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## 1. INTRODUCTION

### 1.1 Executive Summary

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 Sere Wind Farm site was identified as one of the projects that could achieve these objectives. Sere Wind Farm is a 105.8 MW wind facility located near Vredendal in the Western Cape and entered commercial operation on 31 March 2015. To address the urgent need for additional generating capacity, it has been proposed that solar PV technology be installed at the Sere Wind Farm site in phases. The following phased approach has been proposed:

Phase 1a - Photovoltaic plant less than 20 MW nominal capacity, occupying less than 20 ha land area:

Phase 1b – 50 MW Photovoltaic

Phase 2 – 530 MW Photovoltaic

The execution of the proposed phases will result in the Sere PV Plant reaching total capacity of 600 MW. This document is applicable for Phase 1a of the programme. Due to the urgent need for additional generation capacity and the tight time constraints for the project, Phase 1a is required to not trigger a full scoping and detailed Environmental Impact Assessment (EIA) and requires that Phase 1a adhere to environmental basic assessment technical requirements of a plant capacity that is less than 20 MW and occupies land that is less than 20 ha.

### 1.2 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.
- PV technology to be installed at the Sere Wind Farm site consisting of a photovoltaic plant less than 20 MWac capacity and occupying less than 20 ha land area.

## 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

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### **2.1.1 Purpose**

The purpose of the Functional Specification is to document the scope of work for the Engineering, Procurement, Construction and Commissioning of the Solar PV Plant (PV Plant) located at the Sere Wind Farm in the Western Cape.

### **2.1.2 Applicability**

This document shall apply to the Sere 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] 474-12571 Concept Design for Sere Solar PV Plant phase 1a Rev 3
- [2] 474-12534 Stakeholder Requirements Definition for Sere Solar PV Plant Rev 3
- [3] 480/2 – Required Operational Capability Report: Sere PV Plant – Phase 1a
- [4] 240-147711627 – Operational Plan for Small Scale and Utility Scale Solar PV Plants in Northern Cape
- [5] Engineering Work Request (EWR) – Sere Solar PV Plant
- [6] ISO 9001 Quality Management Systems
- [7] 240-53113953 Manage Engineering Accountability Procedure
- [8] 240-53114026 Project Engineering Change Management Procedure
- [9] 240-53114002 Engineering Change Management Procedure
- [10] 240-50317699 Manage Technical Queries Procedure
- [11] 24240-53114194 Control of Non-conforming Product
- [12] 240-53113685 Design Review Procedure
- [13] 240-48929482 Tender Technical Evaluation Procedure
- [14] 240-49910527 Procedure for Plan and Select Technologies
- [15] 240-76992014 Project/Plant Specific Technical Documents and Records Management Work Instruction.
- [16] 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
- [17] 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**

Not applicable.

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## 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 <sup>2</sup> )
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 <sub>dc</sub> ) = Module Rated Power (W <sub>dc</sub> ) × 0.001 (kW/W) × Total Modules
Net Annual Energy	The total annual electric generation in the first year of operation.

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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).

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## 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

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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

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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.

## 2.6 Process for monitoring

The primary process for monitoring will be governed by [12] 240-53113685 Design Review Procedure, which entails assuring that the design achieves the requirements set out in this document. Any changes to this document will be performed as per [8] 240-53114026 Project Engineering Change Management Procedure.

## 2.7 Related/Supporting Documents

None

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### 3. GENERAL REQUIREMENTS

#### 3.1 Contractor's Scope of Work

1. The Contractor 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 two (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  $\geq 50$  MWac (cumulative capacity) completed commercial (not pilot or demonstration) ground mounted, grid connected, front-of-meter Solar PV project within the last seven (7) years, as the principle EPC Contractor, and where at least one (1) these successfully executed projects was  $\geq 20$  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 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

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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 six (6) months before the start of commissioning.

3. On specific systems training to be provided:
  - a. 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.
  - b. 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 22 staff members to be trained on engineering, operations, and maintenance of the PV Plant. These staff members consist of five (5) engineers, three (3) managers/supervisors, eleven (11) technicians/operators as well as two (2) training officers.
7. The Contractor shall identify the required training to operate and maintain the plant. The training includes but is not limited to:
  - a. Plant description and design including single line diagram
  - b. Construction and installation method
  - c. Safety during construction and commissioning
  - d. Introduction to each test type and measurement methods
  - e. Test evaluation procedures and test result interpretation
  - f. Trouble shooting procedures
  - g. A checklist of what to do in case of system failure
  - h. 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.
  - a. All Control & Instrumentation systems in the PV Plant, including monitoring and data capturing system.
  - b. All SCADA hardware and software systems on the plant. Training must include software/network/diagnostic tools where applicable, to enable troubleshooting and configuration.
  - c. Training must include operation and adjustment of grid parameters of the PV Facility via SCADA.
  - d. Remote monitoring and resetting.
  - e. Local monitoring, troubleshooting, and resetting.
  - f. Electrical protection systems within the PV Facility.
  - g. 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.
  - h. Operation and maintenance on MV switchgear and transformers. This includes the relevant support equipment such as protection, interlocking, and communication equipment.

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- i. 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).
  - j. 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.
  - a. 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:
  - a. minimum three (3) years' experience in MW scale solar PV construction and commissioning for training on design, construction, and commissioning.
  - b. 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 or at the Sere Wind Farm offices, the Sere Solar PV Plant or as agreed with the Project Manager.

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## 4. TECHNICAL REQUIREMENTS

### 4.1 Project Definition

#### 4.1.1 PV Plant Description

1. The works comprise of the design for a PV plant that is less than 20 MWac Capacity and occupies less than 20 ha of land at the Sere Wind Farm close to Vredendal in the Western Cape.
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 [16].
3. The PV Plant will be connected to the Skaapvlei substation 132kV busbar, through a dedicated 132/22kV transformer. The PV plant will comprise of ground mounted solar photovoltaic (PV) modules and associated infrastructure.
4. The PV plant shall be designed to C5M (marine) according to ISO 9223.
5. The Civil works shall be designed for a fully functional PV plant and to withstand the site conditions.
6. The site Geotechnical data and conditions are described within an existing geotechnical assessment report that was previously conducted for the Sere Wind Energy Project (Sere Wind Farm) attached in Appendix G (for information only).
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 operates 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. Whenever the combined generation output of the Sere Wind Farm facility and the PV facility exceeds the imposed limitation (105.8 MW), the PV plant is required to curtail automatically in accordance with the conditions set out in this document, ensuring that the combined generation output does not exceed the imposed limitation.
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.
10. The main PV Plant breakdown structure is summarised in Table 1.

**Table 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 (fixed-tilt or tracking) 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.

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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. Existing Sere Wind Farm O&M Buildings will be utilized/repurposed to host offices and control room for Sere PV staff utilising existing kitchen and ablution facilities, 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.)

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11. The exiting Sere Wind Energy facility (Sere Wind Farm) O&M Offices building and Workshop and Stores building shall be re-purposed in certain areas to accommodate the PV facility requirements:
  - a. The existing Sere Wind Farm Control room shall accommodate the PV plant Control Desk.
  - b. The existing Sere Wind Farm Exhibition area shall be re-purposed to accommodate one (1) closed office and ten (10) open plan work stations.
  - c. The existing Sere Wind Farm facility O&M Offices General office shall be closed to create one (1) closed office.
  - d. The existing Sere Wind Farm Dry Battery and Inverter room shall be re-purposed to accommodate the auxiliary backup supply system, including batteries and inverters where applicable.
12. The existing Sere Wind Farm facility Workshop and Stores slab above Office 1 and Office 2 shall be re-purposed to accommodate six (6) open plan work stations, including an access staircase. The PV facility shall have dedicated buildings and facilities, comprising:
  - a. Server and Equipment room
  - b. Spares Stores building
  - c. Process water storage and reticulation system for PV module cleaning
  - d. PV module cleaning equipment storage or undercover parking area
  - e. Access roads and parking areas (if required)
13. Solar PV Plant auxiliary supply equipment
  - a. 22kV Solar PV Collector Substation (if required)
  - b. Sere Wind Farm and PV facility essential back-up supplies
14. A Security Access Building shall be located at the entrance of the Sere Wind Farm (at DR2225)
15. The main access road from the Sere Wind Farm entrance (at DR2225) to the Skaapvlei substation and Sere Wind Farm O&M buildings to be surfaced with either asphalt or block paving.

