer, and switchgear • Switchgear type test certificate including arc flash, proof of type test laboratory accreditation, copy of RMU factory routine test certificate. • MV Cables (Underground and Overhead) • Meters and protection devices • C&I System • Meteorological system • System studies report (Dynamic studies using Powerfactory model)	
18	Training schedule according to specification	A
19	Test and commissioning protocols (including test types, evaluation method, acceptance criteria) and schedules of minimum followings according to specification: • Factory Acceptance Test • Site Acceptance Test • Mechanical Completion Test • Electrical Completion Test • Completion Test	A
20	PV Plant energy yield and performance estimation report – Simulation results, monthly breakdown of results	I
21	Design of LPS, HVAC system	A
22	List of Auxiliary consumption	A
23	List of standards followed for design, design calculation report	A
24	List of Permits or Approvals required for the Project	I/A
25	Operational Philosophy: no. of employees, type of preventive/scheduled maintenance, site management, waste management, electricity, and water management etc.	I/A
26	List of spare parts list, tools of operation and maintenance HAZOP Studies report	A
27	Risk register and mitigation proposal (design, construction and operation and maintenance)	I/A
28	Any other relevant documents, identified by the *Contractor*	I/A
Within 5 weeks after issue of *Contract* Date or at least 3 weeks before the start of construction, whichever is earlier (Final Design)		
29	Final design of complete PV Plants covering all documents, designs, report, and information listed from No. 6 – 27.	A
30	Complete Package of design information, documents, drawings (defined formats), layouts according to requirement from Department of Mineral Resources and Energy (DMRE) - (if any)	I/A
31	Complete Package of design information, documents, drawings, layouts according to requirement from Department of Water and Sanitation (DWS) in regard to Water Use License Approval - (if any)	I/A
32	Confirmation on appointment of Independent ECO (Environmental Control Officer) according to requirement for Department of Mineral Resources and Energy (DMRE) - (if required)	I/A
33	Submission of final design document and any other relevant documents to of Mineral Resources and Energy (DMRE) and Department of Water and Sanitation (if required).	I/A
Within 60 calendar days after issue *Contract* Date		

No.	Document / Drawing	Review Type
34	Freeze complete final design of the Plant covering all items listed from No 6 – 27 above	A

5.3 Procurement Phase

1. The Contractor starts procurement process of PV Plant components during early design phase.
2. The Contractor provides, but not limited to, documents related to procurement of PV Plant components as indicated in Table 5-5.

Table 5-5: Documents related to procurement phase

No.	Document / Drawing	Review Type
Within 2 weeks after issue of *Contract* Date		
1	List of product type and manufacturer that the *Contractor* is intending to consider for the Project: • PV Module • Inverter • Combiner/Junction box • Inverter Station/Cabin • LV/MV transformer type and Auxiliary transformer • Switchgear • Meters • C&I system • DC cabling • AC cabling • Communication cable • C&I System • Security Components • Meteorological System/ Weather Stations	I/A
2	Expected Procurement Schedule for all components	I
Within 1 week after the Placement of Purchase Order		
3	Proof of purchase order for all PV components (minimum for components listed above in item no. 1)	I
4	Technical specification of all components (minimum listed above in item no. 1)	A
5	Warranty documents including terms and conditions for all components (minimum listed above in item no. 1)	A
6	Relevant Certificates for all components including calibration certificates of equipment in weather stations (minimum listed above in item no. 1)	A
Within 3 weeks before the Factory Acceptance Test		
7	Test schedules – date of commencement of each test type	I
8	Test Protocols in accordance with specification including minimum of following, but not limited to: • detail description of inspection test types • components certificates, technical data sheets	A

No.	Document / Drawing	Review Type
	• manufacturers' quality certificates • components to be used during test/inspections • standards to be followed during tests/inspections • acceptance and rejection criteria of each test • Test results from previous inspections/tests, if available	
9	For PV modules • Flash Test Data Sheet from manufacturer for all PV modules to be delivered on site in compliance to specification • Independent Laboratory Test location for counter test including ISO/IEC 17025 certificate according to specification	A
	Within 1 week after Factory Acceptance Test	
10	Factory Acceptance and Independent laboratory Test Report including minimum followings (item no 11 – 14)	A
11	Agreed test protocols according to requirement mentioned under item no: 08	I
12	Data during test/inspection and test evaluation results	A
13	Summary and conclusion in regard to acceptance or rejection of test of components	A
14	Delivery date to site of Plant components	I
	Within 1 week after the delivery of components on site (Site Acceptance Test)	
15	A complete set/package of documents including following items no: 15 – 21	I
16	Technical Specification of components delivered to the site	I
17	Relevant standards of components delivered to the site according to specification	I
18	Warranty documents including warranty terms and conditions for components delivered to the site	I
19	Factory Acceptance Test and Independent Laboratory test results listed on item no 10 – 13 above	I
20	Installation and operation manual for components delivered to the site	I
21	Site Acceptance test results	A

5.4 Site Establishment and Construction Phase

1. The Contractor provides, but not limited to, documents as indicated in Table 5-6 before, during, the site establishment and construction phase.

Table 5-6: Documents related to site establishment and construction phase

No.	Document / Drawing	Review Type
	Within 1 week before the site establishment	
1	Project Construction schedule	A
2	Construction Method, Quality Plan, environment, and waste management Plant	A
3	Proof of compliance to Eskom SHEQ and quality requirements	I
	Within 1 week before the start of construction	
4	Documents showing the approval from of Mineral Resources and Energy (DMRE) regarding compliance to requirement set by DMRE (if any)	I

No.	Document / Drawing	Review Type
5	Documents showing the approval from Department of Water and Sanitation (DWS) regarding compliance of PV construction according to requirement set in water use license approval, if any.	I
6	Compliance to requirements/permits/approval for construction of PV Plants	A
Bi-weekly reporting during construction after the start of site establishment (reports submission within 1 week after each reporting period; a calendar month has 2 reporting periods each on 15 days interval)		
7	Bi- weekly progress reports including items no: 8 – 19, as minimum	I/A
8	Introduction and summary	I
9	Status of construction progress	I
10	Status of construction milestone including shipping and delivery dates of major PV Plant components (minimum list of equipment presented under procurement phase section)	I
11	Site employment report including details of staffing of • Construction *Contractor*s at the site, • *Contractor*'s engineering service support team • Sub-*Contractor*s (if any) at the site • No. of workers on site	I
12	Health and Safety report	I/A
13	Status of permitting, authorization, and any approvals	A
14	Construction progress S curve	I
15	Critical actions to be covered during next 2 weeks period	I
16	Project schedule	A
17	Photographs of construction progress	I
18	A copy of Independent Environmental Commission Officer's (ECO) report according to DMRE requirement. This reporting shall be provided until the appointment of ECO in the Project.	I
19	Any other items that the *Contractor* wishes to include in the report upon discussion with *Employer*.	I
Within one week after the test during construction		
20	Concrete test report for 7 days, 28 days	A

5.5 Mechanical Completion

1. The Contractor provides, but not limited to, documents as indicated in Table 5-7 before, during, and after mechanical completion.

Table 5-7: Documents related to mechanical completion

No.	Document / Drawing	Review Type
Within 8 weeks before the Mechanical Completion		
1	Training material for construction and commissioning of Plant according to requirement set in specification. The training material shall be minimum of followings item no. 2 -10 but not limited to:	A

No.	Document / Drawing	Review Type
2	Plant description, design process, calculation, and results (e.g., Cable sizing, cable route, cable loss, module-inverter configuration, MV switchgear design, PV Plant substation design, transmission line design, civil infrastructure design, security design etc.)	A
3	Construction and installation method of all major PV Plant components including HVAC system, fire protection system and sewage system	A
4	Safety during construction and commissioning	A
5	Introduction to tests types, measurement methods and test equipment for inspection, tests, and commissioning	A
6	Test evaluation method and result interpretation	A
7	Trouble shooting procedure	A
8	A checklist on what to do in case of system failure (at different Plant level e.g., Fault in connection point, PV Plant substation, MV cabin, Combiner boxes, Junction boxes)	A
9	Emergency shutdown/ isolation procedure	A
10	Reporting during construction and commissioning	A
	Within 3 weeks before the start of Mechanical Completion Test	
11	Proof of completion of Training to *Employer* and the *Employer*'s representative according to requirement set on "Training during Construction and Commissioning"	A
12	Test after installation schedules – Mechanical Completion Test and Electrical Completion Test	I
13	Project complete as built design and documents which shall include minimum as followings items no 14 – 30	A
14	Project summary and design description report	A
15	System designers information (name, affiliate, contact details)	I
16	System installer/*Contractor*'s information (name, affiliate, contact details)	I
17	Detailed single line diagram of DC, LV/MV AC system and transmission line including connection and wiring diagrams for array DC junction boxes and inverter cabins	A
18	C&I system network diagram, component list and technical specifications	A
19	List of alarm, signals	A
20	Specification of PV array • Module type • Tracking or Fixed-tilt of module serial numbers • No of modules per string • Number of strings per combiner boxes and per inverter	A
21	Cabling information • DC Cable: cable type, size, length and expected losses calculation • AC Cable: cable type, size, length and expected energy losses calculation • Specification (current and voltage ratings) of all protection devices used in DC and AC system • Cable schedules	A
22	Electrical characteristics of Array Array junction box location, number, and tracking Array main cable specification Location and type and rating of over voltage protection devices	A

No.	Document / Drawing	Review Type
23	Earthing and over voltage protections including a single line diagram showing details of all earthing, lightning protection systems and details of surge protection devices	A
24	A single line diagram showing DC and AC isolators location, type, rating along with similar information for AC over current protection devices	A
25	Technical data sheet, relevant certificates, and warranty documents of all components	A
26	PV array layout, total footprint used during construction, physical location of all civil infrastructures including O&M building, PV Plant substation, roads, drainage system etc.	A
27	Verification on approval of all permits/approvals for construction and operation of Project	A
28	Complete C&I design, network diagram, test certificates and test results (according to specification)	A
29	Complete security system design	A
30	Updates on Final design listed under design phase above if any made during the construction. If not updates, the *Contractor* shall still submit the complete package of final design.	A
	Within 3 weeks before the start of Mechanical Completion Test	
31	Detail test protocol for mechanical completion test according to requirements set in specification	A
32	Information Mechanical Completion Test – Commencement date	I
33	Project Quality Plan during complete commissioning (test after installation and test on completion)	A
	Within 1 week before the Mechanical Completion Test	
34	*Contractor*'s internal inspection report (signed by the *Contractor*'s Site Manager) which verifies the compliance of the physical installation works with the design and the specification.	A
35	Punch list items- if any according to the specification	A
	Within 1 week after the Mechanical Completion Test	
36	Final Mechanical Completion test report singed by the *Contractor* and Accepted by the *Employer*	A
37	Final Punch List signed by the *Contractor* and Accepted by the *Employer*	A

5.6 Electrical Completion

1. The Contractor provides, but not limited to, documents as indicated in Table 5-8 before, during, and after electrical completion.

Table 5-8: Documents related to electrical completion

No.	Document / Drawing	Review Type
	Within 3 weeks before the start of Electrical Completion Test	
1	Test Protocols in accordance with requirement in specification, with minimum following requirements (item no 2 – 6)	A
2	Definition of each test type and detailed testing methods	A
3	List of equipment to be used for each test type and their technical specification, measurement uncertainties and relevant certificates (e.g., Calibration certificates)	A

No.	Document / Drawing	Review Type
4	Test evaluation method (including equations-wherever applicable)	A
5	Acceptance/Rejection criteria for each test type	A
6	Safety to be considered during the test	A
7	Test schedule for each test types including grid connection test	A
Within 1 week before the start of Electrical Completion Test		
11	Final Test protocols and test schedules mentioned in item no 1 – 7 above.	A
12	Proof of Mechanical Acceptance Test Certificate, accepted by the *Employer*'s *Project Manager*	I
Within 1 weeks after completion of Electrical Completion Test		
13	Electrical completion test report (to be signed by the *Contractor*) including followings (item no 13 – 19)	A
14	Final Test Protocol	A
15	Raw data (unprocessed) or measured data for each test type on site	A
16	Evaluation of Raw data (processed data) according to Final Test protocol	A
17	Final results indicating the acceptance or rejection of each test types	A
18	Grid connection test report and results	A
19	Certificate of Compliance (CoC) according to specification which verifies the Project compliance to SA grid code for Renewables	A

5.7 Provisional Acceptance Test

1. The Contractor provides, but not limited to, documents as indicated in Table 5-9 before, during, and after the Provisional Acceptance Test.