#### **4.1.2 PV Plant Operational Requirements**

1. The Contractor shall consider the following boundary conditions for determining the optimum PV plant design solution:
  - a. Comply with the requirements indicated in the Environmental Authorisation.
  - b. Maximise the installed plant capacity on the available land, as defined in the Environmental Authorisation. The PV plant AC capacity shall be less than 20 MWac and shall occupy a footprint less than 20 hectares.
  - c. Maximise the plant's energy yield while minimising on design losses (shadowing and curtailment).
  - d. Optimise the design to provide lowest LCOE.
2. The Contractor shall provide a PV plant that is greater than or equal to the following minimum PV plant capacity requirements:
  - a. The PV plant nominal AC capacity shall be greater than or equal to 14 MWac.
  - b. The PV plant DC capacity shall be greater than or equal to 16.8 MWp.
  - c. The DC to AC ratio shall be greater than or equal to 1.10.

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3. The maximum combined generation output of the Sere Wind Farm facility and the PV facility shall not exceed the Maximum Export Capacity (MEC) of 105.8 MWac. This limitation will impact the PV plant operating philosophy:
  - a. No curtailment will be imposed on the PV plant if the combined generating output of the Sere Wind Farm facility and the PV facility is less than or equal to 105.8 MWac.
  - b. Curtailment will be imposed on the Solar PV plant if the combined generating output of the Sere Wind Farm facility and the PV facility would exceed the limitation of 105.8 MWac.
  - c. The annual wind generation profile for the Sere Wind Farm facility for the financial year 2017 is provided in Appendix H (hourly intervals) by the Employer, enabling the Contractor to approximate the expected curtailment of the Solar PV plant and optimise the design. Take note that the annual wind profile varies and the data provides an indication of MW sent out.
4. The PV plant shall comply with the Renewables Grid Code. A PV plant of maximum 20 MVA falls under Category B of the Renewable Grid Code, therefore, the plant shall comply with all the requirements of a solar PV plant under category B.

#### 4.1.3 PV Plant Location

1. The PV plant is located within the Sere Wind Farm. The site is located on portions of the farms Olifants River Settlement 617 and 620, and Gravewaterkop 158 portion 5 situated on the Namaqualand Coast in the Vredendal District, approximately 20km west of Koekenaap in the north of the Western Cape Province. The different farms on the Sere Wind Farm property consolidated to Lot 1862. Address: Lot 1862 Olifants River Settlement, Lutzville, 8165.
2. The Employer is currently in the process of performing the necessary basic environmental impact studies and other environmental license applications.
3. As per the limitations of the environmental basic assessment, the development of the PV plant shall be on a footprint that is less than 20 ha.
4. The PV plant is located travelling from the R363 road and in turn the DR2225. The PV plant is accessed from the Sere Wind Farm main access road which branches off the DR2225. The R363 is an asphalt surface road, the Sere Wind Farm main access road and the DR2225 road are gravel roads.
5. The proposed site boundary co-ordinates are summarised as follows (co-ordinates may change after the basic assessment is completed):

**Table 2: Site co-ordinates – UTM WG S84 SOUTH ZONE 34S**

Site Boundary	Alternative A – Fixed	
	Latitude	Longitude
NW corner	31°30'59.73"S	18°6'21.70"E
NE corner	31°30'60.00"S	18°6'33.60"E
NE Bend	31°31'18.68"S	18°6'24.97"E
SE corner	31°31'18.61"S	18°6'21.33"E
S corner	31°31'22.04"S	18°6'17.49"E
SW corner	31°31'18.41"S	18°6'13.07"E
Site Boundary	Alternative B – Tracking	
	Latitude	Longitude
NW corner	31°31'0.23"S	18°6'20.77"E

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NE corner	31°31'0.50"S	18°6'32.62"E
NE Bend	31°31'2.34"S	18°6'32.57"E
SE corner	31°31'18.77"S	18°6'24.98"E
SE bend	31°31'18.69"S	18°6'21.25"E
S corner	31°31'22.03"S	18°6'17.49"E
SW corner	31°31'18.51"S	18°6'13.17"E
SW bend	31°31'16.55"S	18°6'13.23"E
<b>Site Centre Point</b>		
Centre Coordinates	31°31'9.5918"S	18°6'22.1182"E
<b>Coordinates of the Project's Power Line/Cable</b>		
<b>Cable Route Alternative 2</b>		
Start point (PV Site)	31°31'20.57"S	18°6'18.74"E
Blend point	31°31'21.65"S	18°6'18.64"E
Blend point	31°31'22.15"S	18°6'18.73"E
Blend point	31°31'23.59"S	18°6'20.50"E
Blend point	31°31'25.33"S	18°6'18.97"E
End point (Substation)	31°31'26.89"S	18°6'20.56"E
<b>Coordinates of the Project's Access Roads</b>		
<b>Fixed Technology</b>		
<b>Access Road Route (Temp) Alternative 2</b>		
Start Point (PV Site)	31°31'21.20"S	18°6'18.42"E
End Point (Existing Road)	31°31'21.88"S	18°6'19.18"E
<b>Construction Road (Temp) Alternative 2</b>		
Start Point (PV Site)	31°31'19.92"S	18°6'19.87"E
End Point (Existing Road)	31°31'21.88"S	18°6'19.18"E
<b>Tracking Technology</b>		
<b>Access Road (Permanent) Alternative 2</b>		
Start Point (PV Site)	31°31'21.20"S	18°6'18.42"E
End Point (Existing Road)	31°31'21.88"S	18°6'19.18"E
<b>Construction Road (Temp) Alternative 2</b>		
Start Point (PV Site)	31°31'19.92"S	18°6'19.87"E
End Point (Existing Road)	31°31'22.47"S	18°6'22.75"E

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#### 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 22 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 long term annual average solar irradiation on horizontal plane (GHI) is expected to be approximately 2161 kWh/m<sup>2</sup>.
2. The annual average temperature at the site is estimated to be approximately 15.5°C.
3. The Contractor designs the plant operation for minimum and maximum ambient temperature of 0.4°C and 43.2°C respectively, unless specified otherwise.
4. The long-term average values in Table 3 are provided for information only. The Contractor shall select and utilise their own TMY dataset (P50 and P90) to design the PV plant, estimate the energy yield, and guarantee the performance accordingly.

**Table 3: Monthly Average Solar Resource, Ambient Temperature, and Wind Speed**

Month	GHI [kWh/m <sup>2</sup> ]	Average Ambient Temperature [°C]	Wind Speed [m/s]
January	268	18.19	6.0
February	230	18.51	5.1
March	200	17.81	5.5
April	142	17.12	5.9
May	104	15.33	4.8
June	86	13.53	6.1
July	105	13.84	6.8
August	129	12.03	6.2
September	164	13.69	6.4
October	230	14.75	6.1
November	241	16.71	7.1
December	251	17.31	6.3
<b>Annual</b>	<b>2161</b>	<b>15.54</b>	<b>6.1</b>

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5. As part of the bid submission, the Contractor shall provide the P50 and P90 TMY datasets used as input in their simulation model, and the energy yield estimation report describing the methodology and TMY dataset used to estimate the PV facility energy yield over the design life, forming the basis of the guaranteed performance.

#### 4.1.6 PV Plant Design Definition

1. The Contractor develops 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 complies 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 ensures that all designs are signed off by a respective Engineering Council of South Africa (ECSA) registered Professional Engineer.
4. The Contractor submits 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.

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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.

#### **4.1.7 Material Quality Specification**

The Contractor:

1. Ensures that all components and materials supplied are designed, manufactured and tested in accordance with the latest applicable South African and international standards.
2. Ensures 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. Ensures appropriate certification and independent testing has been carried out on any materials and products proposed.
5. Ensures materials and products used are suitable for the service conditions.
6. Ensures 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. Does 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. Ensures that, where possible, all materials used are recyclable.
9. Does 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. Does not use any materials or substances that support mould, bacterial growth or vermin or cause objectionable odours under service conditions.
11. Ensures 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. Ensures materials and products are appropriately CE/UL marked or SABS approved.
13. Follows manufacturers' instructions on the use of materials and products.
14. Selects materials & products with regard to standardisation and availability of spare parts and for ease of maintenance.
15. Ensures the same manufacturer is used for materials or products of a similar type and that identical parts of similar products are interchangeable.
16. Ensures that materials and components are transported and stored in accordance with manufacturer's guidelines.
17. Does not use plant and equipment prior to Handover other than for testing, commissioning, and demonstration.

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18. Provides 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. Examines materials and products supplied when delivered to site and immediately prior to installation. The Contractor replaces any damaged or faulty materials or products.
20. Stores all materials on raised boarded platforms under weatherproof covers and/or according to manufacturers' specifications.
21. Ensures 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 in total 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. Protects all materials and equipment which may be exposed to damage, inclement weather, or ultraviolet light.
23. Ensures 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. Repairs any damage to finished materials and equipment prior to handover of the PV Plant.
25. Maintains the minimum level of spare parts throughout the maintenance period and provides to the Project Manager prior to the handover of the PV Plant.

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## 4.2 Civil

### 4.2.1 Overview

1. The civil, structural and architectural works shall include all investigations, assessments, permitting, design, construction, testing, inspection, and other activities as required to complete a fully functional PV Plant in accordance with the minimum requirements of this specification and the requirements of all local and national codes and regulations.
2. The civil work as a minimum will entail:
  - a. Infrastructure works. Rerouting/relocation and dismantling of existing facilities such as foundations, piping, cabling and ducts, where necessary.
  - b. Site preparation, including clearing and grubbing of land, excavation, backfilling, compaction, grading, levelling, earthworks, soil improvement, and rehabilitation of parts of the Site as affected by the Contractors activities.
  - c. Buildings and structures (O&M, stores & workshop, and security access control building) – New and repurposed buildings
  - d. Mounting Structures
  - e. Foundations. Foundation works for mounting structures, trackers, combiner boxes, inverters, power transformers, buildings, weather stations, security system, fence and any other structures or equipment requiring foundations.
  - f. Roads
    - i. Internal PV Plant: All necessary access roads (internal and external) to construct, operate and maintain the Plant, including hard standings areas, permanent access to all power stations/inverters and PV modules.
    - ii. Main access road: The main access road from the Sere Wind Farm entrance (at DR2225) to the Skaapvlei substation and Sere Wind Farm O&M buildings to be surfaced with either asphalt or block paving.)
    - iii. Internal and main access roads to have the required road signage and road markings.
  - g. Parking Areas
  - h. Storm water drainage
  - i. Sewage and waste disposal
  - j. Cable/ Pipe trenches for power evacuation and services, electrical works, earthing and telecommunication systems.
  - k. Site Earthworks. Cut and fill, ground levelling, removal of roots, rocks and other material and vegetation clearing as per Project requirements, environmental authorisations and Applicable Laws and regulations, Permits and Codes.
  - l. Fencing and Gates. Site fencing and gates for construction and operation.
  - m. Site Layout
  - n. Water supply, reticulation, and storage tanks
  - o. Testing and commissioning of the Civil, Structural and Architectural Works
  - p. Brick up / enclose existing Sere Wind Farm fire pumphouse to mitigate exposure to the elements.
3. Integrating and interfacing on all existing civil engineering works within the site boundaries, including the existing Wind Farm infrastructure, where required. The civil works is to have a minimum design

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life of 25 years. A maintenance schedule is to be drawn up to also ensure expected life of the Civil, Structural and Architectural Works.

4. The Contractor ensures that all buildings, structures, cable trenches/routings, internal roads, fencing and service routes are functionally and efficiently located and that each building/component is sized for optimum space usage.

#### **4.2.2 Surveys, studies and reports**

The civil engineering scope will include, but not limited to;

- Topographical Study,
  - Geotechnical Study,
  - Hydrological Study,
  - Design (Design document, full set of drawing, scope of work and specifications),
  - Construction and Deliverables.
- a. 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.
  - b. The Contractor shall, as a minimum, prepare and complete the following surveys, studies and reports:
    - i. 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.
    - ii. Pull-Out tests.
    - iii. Flooding and drainage studies to complete the flood risk assessment of the Site.
    - iv. Seismic study. The Contractor shall make its own investigation of the seismic activity in the area of the Site and shall design the Plant accordingly
    - v. Ecological regeneration plan for the re-vegetation, regeneration and restoration plan of the Site's ecosystem.
    - vi. Ground resistivity test.
    - vii. Access route assessment, access management plan and Traffic Management Plan.
    - viii. Environmental and Storm water management plan
    - ix. Waste management plan.

##### **4.2.2.2 Topographical Survey**

1. The Contractor to do a topographical survey of the proposed PV site.
2. 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).
3. The Surveyor to perform a topographical survey in accordance with the Land Survey Act, Act No 8 of 1997, and the Survey Regulations, as amended.
4. The Surveyor is required to provide the minimum services as listed below:

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5. Collection and collation of topographical information for the area.
6. The Surveyor is required to collect all data describing the site boundaries and servitudes registered over all properties covering the site.
7. Methods and work procedures to be submitted to Eskom prior to commencement of works.
8. Identification or establishment of survey beacons.
9. Identification and protection of existing beacons for use in survey reference.
10. Establishment of new beacons within survey area for survey purposes where existing beacons are insufficient or do not exist.
11. Field work – Surveying
  - a. 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.
  - b. A survey of the area for the proposed site 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.
  - c. The Surveyor ensures that there are a sufficient number of benchmarks as well as surveyed points to establish a detailed contoured surface in order to complete design.
  - d. 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.
  - e. The survey is provided as a set of labelled co-ordinated points (label y, x, z).
  - f. The Surveyor provides a full list of actual descriptions used.
12. Mapping and production of detailed survey drawings.
  - a. The digital terrain model consists of ASCII files stored on disc/hard drive and supplied to Eskom.
  - b. The design files of the package used when the DTM was generated is provided.
  - c. Separate files are provided for spot heights and for detail points or it must be clearly separated when contained in one file.
  - d. The Surveyor shall supply a list explaining the point description codes together with the DTM.
  - e. One master drawing (incorporating all survey layout plans) is supplied to Eskom on CD/hard drive in DWG and DXF formats.
  - f. The contour interval shall be 0.5m for ground slopes less than 10% and 1.0m for ground slopes in excess of 10%.
  - g. The grid spacing is 100m.
  - h. 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.
  - i. 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.
  - j. The digital information must be provided on a CD/hard drive.

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#### **4.2.2.3 Geotechnical Study**

1. The existing Geotechnical Investigation report for Sere Wind Farm will be made available (refer to Appendix G).
2. The Contractor is to 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.
3. 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.

#### **4.2.2.4 Hydrological Study**

1. 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.
2. The Plant will be designed for minimum water consumption.
3. Contractor shall ensure a minimum clearance distance between the perimetral fence and the respective streams margins of 5.0m.
4. The Contractor shall undertake a hydrological and geohydrological survey and submit the associated report and result to the Employer.
5. Hydraulic study shall be developed considering two different scenarios (previously to PV plant construction and after PV plant execution including the proposed drainage system).