Table 5-9: Documents related to Provisional Acceptance Test

No.	Document / Drawing	Review Type
Within 4 weeks before the start of Provisional Acceptance Test		
1	Project Operation and Maintenance (O&M) Manual in compliance to project requirement and specification. The manual shall include followings (item no 2 – 12) as minimum but not limited to;	A
2	Procedures for verifying correct system operation (Start-up / Shut down of PV Plant, HMI operation, Single line diagram, Regular Maintenance on Modules, Inverter first line maintenance, transformer, switchgear, ups, etc.);	A
3	Safety Guidelines including emergency shutdown/isolation procedures	A
4	Preventive and corrective maintenance procedures including site inspection checklist for each component including power evacuation line and security systems	A
5	Scheduling of routine maintenance	A
6	A checklist of what to do in case of system failure	A
7	Documentation on stock of spare parts and spare parts management including contact information and procedures for replacement of defective components	A
8	Inverter O&M Manual (troubleshooting for error codes, repair, software for inverter, Fault finding on the DC Plant);	A

No.	Document / Drawing	Review Type
9	Data Acquisition System and CMS O&M Manual (troubleshooting, equipment descriptions, repair, metering equipment downloading, weather station);	A
10	Method of PV module cleaning	A
11	Operation and maintenance manual for inverter, transformer, and module from respective manufacturers; and	A
12	Performance monitoring and reporting procedures, templates	A
	Within 2 Weeks before the Provisional Acceptance Test	
13	Proof of Mechanical, Certificate of Compliance and Commissioning Certificate, accepted by the *Employer*'s *Project Manager*	I
14	Test Protocols in accordance with requirement in specification, with minimum following requirements (item no 3 – 7)	A
15	Performance Ratio and Plant Availability test methods including guaranteed values for Provisional Acceptance Test in compliance to specification	A
16	List of equipment to be used for each test type and their technical specification, measurement uncertainties and relevant certificates (e.g., Calibration certificates)	A
17	Test evaluation method including equations in accordance with specification	A
18	Acceptance/Rejection criteria	A
19	Safety to be considered during the test	A
20	Test schedule for each test type	A
	Within 1 week before the start of Provisional Acceptance Test	
21	Final Test protocols and test schedules mentioned in item no 14 – 20 above.	A
22	Proof of Mechanical and Commissioning Certificate, accepted by the *Employer*'s *Project Manager*	I
23	Proof of completion of Training (Training during construction and commissioning) according to requirement in specification	I
	Within 2 weeks after completion of Provisional Acceptance Test	
24	Provisional test report (to be signed by the *Contractor*) including followings (item no 25 – 28)	A
25	Final Test Protocol	A
26	Raw data (un-processed) or measured data for each test (both Performance Ratio and Availability)	A
27	Evaluation of Raw data (processed data) according to Final Test protocol	A
28	Results indicating the acceptance or rejection of each test (Performance Ratio and Availability)	A
29	Final Project Operation and Maintenance Manual	A
30	Proof of Spare Parts being available on site	A
31	Calculation of Delay Liquidated Damage according to specification, if any and proof of payment to the *Employer*	A
32	Proof of transfer of all guarantees and warranties to the *Employer*	A
33	Punch List, if any pending accepted by the *Employer*'s *Project Manager* and schedule for the correction	A
34	Schedule for Training on Operation and Maintenance of the Facility	A
35	*Contractor*'s document verifying that the site is clean and free from any waste materials from construction and commissioning	A

5.8 Intermediate Acceptance Tests and Final Acceptance Tests

1. The Contractor provides, but not limited to, documents as indicated in Table 5-10 during and after the Intermediate Acceptance Tests and Final Acceptance Tests.

Table 5-10: Documents related to Intermediate Acceptance Tests and Final Acceptance Tests

No.	Document / Drawing	Review Type
Within 2 weeks after the completion of each Intermediate Acceptance Tests		
1	Test Report in accordance with specification and Annual Reporting requirement in (signed by the *Contractor*)	A
2	Calculation of Performance Liquidated Damage according to specification for both Performance Ratio and Plant Availability, if any	A
3	List of Spare parts list available on Site in compliance to specification	A
Within 4 weeks after the completion of Intermediate Acceptance Tests		
4	Proof of Payment of Performance Liquidated Damage, if any (according to Appendix C) to the *Employer*	A
Within 3 weeks before the start of Final Acceptance Tests		
5	Test Protocols in accordance with requirement in specification, with minimum following requirements (item no 6 – 11)	A
6	Definition of each test type and detailed testing methods	A
7	List of equipment to be used for each test type and their technical specification, measurement uncertainties and relevant certificates (e.g., Calibration certificates)	A
8	Test evaluation method (including equations-wherever applicable)	A
9	Acceptance/Rejection criteria for each test type	A
10	Safety to be considered during the test	A
11	Test schedule for each test types including grid connection test	A
Within 1 week before the Final Acceptance Tests		
12	Final Test Protocol and test schedule	A
Within 2 weeks after the Final Acceptance Tests		
13	Test Report in accordance with specification and Annual Reporting requirement (signed by the *Contractor*)	A
14	Calculation of Performance Liquidated Damage (according to Appendix C) for second year and future loss according to specification for both Performance Ratio and Plant Availability, if any	A
15	Visual Inspection and Electrical measurement test report (signed by the *Contractor*) including followings (item no 16 – 19)	A
16	Final Test Protocol	A
17	Raw data (unprocessed) or measured data for each test type on site	A
18	Evaluation of Raw data (processed data) according to Final Test protocol	A
19	Final results indicating the acceptance or rejection of each test types	A
20	List of Spare parts list available on Site in compliance to specification	A
21	Proof of transfer of all guarantees and warranties of components and Plant to the *Employer*	A
22	The Complete Plant O&M manual and Component O&M Manual	A
Within 4 weeks after the Final Acceptance Tests		

No.	Document / Drawing	Review Type
23	Proof of Payment of final year and future loss Liquidated Damage for performance ratio and Plant availability test (if any) to the *Employer*	A

5.8 Operation and Maintenance

1. Refer to Appendix D of this document.

6. AUTHORISATION

This document has been seen and accepted by:

Name	Designation
Geoff Ledwaba	Engineering Manager (Acting)
Grace Olukune	Senior Manager: Engineering Renewables Division
Lebo Memela	Middle Manager Programme
Lihle Mbothwe	Middle Manager Project Development
Mboneni Ngwenyama	Snr Engineer – C&I
Mbongiseni Mahlangu	Senior Engineer Prof Engineering
Mfundi Songo	Senior Manager Engineering - Gx Engineering
Nathi Mabaso	Manager Axillary Engineering
Rotondwa Mukhwa	Snr Advisor Environ Mngmt
Ryan Hector	Electrical Plant Manager
Sguda Sibande	Snr Engineer - Electrical
Viren Heera	Chief Engineer Prof Engineering
Vusi Mhlari	Snr Engineer - Civil
Yugandra Naidoo	Middle Manager Project Engineering

7. REVISIONS

Date	Rev.	Compiler	Remarks
28 November 2025	0	Sguda Sibande	Technical Specification required for Tendering purpose for the Tutuka Solar PV Plant turnkey project
05 January 2025	1	Sguda Sibande	Incorporating internal review comments

8. DEVELOPMENT TEAM

The following people were involved in the development of this document:

- Sguda Sibande – Engineering Design Work Lead
- Mbongiseni Mahlangu – Central Engineering Technical Support

9. ACKNOWLEDGEMENTS

- Gx Engineering and Renewable Divisions

APPENDIX A: PV PLANT INDICATIVE SITE LAYOUT DRAWINGS

Figure 1: Solar PV Layout

APPENDIX B: PV PLANT INDICATIVE ELECTRICAL SINGLE LINE DIAGRAM

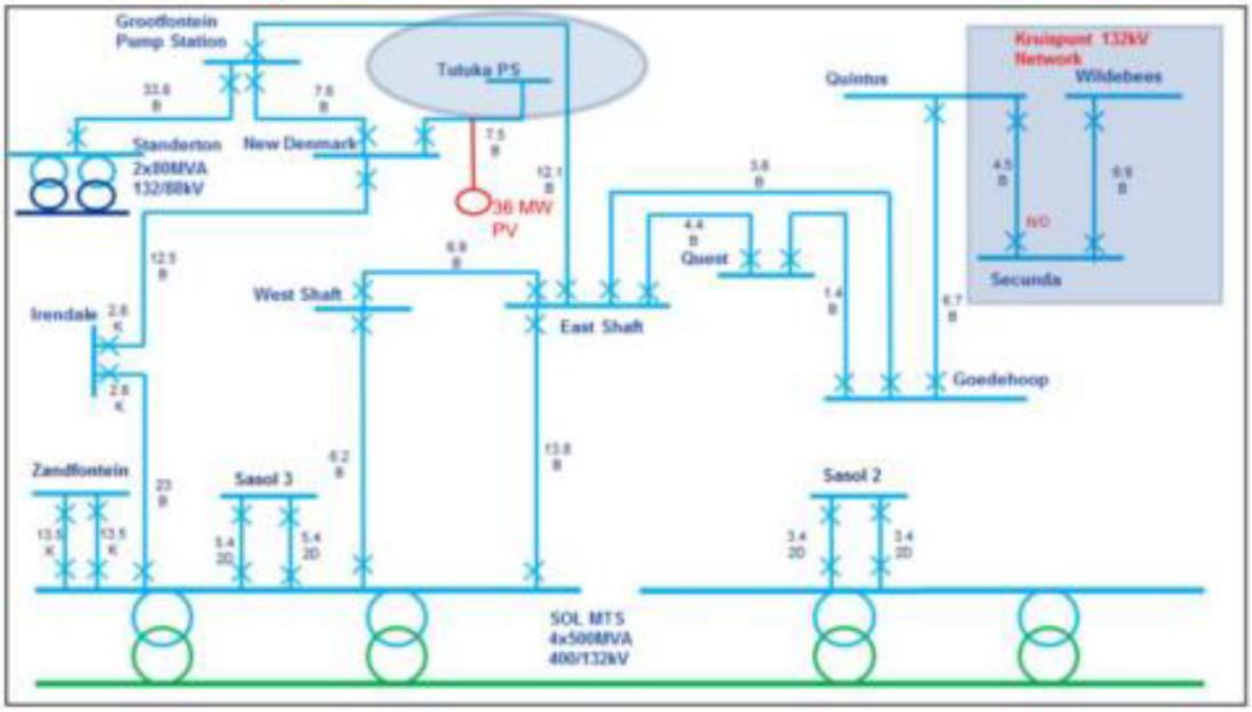

Figure 2: Tutuka Solar PV SLD

APPENDIX C: PV PLANT CODES AND STANDARDS

This section provides an overview of the Codes and Standards to be considered for the PV plant. With respect to the multidisciplinary structure of PV projects, various codes and standards shall be applied within the project lifecycle, particularly in the design and construction phase focusing on electrical interconnection, civil works, regulatory national framework, and C&I system. A summary of the Codes and Standards to be considered is given below.

ELECTRICAL

- All equipment and services supplied comply with the codes and standards listed below.

General

- Occupational Health and Safety Act 85 of 1993
- SANS 9001 - Quality Management Systems-Requirements
- 240-10568000 (QM 58) - Supplier Quality Management Specification
- SANS 45001 - Occupational health and safety management systems - Requirements with guidance for use
- SANS 14001 - Environmental management systems - Requirements with guidance for use
- Grid Connection Code for Renewable Power Plants (RPPs) Connected to the Electricity
- Transmission system (TS) or the Distribution System (DS) in South Africa
- 240-61268576 - Standard for the Interconnection of Embedded Generation
- South African Distribution Code of South Africa
- IEC 62548 - Photovoltaic (PV) arrays - Design requirements
- SANS 10142-1 – The wiring of premises – Part 1: Low voltage installation
- SANS 60529 - Degrees of protection provided by enclosures (IP Code)
- SANS 60071 - Insulation Co-ordination - All Parts
- IEC 61000-6-3/4 - EMC Emission
- IEC 61000-6-1/2 - EMC Immunity

PV Modules

- IEC 61215-1 - Terrestrial photovoltaic (PV) modules - Design qualification and type approval - Part 1: Test Requirements
- IEC 61215-1-1 - Terrestrial photovoltaic (PV) modules - Design qualification and type approval – Part 1-1: Special requirements for testing of crystalline silicon photovoltaic (PV) modules
- IEC 61215-2 - Terrestrial photovoltaic (PV) modules - Design qualification and type approval - Part 2: Test procedures
- IEC 61730-1 - Photovoltaic (PV) module safety qualification - Part 1: Requirements for construction
- IEC 61730-2 - Photovoltaic (PV) module safety qualification - Part 2: Requirements for testing
- IEC 61701 - Photovoltaic (PV) modules - Salt mist corrosion testing IEC 60891 - Photovoltaic devices - Procedures for temperature and irradiance corrections to measured I-V characteristics
- IEC 60904 - Photovoltaic devices - all parts
- IEC 61853-1 - Photovoltaic (PV) module performance testing and energy rating - Part 1: Irradiance and temperature performance measurements and power rating
- IEC 61853-2 - Photovoltaic (PV) module performance testing and energy rating - Part 2: Spectral responsivity, incidence angle and module operating temperature measurements
- IEC 61829 - Photovoltaic (PV) array - On-site measurement of current-voltage characteristics
- IEC 6134 - UV test for photovoltaic (PV) modules
- IEC 62548 - Photovoltaic (PV) arrays - Design requirements

- IEC 62446-1 - Photovoltaic (PV) systems - Requirements for testing, documentation, and maintenance - Part 1: Grid connected systems - Documentation, commissioning tests and inspection
- SANS 62852 - Connectors for DC-application in photovoltaic systems - Safety requirements and tests
- SANS 61140 - Protection against electric shock - Common aspects for installation and equipment
- IEC 60364-4-41 - Protection for safety – Protection against electric shock
- SANS 61204 - Low-voltage power supply devices, DC. output - Performance characteristics
- IEC 60904-1 - Photovoltaic devices - Part 1: Measurement of photovoltaic current-voltage characteristics
- EN 62852 - Connectors for DC-application in photovoltaic systems - Safety requirements and tests
- IEC 60068-2-78 - Environmental testing - Part 2-78: Tests - Test Cab: Damp heat, steady state
- IEC 60068-2-68 - Environmental testing - Part 2-68: Tests - Test L: Dust and sand
- IEC TS 62804 - Photovoltaic (PV) modules - Test methods for the detection of potential-induced degradation
- IEC 62716 - Photovoltaic (PV) modules - Ammonia corrosion testing

Inverters

- IEC 62093 - Balance-of-system components for photovoltaic systems - Design qualification natural environments
- SANS 62109-1 - Safety of power converters for use in photovoltaic power systems - Part 1: General requirements
- IEC 62109-2 - Safety of power converters for use in photovoltaic power systems - Part 2: Particular requirements for inverters
- IEC 62116 - Utility-interconnected photovoltaic inverters - Test procedure of islanding prevention measures
- SANS 60730-1 - Automatic electrical controls - Part 1: General requirements
- IEC 61683 - Photovoltaic systems - Power conditioners - Procedure for measuring efficiency
- SANS 61000-6-2,3,4 - Electromagnetic Compatibility (EMC)
- IEC 61727 - Photovoltaic (PV) systems - Characteristics of the utility interface
- Grid connection code for Renewable Power Plants (RPPs) connected to the electricity Transmission system (TS) or the Distribution system (DS) in South Africa
- IEC 60364-7-712 - Electrical Installations of Buildings: Requirements for Special Installations or Locations – Solar Photovoltaic power supply systems
- IEC 62103 - Electronic equipment for use in power installations
- IEC 62116 - Testing procedure of Islanding Prevention Methods for Utility-Interactive Photovoltaic Inverters
- 240-53114248 - Thyristor and Switch Mode Charger Converter Inverter Power Supply Standard

Electrical Cabling

- TUV 2PFG 1169 - Requirements for cables for use in photovoltaic systems
- SANS 1507 Part 1 - General - Electric cables with extruded solid dielectric insulation for fixed installations (300/500 V to 1900/3300 V)
- SANS 1507 Part 2 - Wiring Cables - Electric cables with extruded solid dielectric insulation for fixed installations (300/500 V to 1900/3300 V)
- SANS 1507 Part 3 - PVC Distribution cables - Electric cables with extruded solid dielectric insulation for fixed installations (300/500 V to 1900/3300 V)

- SANS 1339 - Electric cables - Cross-linked polyethylene (XLPE) insulated cables for rated voltages 3,8/6,6 kV to 19/33 kV
- SANS 10198 Parts 1-14 - The selection, handling, and installation of electric power cables of rating not exceeding 33 kV Part 1 to 14
- NRS 013 - Electric power cables form 1 kV to 36 kV
- SANS 62930 - Electric cables for photovoltaic systems with a voltage rating of 1,5 kV DC. Equivalent to EN 50618
- IEC 60228:2004 - Conductors of insulated cables
- SANS 61386-1 - Conduit systems for cable management - Part 1: General requirements
- SANS 61386-24 - Conduit systems for cable management - Part 24: Particular requirements - Conduit systems buried underground
- SANS 61084-1 - Cable trunking systems and cable ducting systems for electrical installations – Part 1: General requirements
- SANS 61442 – Test methods for accessories for power cables with rated voltages from 6 kV (Um = 7,2 kV) up to 36 kV (Um = 42 kV)
- SANS 62444 – Cable glands for electrical installations
- SANS 1411 – Materials of insulated electric cables and flexible cords – all parts
- IEC 60228 – Conductors of insulated cables
- SANS 60332 / IEC 60332 – All parts
- SANS 60754-1 and -2 – Gases evolved during combustion of cables
- SANS 61034-1 – Measurement of smoke density of cables burning under defined conditions – Part 1: Test apparatus
- SANS 61034-2 - Measurement of smoke density of cables burning under defined conditions – Part 2: Test procedure and requirements
- SANS 60754-2 - Test on gases evolved during combustion of materials from cables - Part 2: Determination of acidity (by pH measurement) and conductivity
- IEC 60216-2: Electrical insulating materials - Thermal endurance properties - Part 2: Determination of thermal endurance properties of electrical insulating materials - Choice of test criteria
- 240-56063710 - MV Cabling in Substations Standard
- 240-56227443 - Requirements for Control and Power Cables for Power stations Standard
- 240-56030619 - Accessories for medium voltage power cables for systems with nominal voltages of 11kv to 33kv standard

Earthing, Lighting, and Surge Protection

- SANS 62305 - Protection against lightning – all parts
- SANS 10292 - Earthing of low-voltage (LV) distribution systems
- SANS 10200 - Neutral earthing medium voltage industrial power systems
- IEC 60364-4-41 - Low-voltage plants installation - Part 4-41 - Protection for safety – protection against shock
- SANS 1063 - Earth rods and coupling
- SANS 10199 - The design and installation of earth electrodes
- IEEE 80 Earthing - Ground System Design
- SANS 61312-3 - Protection against lightning electromagnetic impulse - Part 3: Requirements of surge protective devices (SPDs)
- SANS 10313 - Protection against lightning - Physical damage to structures and life hazard
- NRS 039 Part 1 and Part 2 - Surge arresters for use in distribution systems
- SANS 61643-11 - Low-voltage surge protective devices - Part 11: Surge protective devices connected to low-voltage power systems - Requirements and test methods

- SANS 61643-12 - Low-voltage surge protective devices - Part 12: Surge protective devices connected to low-voltage power systems - Selection and application principles
- IEC 61557 - Electrical safety in low voltage distribution systems up to 1000 V a.c. and 1500 V d.c. – Equipment for testing, measuring, or monitoring of protective measures – all parts
- IEEE P81 - EEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Grounding System
- SANS 62561 - Lightning Protection System Components (LPSC) – all parts
- SANS 62561-2 - Lightning Protection System Components (LPSC) - Part 2: Requirements for conductors and earth electrodes
- IEEE 665 - Standard for Generating Station Grounding

Metering and Measurements

- 240-56227589 - List of approved electronic devices to be used on Eskom Power station standard
- 240-56364444 - Standard minimum requirements for the metering of electrical energy and demand
- IEC 62053 - Electricity metering equipment (A.C.) – particular requirements
- SANS 61869-2 / IEC 61869-2 - Instrument transformers- Part 2: Additional requirements for current transformers
- SANS 61869-3 / IEC 61869-3 - Instrument transformers - Part 3: Additional requirements for inductive voltage transformers
- 240-143485806 Generation Auxiliary Plant Medium Voltage Standard
- ANSI Standard Device Numbers (ANSI/IEEE Standard C37.2-2008)

Performance Monitoring

- IEC 61724 - Photovoltaic system performance monitoring - Guidelines for measurement, data exchange and analysis
- IEC 61683 - Photovoltaic systems - Power conditioners - Procedure for measuring efficiency
- IEC 60364-6 Ed. 1 - Low Voltage Electrical installations
- IEC 62446 - Grid connected photovoltaic systems - Minimum requirements for System documentation, commissioning tests & Inspections
- ISO 9845-1 - Solar energy - Reference solar spectral irradiance at the ground at different receiving conditions - Part 1: Direct normal and hemispherical solar irradiance for air mass 1.5
- ISO 9847 - Solar energy - Calibration of field pyranometers by comparison to a reference pyranometer. / BS 7621 - Method for calibrating field pyranometers by comparison to a reference pyranometer
- ISO 9060 - Solar energy - Specification and classification of instruments for measuring hemispherical solar and direct solar radiation
- ISO/TR 9901 - Solar energy - Field pyranometers – Recommended practice for use
- IEC 61725 - Analytical expression for daily solar profiles
- SANS 61724-1 - Photovoltaic system performance - Part 1: Monitoring

Transformers

- 240-56227520 Eskom Standard for Large Power Generator Transformers in Power Stations,
- 240-68973110 Eskom Standard for Specification for Power Transformers rated for 1.25MVA and above
- SANS 60076 - Power transformers - Part 2: Temperature rise for liquid-immersed transformers
- SANS 60076-3 - Power transformers - Part 3: Insulation levels, dielectric tests and external clearances in air

- SANS 60076-5 - Power transformers - Part 5: Ability to withstand short circuit
- SANS 60076-10 - Power transformers - Part 10: Determination of sound levels
- SANS 60076-11 - Power transformers - Part 11: Dry-type transformers
- SANS 60076-11 - Power transformers - Part 12: Dry-type transformers
- SANS 60076-20 - Power transformers - Part 20: Energy efficiency

Switchgear

- 240-56227516 LV Switchgear and Control Gear Assemblies and Associated Equipment for Voltage up to and including 1000V AC and 1500V DC Standard
- 240-56227573 Generation Air-Insulated Withdrawable AC Metal-Enclosed Switchgear and Control-gear for Rated Voltages above 1kV up to and including 52kV SANS 60269 - Low-Voltage fuses Part 1 and Part 2
- SANS 1765 - Low-voltage switchgear and controlgear assemblies (distribution boards) with a rated short-circuit withstand strength up to and including 10 kA
- SANS 60439-1 to 5 - Low-voltage switchgear and controlgear assemblies - parts 1 to 5
- SANS 60529 - Specification for degrees of protection provided by enclosures (IP code)
- SANS1874 – Switchgear - Metal-enclosed ring main units for rate AC voltage above 1 kV and up to and including 36 kV
- SANS 61439 - Low-voltage switchgear and controlgear assemblies – all parts
- IEC 60255-1 - Measuring relays and protection equipment - Part 1: common requirements
- 240-53114248 - Thyristor and Switch mode chargers, AC/DC and DC/AC and UPS standard
- IEC 62271-200 - AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV
- SANS 62271-200 - High-voltage switchgear and controlgear - Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV
- SANS 62271 - High-voltage switchgear and controlgear - all parts
- SANS 60947-1 - Low-voltage switchgear and controlgear - Part 1: General rules
- SANS 60947-2 - Low voltage switchgear and controlgear - Part 2: Circuit Breakers
- SANS 60947-3 - Low-voltage switchgear and controlgear - Part 3: Switches, disconnectors, switch-disconnectors, and fuse-combination units
- SANS 60947-4-1 - Low-voltage switchgear and controlgear - Part 4-1: Contactors and motor-starters Electromechanical contactors and motor-starters
- SANS 60947-5-1 - Low voltage switchgear and controlgear - Part 5-1: Control circuit devices and switching elements - Electromechnical control circuit devices
- SANS 60947-5-3 - Low-voltage switchgear and controlgear - Part 5-3: Control circuit devices and switching elements - Requirements for proximity devices with defined behaviour under fault conditions (PDDB)
- SANS 60947-7-2 - Low voltage switchgear and controlgear - Part 7-2: Ancillary Equipment
- SANS 1973-1 - Low-voltage switchgear and controlgear ASSEMBLIES - Part 1: Type tested ASSEMBLIES with stated deviations and a rated short-circuit withstand strength above 10 kA
- SANS 1973-3 - Low-voltage switchgear and controlgear ASSEMBLIES - Part 3: Safety of ASSEMBLIES with a rated prospective short-circuit current of up to and including 10 kA
- 240-56030619 - Accessories for Medium-Voltage Power Cables for Systems with nominal voltages of 33kV to 33kV Standard
- 240-56065131 - Specification for 11 kV to 33kV Withdrawable Pattern Air-Insulated Indoor Primary Switchgear Standard and manufactured in accordance with SANS 62271-200