#### **4.2.3 Design**

1. Design of all civil, structural, and architectural works for a fully functional PV Plant.
2. The EPC Contractor is responsible for the design of the works. He assesses the existing site and plant and performs all required design and design changes.
3. The high wind speeds at the Sere site could impact on the PV mounting structure and foundation design. This must be factored and considered in the structural design.
4. The coastal location and corrosive atmosphere could impact the design and corrosion protection requirements for PV modules, equipment, and structures, as well as the required module cleaning frequency due to soiling from salt deposits. This is to be considered in the design.
5. The design must interface with the current civil infrastructure and various items of mechanical and electrical plant.
6. The Contractor designs for the applicable design loads, wind load conditions and seismic design.
7. The design is carried out by the Contractor's professional structural and civil engineers who are registered with the Engineering Council of South Africa. The Contractor's structural engineer provides design certification in accordance with SANS 10400-A, declaring the design "fit for purpose" in terms of the relevant design codes and the OHS Act. The designs are in accordance with the latest relevant SANS codes, standards, and specifications.
8. Structural Design Principles

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- a. All structural calculations shall be in accordance with SANS 10160 and further codes shall be followed where the structural code needs to be complemented. The Contractor will take full responsibility for these structures.
- b. All design reports, calculations and drawings prepared by the Contractor shall be signed by an ECSA professionally registered structural engineer.
- c. The tracker structural calculation performed by the tracker manufacturer will be validated and approved by an ECSA professionally registered engineer to validate the necessary local regulations. The Contractor shall carry out a third party independent structural verification design considering the Project Site location. Calculation shall be signed by an ECSA professionally registered structural engineer.
- d. The Contractor shall make use of finite element (FEM) analysis to calculate the loading conditions at any critical component, including bolts, joints and welding, also including the fixation system of modules to trackers.
- e. The Contractor shall determine, in detail, the mean net pressure coefficients and the peak negative and peak positive net pressure coefficients for the PV Tracker row at each stow/operational location and for all wind directions and taking into consideration the reduction in sheltering effect of the interior trackers due to differences in the relative elevation of each row. Proper justification of this analysis will be required.
- f. Main mounting structure tracker elements shall verify in the calculation included panel rails and joint elements.
- g. Consideration of wind accelerations caused by near obstacles, hills or escarpments shall be considered and properly justified.
- h. Dynamic loads (including possible instability that might occur due to vortex shedding, wake buffeting etc.) shall be considered when these might lead to higher stresses, and they shall be estimated using state-of-art tools and methodologies. A modal analysis shall be performed when necessary.
- i. Fatigue verification shall be performed should fatigue be considered as critical for the component under evaluation. Estimations shall be performed using state-of-art tools and methodologies.
- j. In the calculation reports and drawings notes to be provided to the Employer, the following information shall figure:
  - i. Detailed Supporting Structure characteristics (type, dimensions, etc.).
  - ii. Detailed materials characteristics (concrete technical specifications, steel grade, protection against corrosion, etc.).
  - iii. Detailed design assumptions (environmental conditions, load combinations, modelling software, etc.).
  - iv. Detailed calculation results for all load combinations

## 9. Load Assumptions

- a. In designing the Project, the Contractor shall take into account all the reasonably expectable loads that the Project might be subject to, including, but not limited to:
  - i. Self-weight loads
  - ii. Wind loads.
  - iii. Thermal loads.
  - iv. Seismic loads.

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- v. Snow loads.
  - vi. Water (flooding) loads.
  - vii. Actions induced by cranes and machinery.
  - viii. Actions during execution
  - ix. Basis for geotechnical design and actions
- b. The Contractor shall consider the loads and load combinations in accordance with SANS 10160. Uplift and downforce load at each tilt angle must be provided and must be under PV module manufacturer approved loads.
- i. Dead Loads
    - PV Structure and PV module loads must be considered in the design. Values must be provided on kN. and shall be justified by the Contractor during the detailed design phase.
  - ii. Wind Loads
    - Wind loads shall be defined according to SANS 10160-3.
    - The Contractor shall document the assumptions made using available wind data and any supporting material verifying the suitability of the structures and components for the Site Conditions.
    - Each component forming part of the Project shall be designed or verified against the expected wind loads. This includes, but is not limited to, foundations, buildings, PV module support and mounting systems, tracking systems, towers, weather stations, fences etc.
    - Wind loads shall be duly combined with other loads as prescribed in the Laws, Consents and Standards by implementing adequate safety factors. Consideration of wind accelerations caused by near obstacles, hills or escarpments shall be considered and properly justified.
    - The Contractor shall perform its own investigation as to the maximum expected wind conditions over a return period compatible with the Project design lifetime, in any case not less than 50 years.
    - In case of trackers, deformation and twisting of the structures shall be considered whenever it leads to higher loads at the structure.
    - The Contractor shall seek to support his assumptions and calculations using wind load tests, such as wind tunnel tests or computational fluid dynamics (CFD) tests whenever necessary to demonstrate compliance with the aforementioned conditions and the Laws, Consents and Standards. The wind loads shall be obtained from a dedicated wind tunnel test for the proposed tracker. The wind tunnel test shall include several tracker rows to capture the influence of the trackers upstream in the wind pressure of the trackers downstream.
    - The aerodynamic coefficients and wind loads shall be obtained for several angles of attack including all the tracker movement and several wind directions to cover all the load scenarios.
    - The wind loads shall include the required Dynamic Amplification Factors (DAF) depending on the tracker natural frequency and damping factor.
    - A graph showing the limit between stability and instability at certain frequencies and wind speeds for different tracking angles shall be included, as well as Cp coefficients at different tracking angles.

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## iii. Seismic Load

- The Contractor shall perform its own investigation as to the maximum expected seismic accelerations over a return period compatible with the Design Lifetime and use of the Project according to SANS 10160-4.
- Each component forming part of the Project shall be designed or verified against the expected seismic loads. This includes, but is not limited to, foundations, buildings, PV module support and mounting systems, tracking systems, towers, weather stations, fences etc.

## iv. Snow Load

- Specific snow load (kN/m<sup>2</sup>) for the Project location must be considered in the tracker design and justified by the Contractor during the detailed design phase.

## v. Combined Loads Results and Considerations

- The Contractor must provide a table showing Static moment and Static + Dynamic moment, in Nm, for each tilt and each part of the different trackers, if any, such as exterior, edge, interior, etc.
- The wind loads combinations shall cover all possible load scenarios (wind direction and angles of attack).

## 10. Aeroelastic Stability

- a. The Contractor shall demonstrate the stability of the trackers, showing that the critical wind speed is well above the design wind speed, including aeroelastic wind tunnel if necessary, for instability mechanism such as torsional divergence, flutter instability.
- b. Contractor must provide a graph showing the critical wind speed before instability occurs for each type of tracker and tilt. There must be a 2 degrees tolerance to cover inaccurate installation or tracking. If this information is not available, a 10% safety factor needs to be applied for this expected deviation on stow position angle.
- c. The structural design of the tracker shall ensure that aerodynamic instabilities do not occur for the entire range of design wind velocities. It is furthermore recommended to assume an additional safety margin of 25%, i.e., the onset velocity of aerodynamic instabilities should be at least 25% above the design wind speed.
- d. Wind induced vortex shedding shall be considered and checked against the frequencies of the structure. Wind-induced dynamic instability must be avoided.

## 11. Wind Tunnel Test

- a. The Wind tunnel report (as conducted by third party) shall cover, at least, the following:
  - i. Static and dynamic coefficients based on wind load testing using a rigid model or similar.
  - ii. Aerodynamic stability of the tracker to assess the sensitivity to wind dynamic actions caused by aerodynamic instability such as flutter.
  - iii. Wind-induced buffeting check to assess all combined effect of inertial wind load, mean wind loads, gust wind loads, self-excited forces from own tracker.
- b. Additional requirements for the model-specific wind tunnel test conducted:
  - i. A wind load coefficient consistent with applicable standards (SANS 10160-3) must be recommended.
  - ii. The wind impact on the module (front or back) at each wind direction and tilts shall be modelled.

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- iii. Twist of the tube torque must be not restricted by any obstacles or equipment along the tracker axis, only limited by the torsional stiffness of its closest tube torque.
- iv. Time series of the wind load and the instability condition must be applied on each node according to the actual twist in the previous time step.
- v. The first torsional eigenfrequency used for the analysis and maximum damping ratio must be defined. It must include the mass moment of inertia used for the analysis.
- vi. Terrain roughness used on the test must be in accordance with Project roughness.
- vii. Slopes resulting in different elevation of trackers shall be assessed in order to quantify sheltering reduction of the interior rows.
- viii. The results of the critical wind speed obtained in the sectional wind tunnel test depending on the tilt angle and other system properties must be provided.
- ix. The static pressure coefficients  $C_{drag}$ ,  $C_{lift}$  and  $C_{moment}$  for the different tracker locations in the Site and different tilt angles must be provided.

## 12. Corrosion Protection

- a. The works shall be in accordance with 240-100945498 – Standard for Corrosion Protection of Coastal Gas Generation Plant and Equipment with Coatings, also taking note of considerations and application requirements as detailed in 240-106365693 - Standard for the External Corrosion Protection of Plant, Equipment and Associated Piping with Coatings.
- b. The Contractor to prepare and submit a corrosion protection scheme and coating application schedule including proposals for suitable protective coating systems for acceptance by the Project Manager. The corrosion protection systems to demonstrate that all metal structures are adequately protected against corrosion in the severe corrosive environment of the site (Sere Plant).
- c. Coating products must conform to the Health and Safety requirements (lead based paints are prohibited as well as any potentially carcinogenic or mutagenic substances). Take note that the definitions of painting systems include surface preparation, type of paint, method of application and required dry film thickness.
- d. The entire works of corrosion protection shall be inspected by the Employer's Representative during system application, prior to the start of the Defect Liability Period, and before the Final Acceptance Certificate is issued.
- e. Off the shelf items such as air conditioning units, motors, etc to be specified and chosen such that the components are suitable for the corrosion aggressive environment.

## 13. Mounting Structures and Foundations

- a. The design for the foundations and mounting structures shall be based on the findings from the geotechnical study, requirements and conditions from the EIA approval, as well as considering applicable design loads, wind loading, seismic design and standards. 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. All PV mounting structures are off-the-shelf products as much as possible. Engineered solutions are only allowed for specific circumstances. The Contractor provides the mounting structure solutions which is efficient, cost effective and reliable. The design reduces installation time and material waste.
- b. Foundations shall be designed according to the relevant local and international Standards.

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- c. The Contractor shall assume the ground risk as regulated within the EPC Contract. Prior to construction, the Contractor shall carry out all necessary geological and geotechnical investigations and studies so as to satisfy itself of the ground condition.
- d. In the Contractor's design packages (reports and drawings), the following information, as a minimum, shall be made available to the Employer:
  - i. Detailed foundations design documentation for all required foundations (type, dimensions).
  - ii. Reinforcement characteristics (rebars diameter, rebars separation steel grade)
  - iii. For steel structural elements protection against corrosion.
  - iv. Concrete design mix (grade, composition).
  - v. Design basis statements and supporting calculations.
  - vi. Specific construction methodology and testing criteria requirements.
  - vii. Specific bearing capacity requirements
- e. Foundations shall be designed to withstand the Site conditions for the entire Design Lifetime of the Project, without being replaced.

#### 14. Piling/PV Tracker Foundations

- a. The Contractor will take full responsibility for the design, construction and operability of the solar field foundations. The Contractor shall design the foundations according to the relevant national Standards, international Standards and the structure / tracker manufacturer's specifications.
- b. The mounting structures shall be designed to withstand the Site Conditions (including the soil chemistry) for the entire Design Lifetime of the Project, without being replaced. In designing the foundations, the Contractor shall take into account all loads from the upper structures to determine the tracker foundations embedment depth and specifications. The foundations and substructures shall be able to transfer all actual load combinations, including but not limited to horizontal and uplift forces, safely to the foundation system for the Design Lifetime. To satisfy the imposed loading and these determinations should be verified by load testing on test tracker foundations with a frequency commensurate with international best practice, but at a minimum, in all areas of varying ground conditions and geological make up, as defined in the geotechnical study. Tests shall include investigation and analysis of compression, tension, and horizontal load applications.
- c. The Contractor will design a suitable foundation type. As far as practical, pile foundations shall be used. However, these might comprise pre-drilled piled foundations (or similar). The Contractor shall establish, at the earliest opportunity, tracker foundations drivability trials, including but not limited to pull out and load tests (in accordance with the tracker manufacturer), to ascertain whether the ground conditions are suitable for driven tracker foundations or whether alternative foundations should be adopted.
- d. The final detailed design of mounting structure foundations shall comply with the manufacturer's requirements, the conclusions of the pile load and pull-out tests and the geotechnical report. Prior construction works, the Contractor shall carry out additional pull-out test testing the final tracker pile foundation solution which will be installed in order to verify final foundation design. All the different foundations design must be subject of pull-out tests at using ultimate loads. If the terrain proves to have significant heterogeneities, each type of foundation solution will be tested within the type of terrain where it will be installed.
- e. The Contractor shall state in his calculations the maximum permissible foundation movement that may be tolerated consistent with normal operation of the Project. The design of the mounting structure foundations shall account for settlement align with the manufacturer's requirements.

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- f. The Contractor shall repair any metal surface damage caused accidentally during ramming or required subsequent mechanical interventions such as cuts or drilled holes in accordance with the designer and manufacturer's specifications. During ramming process, the top of the ramming profiles damages should be repaired applying two layers of a zinc coat painting with 95% of Zn content otherwise, according to the post head damage procedure of the manufacturer.
- g. Verification of the possible damage of the Zinc cover in the underground part of the piles during the ramming is required. A sample of each kind of pile will be rammed and extracted in different areas of the plant for checking that there is no significant damage in the galvanized surface.

#### 15. Other Foundations and Structures

- a. The design of foundations for all the buildings/structures that is required. The Contractor shall perform all required geotechnical and other studies, to the extent deemed necessary, to assess the ground conditions of the Site and determine the type of foundations and any ground improvement techniques to be employed as necessary (soil improvement; compaction, etc.).
- b. The Contractor shall provide a detailed structural analysis demonstrating that the design conforms with the Site climatic wind speeds, seismic loads, and snow loads and to the Standards and shall clearly state in the design basis report(s) the loads combinations, assumptions and the design specifications.
- c. The foundations shall be able to transfer all actual load combinations, including horizontal and uplift forces, safely to the support soil material determined by the geotechnical report. The Contractor shall state in the calculations the maximum permissible foundation settlement that may be tolerated consistent with normal operation of the Works.
- d. The material used for the foundation will be steel reinforced concrete. Overall, the minimum strength of structural concrete for the foundation shall be strength class 25MPa, unless otherwise specified. The Contractor is to specify higher grade of concrete where required and submit all designs for review by the Employer. All below ground concrete structures shall be adequately waterproofed. Likewise, the concrete design mix will be specified according to the aggressiveness and the geo-mechanical properties of the ground conditions and groundwater shown in the geotechnical report and laboratory analyses of samples.
- e. Should a risk of excessive soil erosion and/or dune formation be identified, suitable mitigation measures will be implemented to manage any long- and short-term impact subject to Employer approval.
- f. The detailed design documentation and drawings shall include but not limited to the following:
  - i. Detailed foundations characteristics (type, dimensions, material technical specifications, etc.). For concrete foundations, reinforcement characteristics (diameter, steel grade, protection against corrosion, etc.), and design mix requirements (grade, composition, etc.) shall be included.
  - ii. Geotechnical design assumptions and verifications,
  - iii. Specific construction requirements and testing criteria,
  - iv. Climatic condition assumptions and verifications (wind, snow, humidity, temperature, etc.)
- g. The Contractor is responsible for sealing of cable ducts that enter buildings or other areas, which will be suitable for the construction phase (temporary sealing) and for the Design Lifetime (permanent sealing).

#### 16. Plant Layout

- a. The EPC Contractor will optimise on the plant layout, configuration, and panel size to achieve the highest output based on the land, topography, rainfall patterns, ambient temperatures, aerosols, and dust particles.

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- b. The EPC contractor must take cognisance as the Sere Wind Farm may present safety and damage concerns for a PV facility that is located in proximity to the wind turbines. This must be considered in the design and final layout.