Lighting and Small Power

- Occupational Health and Safety Act 85 of 1993
- SANS 164 - Plug and socket-outlet systems for household and similar purposes for use in South Africa
- SANS 890 - Ballasts for fluorescent lamps
- SANS 1041 - Tubular fluorescent lamps for general service
- SANS 1088 - Luminaire entries and spigots
- SANS 10142-1 - The wiring of premises - Part 1: Low-voltage installations
- SANS 10114-1 - Interior lighting - Part 1: Artificial lighting of interiors
- SANS 10114-2 - Interior lighting - Part 2: Emergency lighting
- SANS 1266 - Ballasts for discharge lamps (excluding tubular fluorescent lamps)
- IEC 60898-1 - Electrical accessories - Circuit-breakers for overcurrent protection for household and similar installations - Part 1: Circuit-breakers for a.c. operation
- IEC 60898-2, +A1 - Electrical accessories - Circuit-breakers for overcurrent protection for household and similar installations - Part 2: Circuit-breakers for a.c. and d.c. operation
- IEC 60898-3 - Electrical accessories - Circuit-breakers for overcurrent protection for household and similar installations - Part 3: Circuit-breakers for DC operation
- SANS 60309-1 - Plugs, socket-outlets and couplers for industrial purposes - Part 1: General requirements
- 240-91190294 - DC & Auxiliary Supplies Philosophy

DC SYSTEM

- SANS 62040-1 - Uninterruptible power systems (UPS) - Part 1: Safety requirements
- SANS 62040-2 - Uninterruptible power systems (UPS) - Part 2: Electromagnetic compatibility (EMC) requirements
- SANS 62040-3 - Uninterruptible power systems (UPS) - Part 3: Method of specifying the performance and test requirements
- SANS 62040-4 - Uninterruptible power systems (UPS) - Part 4: Environmental aspects - Requirements and reporting
- IEC 62619 - Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for secondary lithium cells and batteries, for use in industrial applications
- UL 1973 - UL Standard for Safety Batteries for Use in Stationary and Motive Auxiliary Power Applications
- SANS 61204 - Low-voltage power supplies, DC output
- SANS 1019 - Standard voltages, currents, and insulation levels for electricity supply
- 240-56177186 - Acceptance and Commissioning of DC supply equipment
- 240-56176168 - DC systems setting standard
- 240-56360086 - Batteries, Specification for vented and semi-sealed Nickel-Cadmium cells and
- 240-70413291 - Specification for electrical terminal blocks
- 240-56360034 - Specification for vented lead acid cells
- 240-51999453 - Standard specification for valve-regulated Lead-acid cells
- 240-56360034 - Stationary Vented Lead Acid Batteries Standard
- 240-56360086 - Stationary Vented Nickel Cadmium Batteries Standard
- 240-56176852 - Essential Power Supplies for Power Stations Standard
- 240-56227923 - Quality Requirements Stationary Vented Nickel-Cadmium and Lead Acid Batteries Power Stations Standard
- 240-56356510 - Definitions of Terms Applicable to DC Emergency Supplies Standard
- 240-56177186 - Battery Room Standard
- 240-57649110 - Sizing of DC Systems for Substation Applications Standard
- 240-51999453 - Standard Specification for Valve-Regulated Lead-Acid Cells

- 240-62772907 - Specification Standard for Stationary Diesel Generator Systems

CONTROL AND INSTRUMENTATION

- IEC 61724 - Photovoltaic system performance monitoring - Guidelines for measurement, data exchange and analysis
- SANS 61850-7 - Communication networks and systems for power utility automation Part 7-420: Basic communication structure – Distributed energy resources logical nodes
- IEC 60870 - Tele control equipment and systems. Remote control of photovoltaic power plants
- IEC 62381 - Factory Acceptance test (FAT), Site Acceptance test (SAT), and Site Integration Test (SIT)
- IEC 62382 - Electrical and Instrumentation loop check activities
- IEC 62337 - Commissioning of electrical, instrumentation & control systems
- EIA/TIA 568 - Standard for structured cabling
- EIA/TIA 569 - Standard for communication pathways and spaces
- EIA/TIA 607 - Standard for grounding and bonding of communication cabling
- TIA/EIA 485 - Electrical Characteristics of Generators and Receivers for Use in Balanced Digital Multipoint Systems
- SANS 10142-1 - The Wiring of Premises - Part 1: Low-voltage installations
- SANS 10340-1 - Installation of telecommunication cables - Part 1: Fibre optic cables in buildings
- SANS 10340-2 - Installation of telecommunication cables - Part 2: Outdoor fibre optic cables
- SANS 60794-1-1 - Optical fibre cables - Part 1-1: Generic specification – General
- SANS 60794-1-2 - Optical fibre cables - Part 1-2: Generic specification - Basic optical cable test procedures
- SANS 61312 - Protection against lightning electromagnetic impulse
- SABS 1411 - Parts 2-6 – Materials of Insulated Electric Cables and Flexible Cords
- SANS 60947-7-1 and SANS 60947-7-2 - The terminal blocks for the junction box terminations
- SANS 60529 - Degree of Protection provided by enclosures (IP)
- 240-56227443 - Requirements for Control and Power Cables for Power Stations Standard, Sections 3.2.7, 3.4, 3.5, 3.6, 3.7, 3.8.7, 8, Tables 16, 17, 18 & 19
- 240-56355754 - Field Instrument Installation Standard, Section 3
- 240-56355815 - Field Instrument Installation Standard Junction Boxes and Cable Termination
- 240-56355541 - Control System Computer Equipment Habitat Requirements Guideline
- 240-56355731 - Environmental Conditions for Process Control Equipment Used at Power Stations Standard
- 240-56355808 - Ergonomic Design of Power Station Control Suite Guideline
- 240-56355728 - Human Machine Interface Design Requirements Standard
- 32-894 - Eskom Server Rooms and Data Systems Standard
- 240-55410927 - Cyber Security Standard for Operational Technology
- 240-55863502 - Definition of operational technology (OT) and OT IT collaboration accountabilities
- 240-79669677 - DMZ Designs for OT Systems
- 32-373 – IT and OT Third party and Remote Access Standard Rev 5
- 240-56355466 - Alarm Management System Guideline
- 240-56355910 – Management of Plant Software Standard

CIVIL AND STRUCTURAL WORKS

- SANS 10400 - Code of Practice - The Application of the National Building Regulations
- SANS 10100 - The structural use of concrete
- SANS 10160 - Basis of structural design and actions for buildings and industrial standards

- SANS 10162-1 - The structural use of steel - Part 1: Limit states design of hot-rolled steelwork
- SANS 10162-2 - The structural use of steel - Part 2: Limit states design of cold-formed steelwork
- SANS 10162-4 - The structural use of steel - Part 4: The design of cold-formed stainless-steel structural members
- SANS 10021 Ed4.0 - The waterproofing of buildings (including damp-proofing and vapour barrier installation
- SANS121 Ed2 - Hot dip galvanized coatings on fabricated iron and steel articles - Specifications and test methods
- SANS 2001-CS1 Ed.1.01 - Construction works - Part CS1 – Structural steel works
- SANS 1921-3 Ed.1 - Construction and Management requirements for works contracts – Part 3 Structural steel works
- SANS 1200 Ed3 – Standard specification for Civil Engineering Works
- SANS 1200H Ed3 - Standard specification for Civil Engineering construction - Structural steel work installation
- SANS 1200HC - Standardized specification for civil engineering construction Section HC: Corrosion protection of structural steelwork
- SANS 2001 - Construction
- SANS 10163-1 - The Structural use of Timber – Part 1: Limit-states design
- SANS 10163-2 - The Structural use of Timber – Part 2: Allowable stress design
- SANS 10161 - The design of foundations for buildings
- SANS 10164-1 - The structural use of masonry – Part 1: Unreinforced masonry walling
- SANS 10164-2 - The structural use of masonry – Part 2: Structural design and requirements for reinforced and pre-stressed masonry
- 240- 56364545 - Structural design and engineering standard
- 240- 56364542 - Standard for reinforced concrete foundations and structures
- 240 -85549846 - Standard for design of drainage and sewerage infrastructure
- 240- 56364535 - Architectural technical specification for structures and other buildings
- SANS 2001-DP4:2010
- SANS 2001-DP7:2021

Roads

- T.R.H. series - Technical Recommendation for Highways
- T.H.M series - Technical Methods for Highways
- UTG series - Urban Transport guidelines
- SANS 1200 - Standardized specification for civil engineering construction
- SANS 3001 - Civil engineering test methods
- COLTO - standard specifications for road and bridge works for state road authorities
- 240-84418186 - Eskom Road Specification Manual
- SANS 2001-DP4:2010 Construction works - Part DP4: Sewers
- SANS 2001-DP7:2021 Construction works - Part DP4: Sewers for buildings

CORROSION PROTECTION

- SANS 12944 - Corrosion Protection of Steel Structures
- SANS 14713 - Protection against corrosion of iron and steel structures – Zinc and aluminium coatings – Guidelines
- 240-101712128 - Standard for the Internal Corrosion Protection of Water Systems, Chemical Tanks and Vessels and Associated Piping with Linings

- 240-106365693 - Standard for the External Corrosion Protection of Plant, Equipment and Associated Piping with Coatings
- 240-100945498 – Standard for Corrosion Protection of Coastal Gas Generation Plant and Equipment with Coatings

WATER SUPPLY AND RETICULATION

- SANS 241 - Drinking water
- SANS 10252 - Water supply and drainage for buildings
- SANS 2001 DP1 – Earthworks for buried pipelines and prefabricated culverts
- SANS 2001 DP2 – Medium pressure pipelines
- SANS 2001 DP6 – Below-ground water installations
- SANS 2001 DP8 – Pipe jacking

SEWERAGE AND WASTE DISPOSAL

- Occupational Health and Safety Act (Act No. 85 of 1993)
- National Environmental Management Act (Act 107 of 1998)
- National Water Act (Act 36 of 1998)
- Water Services Act (Act 108 of 1997)
- Municipal By-laws, local policies, and practices
- SANS 10400-P - The Application of the National Building Regulations - Part P: Drainage

HEATING VENTILATION AND AIR CONDITIONING (HVAC)

- 240-102547991 - General Technical Specification for HVAC Systems
- 240-70164623 - Eskom Heating Ventilation and Air Conditioning (HVAC) Design Guideline

FIRE PROTECTION AND DETECTION

- International Fire Code: Chapter 1 (Scope and Administration), Chapter 2 (Definitions), Chapter 3 (General Requirements), Chapter 4 (Emergency Planning and Preparedness), Chapter 5 (Fire Service Features), Chapter 6 (Building Services and Systems), Chapter 7 (Fire Resistance Rated Construction) and Chapter 9 (Fire Protection Systems)
- NFPA 850 - Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations.
- SANS 246 - Code of Practice for Fire Protection for Electrical Equipment Installations
- SANS 10400 - The Application of the National Building Regulations SANS 10400-T - South African National Standard - Part T: Fire Protection
- SANS 1186 - Symbolic safety signs
- SANS 1910 - Portable refillable fire extinguishers
- SANS 1464 - Safety of luminaires - Part 22: Luminaires for emergency lighting
- SANS 10105 - The use and control of fire-fighting equipment
- SANS 10139 - Fire detection and alarm systems for buildings - System design, installation, and servicing
- SANS 10177 - Fire testing of materials, components and elements used in building
- 240-54937439 - Fire Protection/Detection Assessment Standard
- 240-56737448 - Fire Detection and Life Safety Design Standard