#### 17. Security/Access Control Building

- a. The design of a new security/access control building which is to be positioned at the main entrance of the Sere Wind Farm at the turn-off at DR 2225 (See drawing 0.95/61 Sere Security Access Control Building).
- b. The security building to conform to Eskom Security Standards 240-91252315 Standard for Bullet-resistant Guard facilities.
- c. The lighting requirements inside and external to the security building and access point to be as detailed in 240-91252315 Standard for Bullet-resistant Guard facilities.

#### 18. PV Plant Security and Lighting

- a. The design of all Sere PV Plant security lighting masts and associated civil work and foundations.

#### 19. Meteorological Stations

- a. The Contractor provides all associated civil work required for the installation of meteorological stations.

#### 20. Potable Water Supply and Reticulation

- a. The Contractor performs the design, drawings, procurement, manufacture, quality control and assurance, supply, delivery, installation, commissioning, testing, training, and maintenance and handing over of Potable Water Supply and Reticulation works based on the Employer's outlined functional specification.
- b. The Contractor should note that there is currently no municipal water pipeline that runs in the vicinity of the plant. Currently, the Sere Wind Farm trucks and stores water for ablution facilities, while bottled drinking water is purchased for site personnel.
- c. Potable water supply and reticulation will be required to service five (5) Security Staff housed at the Security Access Building, including ablution facilities. The Contractor shall design and size the Potable water supply, treatment (if required), storage, and reticulation system accordingly, including evaluating the option for trucking in and storing water in an elevated tank at the Security Access Building.
- d. Potable water meeting SANS 241 is to be used to fill the tank and guaranteed by the Contractor to meet water quality at time of consumption. The Contractor to design and provide a disinfection facility (if required).
- e. The Potable water supply, treatment (if required), storage, and reticulation system shall have a design life of 25 years.
- f. The elevated Potable water tank will have inlet valve for filling, drain nozzle, and outlet valve for supplying the reticulation system. The tank will also have overflow protection, low level and high-level indicators, monitored by the Plant CMS.
- g. The Contractors scope includes:
  - i. Provision of painting and corrosion protection for complete works as per 240-101712128 and 240-106365693.
- h. The Contractor shall provide for all water requirements during construction period. This include potable, drinking and water used during construction & PV panel cleaning.

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- i. During the O&M period the Employer to provide potable water (excluding bottled drinking water) at the Sere Wind Farm O&M buildings and the Contractor will be responsible for the provision of PV panel cleaning water and any other water related to O&M activities.
- j. The existing potable water supply (tank) to the Sere Wind Farm to be reviewed for adequacy and a new refilling regime proposed.

#### 21. Process Water Supply and Reticulation

- a. Process water supply and reticulation will be required for PV module washing and dust suppression activities.
- b. The Contractor performs the design, drawings, procurement, manufacture, quality control and assurance, supply, delivery, installation, commissioning, testing, training, and maintenance and handing over of Process Water Supply and Reticulation works based on the Employer's outlined functional specification.
- c. The Contractor should note that there is currently no municipal water pipeline that runs in the vicinity of the plant.
- d. The quality of water required for PV module cleaning shall be determined based on the requirements of the PV module manufacturer. Suitable treatment processes may be required to ensure the process water is at the required quality.
- e. The Contractor shall design and size the Process water supply, treatment (if required), storage, and reticulation system accordingly, including evaluating the option for trucking in and storing water on site. If required a central point to be located at in the PV plant where water will be collected by a water tanker truck and transported to various locations on the plant.
- f. The process water must be stored and reticulated across the PV plant as required.
- g. The area water scarcity needs to be considered in determining the cleaning method/technology of the PV panels.
- h. The process water supply, treatment (if required), storage, and reticulation system shall have a design life of 25 years.
- i. The system pressure is not to exceed 600 kPa, and the pressure at the furthest point is not to be less than 300 kPa. This pressure is available to all plumbing fixtures. Pipes are to be sized to suite the operational requirements of any chosen fittings and fixtures. No flow velocity shall exceed 1.5 m/s.
- j. The process water storage tank for cleaning of the PV panels shall be designed and sized accordingly. The process water tank will have inlet valve for filling, drain nozzle, and outlet valve for supplying the reticulation system. The tank will also have overflow protection, low level and high-level indicators, monitored by the Plant CMS.
- k. The Contractor shall provide for all water requirements during construction and during the O&M period.
- l. The Contractor complies with the latest revisions of the standards as per Appendix C.

#### 22. Sewage and Waste Disposal

- a. The Contractor must design the sewage and waste disposal system for the security building. There is no existing municipal sewer line to tie into. A conservancy tank shall be designed and installed. As a minimum, the tank's design should meet the following requirements:
- b. The tank shall be constructed and designed in accordance with the information contained within SANS 10400-P: 2010 standard.

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- c. 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.
- d. The inlet should be designed such that blockage by the scum layer is prevented.
- e. The depth of the tank should be designed in line with acceptable standards.
- f. The tank shall be designed with two compartments to allow for periodic desludging. The tank should be easily accessible. The tank must be watertight at all times and shall not allow for any storm water inflow. The tank must be constructed of materials which are not susceptible to excessive corrosion. The interior should be plastered with a waterproof material. Adequate water supply must always be available for use with a water connection point available within the vicinity of the tank.
- g. The sewage tank will have an overflow detection and protection to avoid environment contamination.

### 23. Roads (PV Plant Site)

- a. The road infrastructure will be designed in such a manner as to comply with the relevant legislation and regulations. The EPC Contractor will perform pavement designs for the access road and internal Roads. The pavement designs shall comply with the Eskom Road Specification Manual (240-84418186). The geometric properties of the roads shall be to the safest and optimal geometric design possible. The design of roads, storm water management and pavement design are to conform to SANS 1200, TRH series for roads, THM series for roads, UTG series for roads, COLTO specification.
- b. As a minimum the roads will entail:
  - i. Construction of a new gravel access road to the PV site branching off the Eskom main access road of the Sere Wind Farm site.
  - ii. A perimeter ring road around the PV plant
  - iii. Internal gravel roads to inverters and transformers
- c. Roads for maintenance purposes.
- d. Paved internal roads at and around the stores and server building should it be positioned on the PV Plant Environmental Approved Area.
- e. The internal roads at the buildings will be finished with interlocking segmental paving blocks, road kerbs, road signage and paint demarcations. The road design provides sufficient slope (camber 2%) for drainage of rainwater and must include a proper drainage system.
- f. Where construction is required on the existing Sere Wind Farm administration footprint, e.g. construction of the stores, server room, parking areas, etc. the existing infrastructure such as paving and parking areas to be integrated appropriately with the changes utilising similar materials to match the existing.
- g. The EPC Contractor will be responsible to conduct the required geotechnical investigation and survey, to enable them to perform the designs for the access road and internal roads. Gravel roads shall be finished to minimise dust. The roads will be designed for abnormal vehicle loads where required. Road access to Inverter/MV switch-rooms must cater for a truck with a crane and have a suitable width for ease of access and maintenance.
- h. The Contractor is responsible for any permit requirements and liaise with local authorities and other to ensure permanent access during construction and during operation to the Plant.
- i. The access road up to the boundary of the Site, internal roads, parking areas, and other surfaces within the Site shall be the responsibility of the Contractor.