CODING

- 240-93576498 - KKS Coding Standard
- 240-71432150 - Plant Labelling Standard
- 240-109607332, Eskom Plant Labelling Abbreviation Standard

SAFETY ACT

- Occupational Health and Safety Act 85 of 1993
- ISO 18001 – Occupational Health and Safety Management Systems

ENVIRONMENTAL PROTECTION

- ISO 14000 – Environmental Management Systems
- IEC 60721-3-1 - Classification of groups of environmental parameters and their severities; Storage.
- IEC 60721-3-2 - Classification of groups of environmental parameters and their severities; Transportation.
- IEC 60721 -3-3 - Classification of groups of environmental parameters and their severities; Stationary use at weather protected locations

SECURITY

- 240-91252315 - Standard for Bullet-resistant Guard facilities

APPENDIX D: PV PLANT OPERATION AND MAINTENANCE REQUIREMENTS

1. Introduction

The Employer intends to procure the construction of a Solar PV plant, within the borders of South Africa in the Gert Sibande Local Municipality, in the Mpumalanga Province. To procure the construction of the PV installations, the Employer will enter contracts with:

- The Contractor, responsible for surveying, studies, permitting, design, engineering, manufacture, procurement and supply of all materials and labour, delivery to site, offloading, construction, erection, installation, off-site testing (construction Quality compliance to Regulations and Eskom requirements), on-site testing, commissioning, performance testing, provision of samples, preparation of all detail design drawings, as-built record drawings, operation and maintenance manuals and instructions for the works, in accordance with the general requirements and performance requirements as detailed in this document, and
- Enter a two (2) year contract with the EPC contractor for the Operations and Maintenance (O&M) of the PV installations and associated equipment.

This Appendix relates to the second bullet above and it defines the functional minimum requirements for the Operations and Maintenance (O&M) to be supplied as part of the Works for the installation of Solar PV Plant at Tutuka Power Station and associated PV plant equipment that will collectively be referred to as the PV O&M Plant, (Referred to interchangeably as the “Plant” or the “Site”).

2. Contractor’s Scope of Work

- The EPC Contractor performs the role of O&M Contractor for the first two (2) years of operation (referred to as the O&M period) and comes into effect upon Completion of the EPC Contract for the Tutuka Power Station Solar PV Plant. The Contractor conducts Operation and Maintenance (O&M) of the PV installations and associated equipment for the O&M period.

3. Contractor’s Experience

- The EPC Contractor shall have successfully performed the Operations and Maintenance (O&M) for at least two (2) years as the main O&M Contractor for at least two (2) ground mounted PV plants which were ≥ 24 MWac.
- The Contractor shall provide project details such as the name of the solar PV plant, location of the plant, name and contact details of developer, type of module technology, type of PV module mounting (fixed, tracking, etc.) mechanism, installed nameplate DC capacity (MWp), plant AC capacity (MWac), duration of operations and maintenance (months), commercial operation date, photographs (if possible), and proof verifying Solar PV plant O&M duties.

4. General Requirements

- The Contractor shall be responsible for the all-inclusive operations and maintenance (preventive, corrective, and spare parts replacement) and performance monitoring activities of the facility during the first two (2) years of operation.
- The Contractor shall perform operating and maintenance activities together with the Employer personnel, where the Employer personnel will be continuously trained during the O&M period.
- The Contractor shall form part of the Employers regular maintenance planning practices and this require, amongst others, that all operating and maintenance activity planning and decision-making processes to be done in combination with the Employer's supervision and with the Employers approval.

- The Contractor shall maintain and operate the PV Plant (including the complete solar PV Plant, the PV Plant MV stations/cabins enclosing the inverter, transformer and switchgear, Power evacuation cabling, and the Support Facilities), in good condition and performs the agreed O&M services in good faith, in accordance with the best industry practice.
- The Contractor shall perform periodic inspection and testing of the PV plant and each component and report on the status of modules, cabling, structures, inverters, transformers, security system, monitoring system, power evacuation lines etc.
- The Contractor shall repair any defect or replace any item, equipment, and component.
- The Contractor shall perform maintenance activities as minimum as defined under preventive maintenance and corrective maintenance and as per guiding principles indicated in IEC 62446-2 for preventive and corrective maintenance.
- The Contractor shall supply all required tools, equipment, and facilities (including water for PV module cleaning) which are necessary for carrying out the operation and maintenance of the PV plant.
- The Contractor shall always provide guarantee for the on-site availability of minimum spare parts.
- The Contractor shall operate the plant to meet the guaranteed performance ratio and availability.
- The Contractor shall maintain and ensure the compliance of the plant in respect to safety laws and regulations, also in respect of the safety of the workers and performing the services. This includes compliance with the Employer's work requirements detailed in 240-150642762 - Generation Plant Safety Regulations (PSR) and 240-114967625 - Eskom's Operating Regulations for High Voltage systems (ORHVS).
- The Contractor shall follow the maintenance manuals for entire plant monitoring including the operational manual of specific components and safety instructions.
- The Contractor shall protect any plant warranties and support the Employer on negotiation of any warranty or the claims available to Employer for material or equipment supply and for the performance work associated with the plant.
- The Contractor shall respond in the shortest possible time to any alarm generated in PV plant and take the necessary actions (repair or replacement) and shall report to the Employer.
- The Contractor shall operate and provide the maintenance of surveillance and control system, communications, security, and meteorological stations.
- The Contractor shall provide O&M training to the Employer and Employer's representative along with all required material in hard copy and in electronic copy. Training requirements are further described in Section 9 of this document.
- The Contractor shall co-operate and co-ordinate with the Project Manager in the best way to ensure the operation and maintenance activities are performed respecting all Employer's requirements.
- The Contractor shall commence Operation and Maintenance activities respecting all legal, environmental, and administrative requirements.
- The Contractor shall co-operate with third parties (upon request from the Employer) and with the Authorities for verification of their requirement during Project installation, commissioning, and operation.
- The Contractor shall report periodically regarding the status of the plant, maintenance work and the performance evaluation of the pant according to the reporting schedule defined in this document.
- The Contractor shall warrant the absence of defects on any repair, replacement and generally on any activities of maintenance for two years in case of replacement or repair.

- The Contractor will be allowed to utilise the Employer's storage space as agreed with the Employer. The Contractor to provide his spares storage requirements to the Employer 3 months prior to the commencement of the O&M Contract for review and agreement. The Contractor to make provision for temporary storage facilities should there be a shortfall between the Contractor's storage requirements and the Employer's available space.
- The contractor shall provide the services in accordance with the latest revision of the Employers document, 240-10568000 (QM 58) supplier quality management specification, including the applicable and approved Contract Quality and Inspection and Test Plans.

5. Boundaries of Responsibility

- The Contractor shall be responsible for the Operation and Maintenance of the PV Plant. The PV Plant shall mean the following:
  a. The installation of Solar PV plant at Tutuka Power Station and all associated equipment and facilities. This includes all the power evacuation cable/s up to the cable termination point of the PV feeders on the 132kV Switchgear in the PV Solar Substation.
  b. PV site security systems (CCTV, detection and alarm system, access control system, and security lighting).
  c. The boundary includes operating and maintenance required on the server room, and control room, and the PV supplied back-up power and related equipment.
- The O&M of the Network Integration Equipment 132kV Switching Station and associated equipment shall be the Employer's responsibility. The Contractor shall be responsible for the operating and maintenance from the PV Plant up to and including the cable termination connecting on the switchgear located in the Tutuka Solar PV Substation, where the boundary is the termination point on the switchgear (Contractor also responsible for the entire cable termination).

6. Preventative Maintenance

- Preventive maintenance of the Plant shall include all necessary measures to be performed by the Operator as indicated in the maintenance manuals provided by the Contractor under the EPC Contract, and in the preliminary maintenance plan guideline provided in Table D 1, to avoid or anticipate possible or future malfunctions of the plant.
- The Contractor shall define the preventive maintenance plan for the PV Plant, including the frequency and scheduling of each maintenance activity. The frequency of preventive maintenance depends upon the component criticality. In this regard, the preventive maintenance of the inverter receives the greatest focus among all. The Contractor pays high level of attention to such components in its O&M plan.
- The Contractor shall submit the preventative maintenance plan to the Employer for acceptance 3 months prior to the O&M period starting.
- Preventive inverter maintenance shall include at least:
    a. The inspection and tightening of connections,
    b. Ensuring water and dust tightness,
    c. Cleaning and replacing filters, lubricating moving parts which may include fans, handles and disconnects,
    d. Running electronic diagnostics,
    e. Routine maintenance according to manufacturer's recommendation
- Preventive maintenance shall involve module cleaning, inverter servicing, tracker system servicing including motors, gear mechanism and other associated components, foundation and mounting structure maintenance, civil building work maintenance and balance of Plant inspection. The inspection on balance of Plant includes, but is not limited to, the inspection of junction boxes, conduit runs, combiner boxes, communication equipment, monitoring equipment, O&M building, PV Plant MV stations/cabins, security system, etc.
- Preventive maintenance shall include erosion control, drainage system control, and vegetation management. Vegetation control must be performed to meet following criteria:
    a. Modules are not shaded.
    b. A fire hazard is not created.
    c. Unrestricted access to the major equipment of the site is maintained.
    d. Any vegetation clearing that is required shall be done in accordance with the approved EMPr.
- Module Cleaning Requirement - It is expected that the Contractor shall provide suitable cleaning methods as well as cleaning frequency for the PV Plant design proposed. The following requirements are applicable, but not limited to:
    a. The Contractor uses the methods, tools, and recommendations from equipment manufacturer for cleaning PV modules.
    b. The Contractor provides all necessary tools for cleaning PV modules and transfers these to the Employer after the Operation and Maintenance period.
    c. The Contractor cleans all PV modules on site upon the following situation (whichever occurs earlier):
    i. When the solar irradiation measured by the two reference cells (one cleaned minimum on weekly basis and another not cleaned) differs by more than 5% for continuous five days period; or

ii. On quarterly basis.

d. The Contractor shall be responsible for all necessary arrangements for PV module cleaning during the contract period.

- Any waste that is generated during operation & maintenance of the solar PV plant shall be disposed in accordance with the Tutuka Waste Management Procedure.
- Any excavation activities that are required to be performed as part of maintenance activities therefore, a signed approval shall be obtained from the Environmental Management Department at Tutuka Power Station.
- The Contractor shall prepare the report according to minimum requirements indicated in the reporting template presented in Section 11 of this Appendix.
- The Contractor shall develop Work Instructions, Safe Work Procedures and Safe Operating Procedures for the maintenance activities defined in the maintenance plan. This to be submitted to the Employer for review and acceptance 2 months prior to the O&M period starting.
- A preliminary maintenance plan guideline is indicated in **Table D 1**, providing a general overview for preventive maintenance of the main components. The maintenance type and frequency of maintenance may depend upon the specific component type, manufacturer's recommendation, and local grid requirements. Furthermore, preventive maintenance that requires shutdown shall be conducted where possible during non-peak production periods such as early mornings or evenings. Therefore, the Contractor shall provide the detailed preventive maintenance plan of each equipment, configuration, and systems considered in the plant.

Table D 1: Preventative Maintenance Plan Guideline – Minimum Requirement

No.	Items	Frequency
1	PV Modules	
1.1	Cleaning of modules	Q (at least)
1.2	Visual Inspection - glass breakage, yellowing & browning, corrosion, delamination, cracks on cell, hot spot, deformed connection box, module mounting and module frame condition etc.	M
1.3	Visual Inspection terminal connections and panel cabling - cable tightness, terminal box watertight, cleanliness, clamping etc.	M
1.4	I-V Curve measurement of strings	Once in two years
1.5	I-R Scanning of modules	A
2	Mounting structure and Foundation	
2.1	Visual Inspection of mounting structure	M
2.2	Check of integrity of mounting structures and clamping	M
2.3	Inspection of corrosion in fasteners, structure and check adequacy of fastener tightness	SA
2.4	Check on grounding connection (if any)	M
2.5	Visual inspection on foundation	M
3	Single-axis tracking system	
3.1	Visual inspection for smooth operation of gear mechanism	D
3.2	Visual inspection for smooth operation of motors	D
3.3	Visual inspection for rust/loose of bolts and nuts	W

No.	Items	Frequency
3.4	Check integrity of wires/cables	W
3.5	Check proper functioning of sensors	D
4	String box/Junction Box/Combiner Box	
4.1	Visual Inspection - box screw tightness, incoming and outgoing cable tightness, cable labelling, water and dust tightness, etc.	M
4.2	Check of proper functioning of string fuses, DC disconnect switch and earthing cable etc.	M
4.3	Visual inspection of string monitoring equipment inside combiner box	M
4.4	Verify preventive maintenance activities described from 3.1 to 3.3 for secondary combiner box and fuse box (if any included in plant)	M
5	Inverter - General Preventive measures	
5.1	General visual inspection of the inverter and inverter enclosure	M
5.2	Inspection on cables and connection of the components	M
5.3	Check if inverter is running at adequate temperature range, as specified by the manufacturer	M
5.4	Check of inverter runs smoothly without producing strange noise	M
6	Inverter - Periodic and Specific measures	
6.1	Periodic efficiency measurement (DC/AC conversion from inverter meter)	M
6.2	Cleaning of air filter - as per manufacturer's recommendation	MS
6.3	Checking and replacement of ventilation system - as per manufacturer's recommendation	MS
6.4	Visual inspection of earth connections	M
6.5	Checking and verification of proper functioning of safety switches, fuses, cooling fan	M
6.6	Control and LCD display operation	M
6.7	Check of inverter according to manufacturer's operation and maintenance manual	MS
7	Inverter Station/Cabin	
7.1	Visual inspection of inverter station/cabin	M
7.2	Visual inspection of ventilation system, earthing and fire protection system	M
7.3	Check inverter temperature while running during the day and verify that ventilation is working properly, and inverter operating temperature is within manufacturer’s recommended range	M
7.4	Visual inspection of transformer, switchgear board and protection device and verify that they all are running without any defects	M
8	Electrical Wiring	
8.1	Check on integrity and completeness of all electrical cables from PV module to connection point	M
8.2	Check for any damaged or discoloured cable	M
8.3	Check on status of fuses, circuit breakers and safety switches	M
8.4	Verification of proper earthing connections of the plant components	M
8.5	Verification of water tightening of electric cables and conduits	M

No.	Items	Frequency
8.6	Electrical Insulation and grounding measurement of DC and AC cables	once in two years
8.7	Check and verify the labelling on electrical cables	M
8.8	IR scanning of electrical cable connection and verify that all cable connection are made properly and no heat generation in the connection	A
9	Security and Site Condition	
9.1	Check of integrity of security fences	SA
9.2	Verify that all security cameras and gates are working properly	M
9.3	Verify that communication of security systems with power station security system	M
9.4	Verify that internal roads are in good conditions	M
9.5	Keeping plant clean and free from waste and taking proper steps of the disposal of waste according to local regulation and procedures	SA
9.6	On Site presence – immediate answering to all alarms by an emergency service assuring on-site presence	
9.7	Check the vegetation level and ensure that they are controlled	M
9.8	Check the drainage channels and erosion control	M
10	O&M Building (Server room, Stores Building, Security Building and all other Buildings on the PV Environmental Approved Area)	
10.1	Visual inspection of O&M building and their walls, roofs, foundation and verify that there is no visual damage	M
10.2	Verify that control system, server and its back up system are working properly	M
10.3	Verify that the inventory of spare parts is maintained according to the contract requirement	M
10.4	Verify that all security measures inside the O&M and switchgear room are free of any defects and working properly	M
11	Power Evacuation	
11.1	Visual inspection of power evacuation route	M
12	Meteorological Stations and Monitoring System	
12.1	Cleaning of meteorological stations, routine inspection of sensors to be performed to check for soiling, misalignment, and other fault conditions (reference cell and pyranometer)	W
12.2	Calibration of meteorological equipment, if required	MS
12.3	Check of connection on meteorological components and communication with monitoring system	M
12.4	Check the weather station mounting structure and general physical condition	M
12.5	Check the slope and azimuth of reference cells pyranometers	M
12.6	Check on online record of energy output and irradiation through remote monitoring system	D
12.7	Check on alarm, event and status database - through remote monitoring system	D
12.8	Check on online record of availability of each inverter and availability of the plant - through remote monitoring system	D
13	Reporting	
13.1	Report on plant performance ratio and plant availability	M

No.	Items	Frequency
13.2	Report on energy production recorded through inverters, meters at site and meters at point of connection	M
13.3	Report on meteorological measurement on site	M
13.4	Submission of raw and processed data on meteorological measurements and performance measurements to the Employer	M
13.5	Report on status of plant component and status of preventive maintenance	M
13.6	Report on alarms, events and status recorded	M
13.7	List of damage and faults verified	M
13.8	List of corrective maintenance service performed	M
13.9	List of spare parts available in inventory	M

Frequency: D→ Daily, W → Weekly, M → Monthly, Q→ Quarterly, SA→ Semi-Annually, A→ Annually, MS → Manufacturer specification and operation manual

7. Corrective Maintenance (Unscheduled Maintenance)

- Corrective maintenance shall always include during the contract period and in all cases attending to and repairing breakdowns and failures of the components of the plant caused by wear and tear and/or breakages under normal operating conditions to ensure that the plant operates normally (in the desired condition) throughout the duration of the O&M Period.
- Corrective maintenance shall be carried out during the preventive maintenance visits (if the faults/failures do not affect energy production) or when the remote monitoring system registers an operational problem. In case of corrective maintenance, the Contractor shall perform: -
  a. A problem diagnosis, performance notification, and identification of which parts are to be replaced,
  b. Supplying the replacement component parts in the event of failure or anomaly,
  c. Repairing or replacing, when necessary, the affected component/equipment from inventory and bringing the plant back in working condition,
  d. Purchasing and transporting the replaced component and keeping the inventory at the level defined by the Contractor.
- Where market conditions prevent the supply of parts identical to those already installed. The Contractor shall propose the replacement parts for the Employer acceptance. Proposed replacement parts shall not result in a reduction below the rated output or efficiency of the plant.
- The Contractor shall be responsible to update any plant drawings, catalogues, manuals for such a replacement once approval has been obtained from the Employer. The Contractor shall perform repairs or replacement (with the spare parts) for the affected item immediately or, under all circumstances, within the time frame agreed with the Employer. In the absence of an agreement with the employer the repair time shall not exceed forty-eight (48) hours following the identification of the failure / initiation of alarms.
- The Contractor shall be responsible for maintaining the plant in accordance with the laws in force at any given time.
- In case where an immediate repair or replacement is not possible due to the lack of sufficient availability of components in inventory, the Contractor shall propose a temporary solution to the Employer for approval to mitigate the risk of production losses, prior to implementation of the solution.

- All work related to the corrective maintenance of each component or part shall be performed in accordance with the relevant manufacturer's manual and recommendations. All materials, components and parts used by the Contractor must be new.
- In case the incident or breakdown or malfunction is caused by Force Majeure or by the Employer's actions, not authorized by the Contractor, the Contractor shall perform all necessary activities (procurement, transportation, installation/repair/removal etc.) of corrective maintenance. Prior to such corrective maintenance activities, the Contractor shall notify the Employer of the necessary cost and plan. The Contractor's offer must be according to the market and competitive. Only upon the approval from the Employer, the Contractor shall execute the process. To avoid doubt, if such malfunction or breakdown requires the replacement of the components and the necessary components are made available in the inventory of spare parts, the Contractor shall immediately correct the breakdown or malfunction with the available spare parts.
- The Contractor, in any case shall warrants the absence of defects on any repair, replacement and generally on any activities of corrective maintenance for two years in case of replacement or repair.

8. Permit to Work system

- All work to be performed under this contract shall be performed as per the following Employers regulations:
    - 240-150642762 - Generation Plant Safety Regulations (PSR)
    - 240-114967625 - Eskom's Operating Regulations for High Voltage systems (ORHVS)
- These regulations detail the permit to work system (PTW) to be applied when performing work. This requires the Contractor to have the required Responsible Persons appointed as per the requirements of the PSR and ORHVS.
- The Contractor shall plan and train his own personnel as per the requirements of the Employers Plant Safety and ORHVS requirements.
- The Employer shall provide the details of suitable vendors for the training of personnel. The practical assessment and appointment of personnel is done by the Employer's Assessment panel as per the Employer's requirements.

9. Training

- O&M Training shall be provided to the Employer and Employers' representatives during the O&M period. The focus of this training to be on practical operating and maintenance related activities during plant operation covering at least the following: Plant monitoring, identifying plant normal and abnormal operations and resolving plant abnormalities during actual plant operation.
- O&M Training shall illustrate the different modes of plant isolations that may be required as per the Plant Safety Regulations and Operating Regulations for High Voltage Systems.
- Where required the Contractor shall provide formal classroom training of the operations and maintenance to ensure Employer's representatives have a sound understanding of the plant layout, characteristics, and functionality.
- Training material shall be provided where applicable.
- The Contractor shall ensure that all training is conducted by experienced personnel in a professional manner.

10. Documentation Requirements

The Contractor shall provide, but not limited to, documents as indicated in Table D2 before, during, and after the Operation and Maintenance period.

Table D 2: Documents related to Operation and Maintenance

No.	Document / Drawing	Review Type
Within 12 weeks prior to the issue of EPC Completion Certificate		
1	Preventative maintenance plan in compliance to specification	A
Within 8 weeks after the issue of EPC Completion Certificate		
1	Training Material for “Training of Operation and Maintenance of the Project” in compliance to specification	A
2	Training schedule for both classroom and on-site operation and maintenance training	A
3	Project Quality Plan during operation and maintenance	A
Within 12 Weeks after the issue of EPC Completion Certificate		
4	Final Training Material for “Training of Operation and Maintenance of the Project” in compliance to specification	A
5	Final Training schedule for both classroom and on-site operation and maintenance training	A
Operation and Maintenance Report		
6	O&M activities and O&M report according to Section 11.1of this Appendix.	A
7	Daily reporting shall be provided within immediate next calendar day	A
8	Monthly reporting shall be provided within 1 weeks after the reporting month period	A
9	Annual reporting shall be provided within 4 weeks after the reporting annual period	A
10	Maintenance Engineering Standard	A
11	Maintenance Implementation Standard	A
12	Task Manuals including inspection sheets	A
13	Job Plans	A
14	PMs in Maximo	A
15	Location of assets (Maximo / Small world)	A
16	Assets in Small World / CMMS	A
17	Maintenance assurance processes	A
Within 24 weeks (6 months) after the issue of Substantial Completion Certificate		
18	Proof of completion of “Training on Project Operation and Maintenance”, accepted by the Employer’s Project Manager	A

11. O&M Reporting

11.1. General

- The Contractor shall report on plant status and operation and maintenance activities to the Employer.
- The Contractor shall prepare following reports during the Operation and Maintenance period:
    a. Daily Report
    b. Monthly Report

c. Annual Report

11.2. Daily Reporting

- The web-based monitoring system shall have ad hoc reporting capabilities that allow the Employer at any time to produce reports for any period.
- The Contractor shall prepare the report of the preceding day and submit to the Employer with the following information, as a minimum:
    a. Plant Performance and meteorological records (according to Table D 3)
    b. Alarms, faults (if any) and cause
    c. Force Majeure event (if any)

Table D 3: Plant Performance and Meteorological Records – Daily Reporting Format

Parameter	Unit	Value	Comment
Date	dd:mm:yy		
Global Solar Irradiation on Horizontal plane	[kWh/m^2]		
Global Solar Irradiation on front side of module plane	[kWh/m^2]		
Global Solar Irradiation on rear side of module plane (in case of bifacial systems)	[kWh/m^2]		
Net energy production recorded in inverter level	[kWh]		
Net energy production recorded in meter at site	[kWh]		
Net energy production recorded in meter at POC	[kWh]		
Daily Average Performance Ratio	[%]		
Daily Average Plant Availability	[%]		
Avoided CO2 emission	[tons]		
Maximum Inverter Station/Cabin Temperature	[°C]		

- The Contractor shall check the completeness of the monitoring data daily and store them as raw data (on hourly basis, as minimum) for the evaluation of plant performance.
- Every recorded technical parameter (plant performance, meteorological, inverter parameters, grid measurement) shall be included in raw data.
- The Contractor shall provide such raw data upon the request from Employer at any time or provide them at the end of every month on an electronic storage device (CD, DVD, or an external storage unit).