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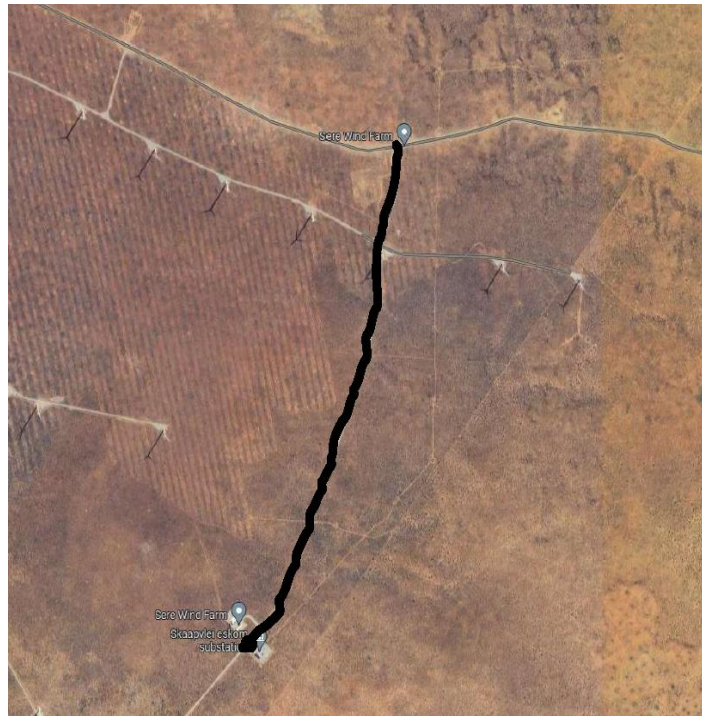
- j. The Contractor shall develop and carry out a construction Traffic Management Plan and best practice traffic management procedures, including a traffic incident response plan.
- k. The design, construction and maintenance of all roads shall be entirely suitable for the size of vehicles to be used for the operation and maintenance activities that will be required for the 25-year design life of the Plant. The road structural layers shall be designed taking into account the most restrictive scenario (construction phase: heavier loads, longer turning radius).
- l. The CBR shall be established from the geotechnical investigation in order to evaluate the mechanical strength of the road subgrades and basecourses.
- m. Roads and surfaces shall be designed in conformity with a specialist geotechnical report to support the use of heavy vehicles needed for the transportation of Goods, Materials and Plant to and within the Site during the Construction and Operation and Maintenance phases of the Project. The wheel and/or axle loads shall be submitted for all road designs. Furthermore, the Contractor shall take into consideration the loading capacities and clearances of existing services and connecting roads when carrying out transportation studies.
- n. Suitable materials, according to the SANS or COLTO soil classification's, from excavations may be re-used in road construction provided the material is uncontaminated and deemed appropriate for load-bearing capability.
- o. Roads and parking areas shall be designed to suit Site Conditions and compacted crushed rock shall be used as a construction material if periods of wet weather are anticipated. The maximum size of crushed rock shall be 40mm. The compaction ratio for each layer of the roads shall be defined according to SANS or COLTO standard (using Modified Proctor test).
- p. Road widths (the usable surface) shall be at least 4.0 metres, or as deemed required by the component manufacturer(s) requirements and turning radius shall be sufficient but at least 10m from the axis of the road) to allow access for maintenance and replacement of the largest components and for emergency personnel.
- q. All surfaces shall be designed to allow proper drainage, both cross and longitudinal drainages. During the road's construction, roads shall be backfilled with suitable material and properly compacted in layers not exceeding 0.25m in order to achieve the density required for supporting structure stability and resistance against erosion and light vehicles traffic. All surfaces shall be designed to allow proper drainage.
- r. Internal roads shall be carried out at the Plant, as many interior roads as needed for providing access to string combiner boxes, inverters, transformers, substation, permanent buildings, and any other relevant equipment by its dimensions deployed within the Site. Furthermore, SCADA boxes and tracker drives shall be easily accessible.
- s. In the areas of the solar field where no roads are included, the layout shall consider sufficient space for circulation of light all road vehicles to reach any equipment where recurrent maintenance needs may be expected. At least 3 meters wide free of obstacles paths shall be considered for this purpose.
- t. The Contractor shall be responsible for keeping the roads clean and usable during all weather conditions for the areas within its limit of supply.
- u. Different tests in situ and laboratory tests shall be developed by the Contractor among others: Compaction grades, bearing capacity or vertical deformation of foundation road and topographic survey-road levels according with SANS or COLTO

#### 24. Sere Wind Farm Access Road from DR 2225

- a. The existing access road surface finish shall be finished as an all weathered surface (a seal, asphalt or block paving).

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- b. It is expected that the EPC Contractor will perform pavement design for the access road and shall comply with the Eskom Road Specification Manual (240-84418186).
- c. The geometric properties of the road shall be to the safest and optimal geometric design possible and shall comply with the Eskom Road Specification Manual (240-84418186).
- d. As a minimum the access road will entail:
  - i. The design and construction of a new all weathered access road.
  - ii. The main access road width for now can be taken as 8m wide, 2% crossfall and a length of 2.66 km from the Provincial gravel road passing Skaapvlei substation.
  - iii. Admin Access Road, width of 8m, 2% crossfall and a length of approximately 0.130 km. From the Main Access Road to the gate.
  - iv. Substation Access Road, width of 8m, 2% crossfall and a length of approximately 0.030 km. From the main access road to the gate.
  - v. PV Plant Access Road, width of 8m, 2% crossfall and a length of approximately 0.020km. From the main access road to the PV Plant gate.



**Figure 1: Main Access Road**

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**Figure 2: Admin and Substation Access Roads**

- e. The road width and pavement structure to be confirmed at design stage as well as traffic loading (type of vehicles).
- f. The EPC Contractor will be responsible to conduct the required geotechnical investigation and survey, to enable them to perform the design for the access road as well as all the associated works like drainage, road marking, road signs, etc.
- g. The access road surface finish shall be finished as an all weathered surface (a seal, asphalt or block paving).

The access roads to have the required road signage and road markings.

#### 25. Construction and Maintenance Access

- a. Access for construction equipment and materials during the construction phase must be provided for in the design.

#### 26. Storm Water Drainage

- a. A suitable storm water drainage system for the site shall be designed and constructed according to the approved environmental permit and Water Use License permit.
- b. With reference to Site Conditions (specifically climatic data and especially the rainfall data and the Site's configuration and topography), the Contractor shall design and build a drainage system suitable for the Design Lifetime in order 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 will be provided or utilized.

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- c. 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.
  - d. In this regard, the drainage philosophy will require two parts:
    - i. External drainage: This drainage protects the Plant for external water runoff through the watershed from upstream of the Plant location; and
    - ii. Internal drainage: This refers to the runoff generated from rainfall within the Site.
    - iii. For the external drainage, the return period required is 1:50 year. Conditions shall also be checked for the 1:100 and 500 years event to assess the risk of floor levels being inundated and a flood risk assessment presented to the employer with the conclusions. Mitigation measures (if any) shall be subject to the Employer's approval. The internal drainage system will be designed, taking into account the 1:50 year return period, such that water drains away from the permanent Site infrastructure following periods of rainfall. The drainage system shall be designed in a manner such that other infrastructure (such as trenches, ducts or cable conduits) does not act as part of the drainage system.
  - e. 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.
  - f. Existing drainage courses shall be maintained as far as possible. Before any discharges off-Site, the discharge water shall be treated to retain or neutralize unacceptable pollutants. Provisions shall be required in respect of surface water and Plant drainage.
  - g. Longitudinal or transversal elements of the drainage system shall not block circulation within the solar field significantly increasing the distances to reach PV equipment for maintenance.
  - h. Surface drainage in areas which may be contaminated by oil shall be routed via the appropriate oily water drainage system with oil separator.
  - i. All drains and liquids discharged from the Plant shall be disposed in accordance with the EIA, the EMP, the EA and the relevant permits.
  - j. The Contractor will be responsible to cover the ditches of concrete in case is needed due to the water speed in order to avoid erosion at the bottom of the ditch.
  - k. A maintenance plan shall be submitted for the Employer's review and approval prior to commencement of implementation.
  - l. Records of the drainage designs and construction shall be submitted to the Employer for review and record purposes at each development stage.
  - m. No water-induced erosion is allowed within the Site and the drainage system will be designed to prevent erosion.

## 27. Parking Area

- a. A vehicle parking area, surfaced with interlocking segmental paving blocks for a minimum of six vehicles as well as a tractor with a trailer, shall be catered for in the design. The parking area is to be covered with a car port structure. The parking area shall preferably be on the existing Sere Wind Farm parking area and be located close to the Sere Wind Farm administration building. The new parking areas to match existing materials utilised in the Wind Farm parking area. A parking area is required for minimum 4 vehicles at the new security access control building.