11.3. Monthly Reporting

- Within the first week of every month, the Contractor shall prepare and provide the report on operation and maintenance activities performed during previous month.
- The report shall be reviewed and approved by the Employer.
- The monthly report shall include as minimum following information:
    a. List of preventive maintenance activities performed during the respective month and the Contractor's comments on findings, if any – as presented in Table D 4.

b. List of corrective maintenance performed if any, as presented in Table D5**.**

c. Update of spare parts in stock, changes, and re-order status.

d. Alarms, faults (if any) and cause, as presented in Table D 6**.**

e. Force Majeure event (if any).

f. Tabular presentation and comparison of daily average energy recorded in each inverter and energy fed into the grid – as presented in Table D 7.

g.Tabular representation of recorded average solar irradiation on front side of module plane – as presented in

h. Table D 8.

i. Tabular representation of recorded average solar irradiation on rear side of module plane (in case of bifacial systems) – as presented in Table D 9.

j. Tabular representation of recorded meteorological parameters (i.e., global solar irradiation on horizontal plane, ambient temperature, and wind speed) on daily basis – as presented in Table D 10

k. Tabular representation of recorded global solar irradiation on module plane by reference cells and recorded module temperature – as presented in Table D 11

l. Summary of monthly Plant Performance and meteorological records – as presented in Table D 12

m. Evaluation of daily average plant performance and plant availability – as presented in Table D 13 and Table D 14

n. Tabular representation of minimum and maximum operating temperature of each inverter installed in the plant and comparison with the corresponding manufacturer specification – as presented in Table D 15

o. Raw data (from monitoring system on 15 minutes basis), intermediate calculations in Excel or PDF format.

p. Preventive maintenance schedule for the following six months.

Table D 4: Preventive Maintenance – Monthly and Annual Reporting Format

No.	Items	Frequency	Date Performed	Findings, If any
1	PV Modules			
1.1	Cleaning of modules	Q (at least) or see below		
1.2	Visual Inspection - glass breakage, yellowing & browning, corrosion, delamination, cracks on cell, hot spot, deformed connection box, module mounting and module frame condition etc.	M		
1.3	Visual Inspection terminal connections and panel cabling - cable tightness, terminal box watertight, cleanliness, clamping etc.	M		
1.4	I-V Curve measurement of strings	Once in two years		
1.5	I-R Scanning of modules	A		

No.	Items	Frequency	Date Performed	Findings, If any
2	Mounting structure and Foundation			
2.1	Visual Inspection of mounting structure	M		
2.2	Check of integrity of mounting structures and clamping	M		
2.3	Inspection of corrosions in screws, structure and check adequacy of screw tightness	SA		
2.4	Check on grounding connection (if any)	M		
2.5	Visual inspection on foundation	A		
3	Single-axis tracking system			
3.1	Visual inspection for smooth operation of gear mechanism	D		
3.2	Visual inspection for smooth operation of motors	D		
3.3	Visual inspection for rust/loose of bolts and nuts	W		
3.4	Check integrity of wires/cables	W		
3.5	Check proper functioning of sensors	D		
4	String box/Junction Box/Combiner Box			
4.1	Visual Inspection - box screw tightness, incoming and outgoing cable tightness, cable labelling, water and dust tightness, etc.	M		
4.2	Check of proper functioning of string fuses, DC disconnect switch and earthing cable etc.	M		
4.3	Visual inspection of string monitoring equipment inside combiner box	M		
4.4	Verify preventive maintenance activities described from 3.1 to 3.3 for secondary combiner box and fuse box (if any included in plant)	M		
5	Inverter - General Preventive measures			
5.1	General visual inspection of the inverter and inverter enclosure	M		
5.2	Inspection on cables and connection of the components	M		
5.3	Check if inverter is running at adequate temperature range, as specified by the manufacturer	M		
5.4	Check of inverter runs smoothly without producing strange noise	M		
6	Inverter - Periodic and Specific measures			
6.1	Periodic efficiency measurement (DC/AC conversion from inverter meter)	M		
6.2	Cleaning of air filter - as per manufacturer's recommendation	MS		
6.3	Checking and replacement of ventilation system (if required) - as per manufacturer's recommendation	MS		

No.	Items	Frequency	Date Performed	Findings, If any
6.4	Visual inspection of earth connections	M		
6.5	Checking and verification of proper functioning of safety switches, fuses, cooling fan	M		
6.6	Control and LCD display operation	M		
6.7	Check of inverter according to manufacturer's operation and maintenance manual	MS		
7	Inverter Station/Cabin			
7.1	Visual inspection of inverter cabin	M		
7.3	Visual inspection of ventilation system, earthing and fire protection system	M		
7.4	Check inverter temperature while running during the day and verify that ventilation is working properly and inverter operating temperature is within manufacturer’s recommended range	M		
7.5	Visual inspection of transformer, switchgear board and protection device and verify that they all are running without any defects	M		
8	Electrical Wiring			
8.1	Check on integrity and completeness of all electrical cables from PV module to connection point	M		
8.2	Check for any damaged or discoloured cable	M		
8.3	Check on status of fuses, circuit breakers and safety switches	M		
8.4	verification of proper earthing connections of the plant components	M		
8.5	Verification of water tightening of electric cables and conduits	M		
8.6	Electrical Insulation and grounding measurement of DC and AC cables	once in two years		
8.7	Check and verify the labelling on electrical cables	M		
8.8	IR scanning of electrical cable connection and verify that all cable connections are made properly and no heat generation in the connection	A		
9	Security and Site Condition			
9.1	Check of integrity of security fences	SA		
9.2	Verify that all security cameras and gates are working properly	M		
9.3	Verify that communication of security systems with power station security system	M		
9.4	Verify that internal roads are in good conditions	M		
9.5	Keeping plant clean and free from waste and taking proper steps of the disposal of waste according to local regulation and procedures	SA		

No.	Items	Frequency	Date Performed	Findings, If any
9.6	On Site presence – immediate answering to all alarms by an emergency service assuring on-site presence			
9.7	Check the vegetation level and ensure that they are controlled	M		
9.8	Check the drainage channels and erosion control	M		
10	O&M Building (Server room, Stores Building, Security Building and all other Buildings on the PV Environmental Approved Area)			
10.1	Visual inspection of O&M building, walls, roofs, foundation and verify that there is no visual damage	M		
10.2	Verify that control system, server and its back up system are working properly	M		
10.3	Verify that the inventory of spare parts is maintained according to the contract requirement	M		
10.4	Verify that all security measures inside the O&M building is free of any defects and working properly	M		
11	Power Evacuation			
11.1	Visual inspection of power evacuation route and verify that all poles and lines are in good condition	M		
12	Meteorological Stations and Monitoring System			
12.1	Cleaning of meteorological stations (reference cell and pyranometer)	W		
12.2	Calibration of meteorological equipment, if required	MS		
12.3	Check of connection on meteorological components and communication with monitoring system	M		
12.4	Check the weather station mounting structure and general physical condition	M		
12.5	Check the slope and azimuth of reference cells. pyranometers	M		
12.6	Check on online record of energy output and irradiation through remote monitoring system	D		
12.7	Check on alarm, event and status database - through remote monitoring system	D		
12.8	Check on online record of availability of each inverter and availability of the plant - through remote monitoring system	D		
13	Reporting			
13.1	Report on plant performance ratio and plant availability	M		

No.	Items	Frequency	Date Performed	Findings, If any
13.2	Report on energy production recorded through inverters, meters at site and meters at the Eskom 33kV switching station.	M		
13.3	Report on meteorological measurement on site	M		
13.4	Submission of raw and processed data on meteorological measurements and performance measurements to the *Employer*	M		
13.5	Report on status of plant component and status of preventive maintenance	M		
13.6	Report on alarms, events and status recorded	M		
13.7	List of damage and faults verified	M		
13.8	List of corrective maintenance service performed	M		
13.9	List of spare parts available in inventory	M		

Frequency: D→ Daily, W → Weekly, M → Monthly, Q→ Quarterly, SA→ Semi-Annually, A→ Annually, MS → Manufacturer specification and operation manual

Table D 5: List of Corrective Maintenance – Monthly Reporting

Date	Corrective maintenance type		Reasons for replacement/Repair
	Repair	Replacement	
dd:mm:yy			

Table D 6: List of Alarms/Faults – Monthly Reporting

Date	Time on which alarm or faults are received	Cause	Date and time on response to alarm	Comments
dd:mm:yy				

Table D 7: Comparison of Daily Energy Production Recorded in Inverter and Meters – Monthly Reporting

Date	Energy Production [kWh] recorded in inverter					Energy Recorded at meters on site [kWh] (per PV Block)		Energy Recorded at 22kV Eskom Switching Station [kWh]	
	Inv 1	Inv 2	……	Inv (n-1)	Inv n	Meter 1	Meter n	Meter at 22kV Eskom Switching Station busbar 1a PV Feeder 1	Meter at 22kV Eskom Switching Station busbar 1a PV Feeder 2
dd:mm:yy									

Table D 8: Average Solar Irradiation on front side of Module Plane – Monthly Reporting

Date	Average Global Solar Irradiation [kWh/m^2] recorded on front side of				
	Module plane, 1	Module plane, 2	Module plane, 3	Module plane 4	Average on Module plane
dd:mm:yy					

Table D 9: Average Solar Irradiation on rear side of Module Plane – Monthly Reporting

Date	Average Global Solar Irradiation [kWh/m^2] recorded on rear side of				
	Module plane, 1	Module plane, 2	Module plane, 3	Module plane 4	Average on Module plane
dd:mm:yy					

Table D 10: Record of Meteorological Parameters – Monthly Reporting

Date	Average Global Solar Irradiation [kWh/m^2] recorded on				Temperature [°C]		Wind Speed [m/s]
	Horizontal plane	Reference Cell 1 – cleaned frequently	Reference Cell 2 – not cleaned	Difference between Reference cells	Ambient Temp.	Average Module Temp.	
dd:mm:yy							

Table D 11: Summary of Plant Performance and Meteorological Records – Monthly Reporting

Parameter	unit	Value	Comment
Month	-		
Average Global Solar Irradiation on Horizontal plane	[kWh/m^2]		
Average Global Solar Irradiation on front side of module plane	[kWh/m^2]		
Average Global Solar Irradiation on rear side of module plane (in case of bifacial systems)	[kWh/m^2]		
Net energy production recorded in inverter level	[kWh]		
Net energy production recorded in meters at Site	[kWh]		
Net energy production recorded in meters at PoC	[kWh]		
Monthly Average Performance Ratio	[%]		
Monthly Average Plant Availability	[%]		
Avoided CO2 emission	[tons]		

Table D 12: Summary of Plant Availability – Monthly Reporting

Parameter	unit	Value	Comment
Month	-		
Total hours during which the irradiation on module plane is higher than 50 W/m^2	[h]		
Total hours during which the inverters were producing energy and the irradiation on module plane were higher than 50 W/m^2	[kWh]		
Total time period during which the plant could not feed energy into the grid because of the fault from utility	[h]		
Total hours during which the plant could not feed energy into the grid due to force majeure events	[h]		
Monthly average plant availability	[%]		

Table D 13: Plant Performance Evaluation – Monthly Reporting

Date	Average Global Solar Irradiation on Module plane [kWh/m^2]	Energy supplied to Eskom 22 kV Switching Station [kWh]	Performance Ratio [%]	Plant availability [%]
dd:mm:yy				

Table D 14: Record of Inverter Operating Temperature – Monthly Reporting

Date	Minimum [°C]	Maximum [°C]	Manufacturer's recommended operating range [°C]	Comment
dd:mm:yy				

Date	Minimum [°C]	Maximum [°C]	Manufacturer's recommended operating range [°C]	Comment

11.4. Annual Reporting

- The Contractor shall provide the Employer with an annual report for each year by the end of the first month of the following year under review including but not limited to the followings: -
    a. All monthly reports during the reporting year.
    b. Summary on preventive maintenance activities performed during the year, comparison with planned frequency and Contractor's comments on findings, if any – as presented in **Table D 4.**
    c. Summary on general status of the plant, Contractor's recommendation or comments on requirement of improvement (if any).
    d. Update of spare parts in inventory, changes and re-order status.
    e. Annual Summary of Energy Production, Plant Performance Ratio and annual availability as presented in **Table D 15**.
    f. Monthly breakdown of plant performance ratio and plant availability a presented in Table D16
    g. Comparison of measured annual plant performance ratio and annual plant availability with guaranteed plant performance ratio and annual average plant availability as presented in **Table D 17**.
    h. Calculation of Performance Liquidated Damage, if any.
    i. Raw data (from monitoring system on 15 minutes basis), intermediate calculation in Excel or Pdf format.
    j. Preventive maintenance schedule for the following year.

Table D 15: Summary of Plant Performance and Meteorological Records – Annual Reporting

Parameter	unit	Value	Comment
Year	-		
Average Global Solar Irradiation on Horizontal plane	[kWh/m^2]		
Average Global Solar Irradiation on module plane	[kWh/m^2]		
Net energy production recorded in inverter level	[kWh]		
Net energy production recorded in meters at Site	[kWh]		
Net energy production recorded in meters at PoC	[kWh]		
Monthly Average Performance Ratio	[%]		
Monthly Average Plant Availability	[%]		
Avoided CO2 emission	[tons]		

Table D 16: Plant Performance Evaluation – Annual Reporting

Month	Average Global Solar Irradiation on Module plane [kWh/m^2]	Energy supplied to station boards [kWh]	Performance Ratio [%]	Plant availability [%]
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
Annual				

Table D 17: Measured and Guaranteed Performance Comparison

Parameter	Unit	Value	Comment
Year	-		
Annual average measured Performance Ratio	[%]		
Annual average guaranteed Performance Ratio	[%]		
If applicable, Performance Liquidated Damage	[Rand]		
Annual average measured plant availability	[%]		
Annual average guaranteed plant availability	[%]		
If applicable, Performance Liquidated Damage	[Rand]		

APPENDIX E: PV PLANT LIQUIDATED DAMAGES

Please refer to separate file attached to this document.

APPENDIX F: PV PLANT ELECTRICAL POINT OF CONNECTION REQUIREMENTS

1. Scope of Work

Refer to the Cost Estimate Letter Scope of Works as detailed in the attached document App-F - IPP907459217 SC0092 Dx IPP CEL both Dx SBA Tx SBA for Tutuka PS PV 36MW Facility- 17 June 2025 signed

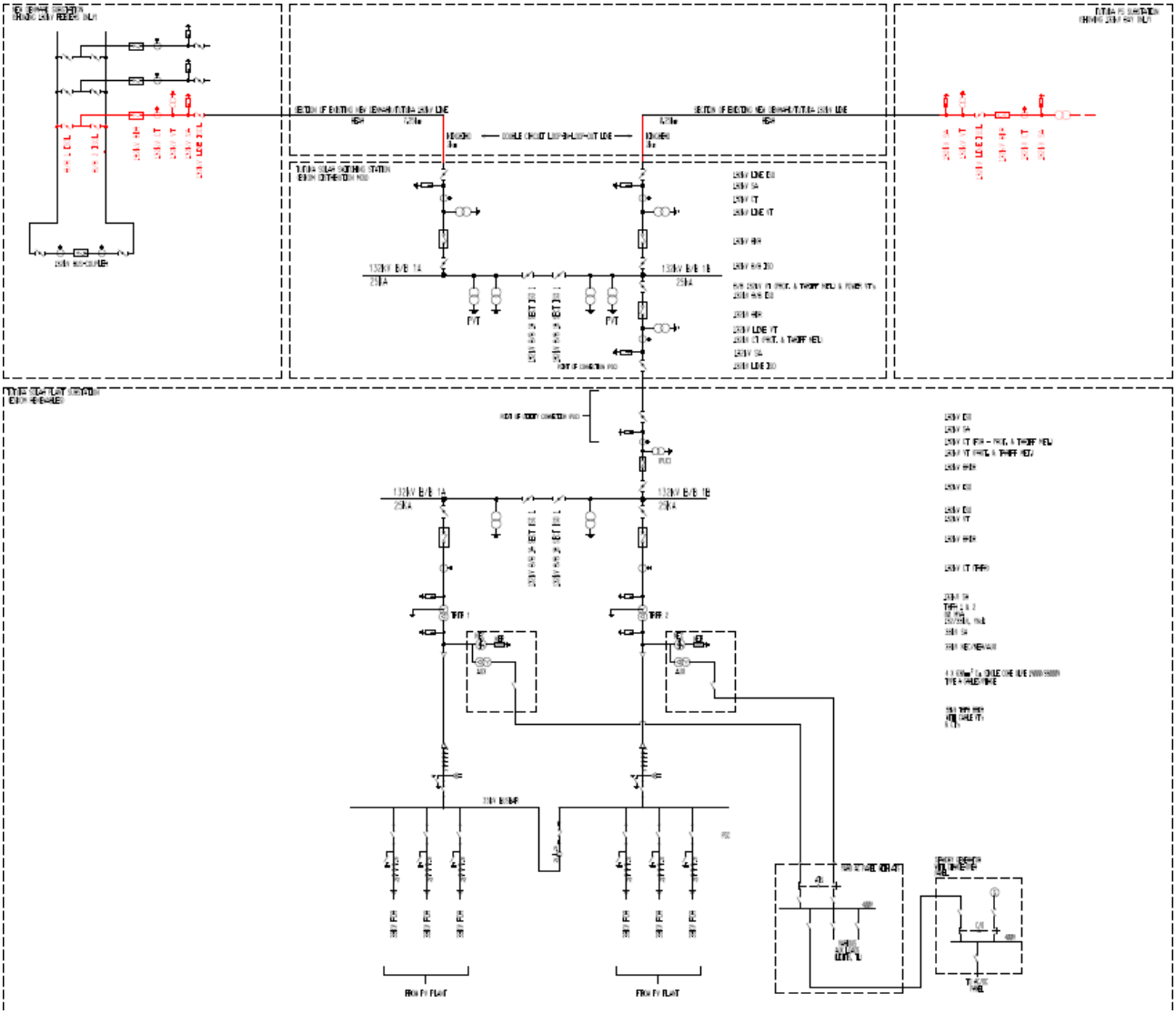

Figure 3: POC layout

Figure 4: HV Line layout

2. Reticulation Philosophy

Refer to the Cost Estimate Letter Scope of Works as detailed in the attached document App-F - IPP907459217 SC0092 Dx IPP CEL both Dx SBA Tx SBA for Tutuka PS PV 36MW Facility- 17 June 2025 signed

3. Engineering Design

3.1. It is a requirement by Eskom Distribution that the Engineering Design performed under the self-built agreement, be performed by the EPC or their Consultant Engineer accredited by Eskom Distribution for Substations, Control Plant, and HV lines. The same Consultant shall also design the 132 kV PV Collector substation where possible which will share a common platform and adjacent earth mats.

3.2. The EPC Contractor shall appoint such an Eskom accredited Consultant who shall be responsible for the design as well as the submission for approval to Eskom in terms of Eskom Distribution processes.

3.3. In terms of the self-built agreement requirements by Eskom Distribution, the Eskom accredited Engineering Consultant shall remain involved during the construction process to oversee that the design is implemented correctly.

3.4. The Engineering Consultant shall also provide an Eskom approved Clerk of Works (CoW) with suitable High Voltage Regulations (ORHVS) qualifications to act as Clerk of Works on behalf of the Developer, and shall carry out all inspections prior to, during and after all visits by Eskom Distribution Clerk of Works. The Clerk of Works shall maintain the hand-over file for handing over to Eskom at the end of the project. The Hand-over file shall as a minimum contain all test certificates, copies of inspections sheets, test reports and eventually, the as-built drawings. The Eskom accredited Engineering Consultant or his appointed Clerk of Works shall maintain a full-time presence during factory acceptance tests, site acceptance tests, and commissioning to witness the tests.

4. Grid Connection Works Sub-contractor

4.1. It is a requirement by Eskom Distribution that the construction works performed under the self-built agreement , be performed by a contractor accredited by Eskom Distribution for Substations, Control Plant and HV lines.

4.2. It is advisable that the EPC Contractor also appoints the same Sub-contractor to construct both the IPP as well as the Eskom parts of the Grid Connection Works.

5. Environmental Aggressiveness

5.1. The Contractor shall take into account the conditions found at the Site and in the subsurface layers in order to avoid any corrosion problems above and underground, especially with equipment installed outdoors. Additionally, respective environmental requirements shall be included and taken into consideration after the respective EIA submission. Given the location of the Site, the Contractor shall confirm the atmosphere and soil corrosivity category for further observation and proper design accordingly protection to SANS 12944 Part 1 to 8 for steel structures. Additionally, corrosion protection shall be designed, as a minimum, for design operational lifespan of 25 years and the specific location conditions, such as soil chemical testing results, humidity, wind loading, ambient temperature, proximity to ocean/sea for salt mist concentration and air corrosivity, etc.

5.2. The Contractor shall ensure that precautions are taken in packing and crating, to avoid damage to the protective treatment during transportation to the Site. Any damage to paintwork which occurs during transport shall be made good at Site. All surfaces shall be thoroughly cleaned prior to any painting, in accordance with the requirements of the specific paint used.

5.3. Paint shall be stored in dry covered conditions and shall not be used if it has been in storage for more than three (3) months or not used for more than six (6) months after the manufacture date.

5.4. Unless otherwise specified, galvanising shall be hot dip galvanising in accordance with SANS 121 and SANS 14713 Part 2. Bolts, nuts, and washers together with all other threaded components used as fasteners shall be finished with a centrifugal galvanised coating in accordance with this standard.

5.5. The thickness of zinc in every galvanized element shall be higher than the calculated minimum thickness required in all its sides and parts. Local mean thicknesses below the minimum calculated thickness shall be avoided.

5.6. All drilling, punching, stamping, cutting and welding of parts together and removal of burrs shall be completed before articles are galvanised in accordance with SANS 121 and SANS 14713 Part 2. Any Site modifications of galvanised steelwork shall be made good with an approved cold galvanising system as reviewed by the Employer.

5.7. Materials and coatings for all structures shall be based on the findings of the soil chemical testing and with a durability range of at least 25 years.

5.8. Details shall be provided of any special finishes including those on components manufactured from sheet aluminium or steel.

5.9. All ferrous metals shall be protected from corrosion in accordance with SANS 121, SANS 14713, SANS 12944 or equivalent local or internationally recognised standards. The exposure conditions to be used shall be entirely suitable for the type and intended purpose of each structure, taking full account of the components' and Plant's location.

5.10. Where the Contractor uses a paint system for corrosion protection, the Contractor shall ensure that the paint system is applied in full accordance with the manufacturers' recommendations and that each coat applied to any member shall be from the same manufacturer.

5.11. The Contractor shall submit full details of its proposals for corrosion protection for Employer's consideration. Proper analysis for avoidance of galvanic corrosion due to contact between different metals shall be done and justified if required.

5.12. All external coating systems shall be designed to be UV resistant from the UV radiation spectrum expected for the Site.

5.13. Considerations must be given to fauna protection of all equipment and materials which may come into contact with rodents or other vermin. This includes cable sheaths, outdoor switchboards transformers and switchgear buildings, etc. Means of protection shall be valid under planning approval conditions and environmental management plan.

5.14. The Works shall be adequately protected against any kind of frost damage if applicable to the location.

6. Grid Code Requirements

6.1. The Contractor shall ensure that his design complies with the requirements of the Grid Connection Code for Renewable Power Plants (RPPs) Connected to the Electricity Transmission System (TS) or the Distribution System (DS) in South Africa.

6.2. In addition, the protection and telecommunication system of the substations shall comply with Standard for The Interconnection of Embedded Generation (240-61268576).

6.3. Critical References

6.4. Normative references (Section 2.2.1) of 474-12955 viz, this Functional Specification

6.5. Appendix C: PV Plant Codes and Standards

APPENDIX G: SITE INFORMATION

APPENDIX H: TUTUKA SOLAR PV SECURITY FUNCTIONAL SPECIFICATION