## 28. MV Cabins/Enclosures

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- a. The contractor provides the required civil works for the enclosures and MV cabins to house the inverters and switchgear. The cabin includes proper fire protection, lighting and ventilation system.

## 29. O&M Buildings

- a. The Contractor designs, procures and constructs the new store, the new server room as well as the changes required in the existing Sere Wind Farm Administration Building and/or Sere Wind Farm Workshop and Stores Building. All buildings and structures shall be designed and constructed in accordance with the requirements and recommendations of the Structural Code. Final design of the building shall be approved by a structural engineer and local authority.
- b. All design and construction work are subject to review and inspection by the Employer and subject to approval.
- c. Provisions should be made in the design for easy offloading of the relay panels and other equipment into the control room (i.e., due consideration shall be given to door size and height and consider a slanted floor entrance).
- d. With new buildings the finishes shall suit the requirements of each building, its function, requirements of occupancy and operation requirements. Where changes are required in existing buildings the finishes need to be the same as existing building finishes. All buildings shall have appropriate signage. As a general rule for all new buildings, the floor finish shall be an epoxy material on a concrete floor. All the new buildings shall have one (1) m of apron slab/sidewalk all around it.
- e. Attention shall be given to detailing, design and construction of reinforced concrete flat roof systems to ensure that crack widths in the concrete are minimised and to ensure that the long-term integrity of waterproofing membranes are maintained.
- f. All soffit slabs over rooms housing electrical equipment rooms shall be watertight. Neither drainage pipework nor water supply pipes shall pass through the electrical equipment rooms.
- g. The Contractor shall provide emergency doors with suitable quick exit mechanisms and/or panic bars at appropriate locations to provide safe means of escape in the event of an emergency.
- h. Any cable basement shall be fully watertight reinforced concrete construction and shall extend at least 300mm above the surrounding ground levels.
- i. Cable, pipe and services entries through technical floors and walls shall be designed such that after the cables and the like have been installed the entries are closed completely to be smoke/fireproof. The sealing materials used for this purpose must be fire resistant, and easily removed for the installation of further cables, or services, in the future.
- j. Lightning protection shall be provided for all structures exposed to lightning strikes. The down conductors shall connect to the primary below ground earthing system. Pedestrian reinforced shallow foundations shall have an own grounding earthing system and it shall be connected to the PV grounding grid. Component materials for the installation and the protective system shall conform to relevant standards.
- k. The contractor shall consider all the requirements for fire protection system and associated alarms and implement it in the design.
- l. The Contractor to create the following offices in the existing Sere Wind Farm Administration Building and/or the existing Sere Wind Farm Workshop and Stores Building (See drawings 0.95/20 Sere Wind Energy Facility O&M Offices and Visitors Centre Ground Floor Plan and 0.95/25 Sere Wind Energy Workshop & Store Ground Floor Plan & Details). These are indicative layouts.
- m. Closed offices

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- i. Create a total of 1 x closed office in the Exhibition room and 1 x closed office in the General office. This is to be done utilizing dry walling and appropriate sound proofing applied. The Contractor to;
  - Check if there are adequate space/area to accommodate the requirements and modify accordingly.
  - Modify power reticulation, lighting, HVAC, LAN, etc.
- n. Open plan offices
  - i. Create
    - A total of 10 open plan work stations within the remaining area of the Exhibition room;
    - The existing Sere Wind Farm Workshop and Stores slab above Office 1 and Office 2 shall be re-purposed to accommodate six (6) open plan work stations, including an access staircase. This to be done by applying suitable dry walling methods.
    - The EPC Contractor to;
      - Confirm the feasibility of doing this modification compared to other options.
      - Check if there are adequate space/area to accommodate the requirements,
      - Modify power reticulation,
      - Install required lighting, HVAC, LAN, etc..
      - Confirm that there are adequate ablution facilities to accommodate the additional people.
      - Confirm if any safety aspects are not compromised.
      - Create storage space (temporary or permanent) for the equipment currently stored in the Dry Battery & Inverter room. The Contractor to consider creating temporary storage space or construct the new store first.
- o. The Sere Wind Farm and the PV Plant control rooms to be combined in the existing Sere Wind Farm administration building office 3 (See drawings 0.95/20 Sere Wind Energy Facility O&M Offices and Visitors Centre Ground Floor Plan).
- p. The new Server Room (Air-conditioned room for sensitive electronic equipment) to be positioned next to existing shaded parking area close to existing Sere Wind Farm server room and control room (See drawings 0.95/20 Sere Wind Energy Facility O&M Offices and Visitors Centre Ground Floor Plan and 0.95/19 Sere Wind Energy Facility O&M Offices and Visitors Centre Site plan) or in the PV Plant Environmentally Approved footprint if required.
- q. The existing Sere Wind Farm Dry Battery and Inverter room shall be re-purposed to accommodate the auxiliary backup supply system, including batteries and inverters where applicable.
- r. The Contractor ensures that space in the new store, new server room and modifications to existing buildings (closed & open offices and control room) is sufficient for their purposes.
- s. The Contractor designs the new buildings and modifications to existing buildings according to ergonomic principles (Eskom standard 240-56355808 Ergonomic Design of Power Station Control Suite Guideline) and sound PV Plant practice
- t. The new store and server room includes proper fire protection and ventilation systems according to the requirements. Where modifications are required to existing buildings the fire detection and protection to be modified to suit the new requirements

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- u. The buildings are equipped with normal florescent lighting, as well as essential lighting with a battery pack backup in the case normal lighting fails. The minimum lux level is as per OHS Act.
- v. The Contractor considers Eskom Architectural technical specification 240-56364535 to select the appropriate materials for the new buildings.
- w. All new building platforms must be waterproof and be suitable for the ground conditions for the Design Lifetime considering a minimum elevation of 0.25m higher than the 1:100-year return period maximum water level) especially cable entrance, door, etc.
- x. Sufficient clearance around the new buildings must be provided for future maintenance (equipment replacement, transformer access, etc.).
- y. Thermal insulation materials shall be incorporated into the fabric of the new buildings to minimise heat gain and the load on the heating, ventilation and air conditioning (HVAC) systems. Proper waterproofing system shall be used for all buildings.

### 30. Store Building

- a. A store for the storage of spare solar panels and electronic equipment. The store must be optimised in size to cater for sufficient storage of spare PV panels and any other equipment, including necessary workshop tools, and spares that would require storage but needs to be not smaller that the drawing provided.
- b. The stores shall also retain spares to carry out recommended routine and scheduled servicing of the Project. These items shall include, but not be limited to:
  - General mechanical spares.
  - PV modules, inverter, inverter station spare parts.
  - Electrical equipment (lamps, fuses, connectors, cables, switches, etc).
  - Instrument spares.
  - Operational equipment.
- c. Small items shall be binned in suitably shelved racks. Larger items shall be stored in an adequate area with lifting equipment, i.e., one handler, to load and unload as necessary.
- d. Adequate utility supplies such as power sockets etc. shall be provided.
- e. Fire detection system connected to the control room / building shall be provided.
- f. The storage of inflammable and hazardous materials such as lubricating oil, chemical, paints, dosing inhibitors shall not be stored within the main stores building and shall be stored in suitable covered and ventilated areas local to the main stores.
- g. External access to the room shall be provided, suitably sized in order to allow forklift access. Main door shall have a minimum height of 4-5 meters and secondary pedestrian door shall be installed.

### 31. Control Room

- a. All activities associated with the operation, control and monitoring of the Project shall be carried out from the control room.
- b. The control room with regards to operator interface shall be designed to ergonomic principles and good Solar Power Plant practice. All security requirements associated with the O&M building must be catered for. This includes but is not limited to cable routings and trunking/racking.

### 32. Server Room

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- a. A server room capable of housing the Facility SCADA, security and UPS and devices shall be provided.
- b. The Contractor designs the server room with sufficient walking space of at least 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.
- c. The Contractor provides sufficient lighting and HVAC inside the server room.
- d. The Contractor installs raised floors inside the server room to allow for adequate cable access into the network cabinets.

### 33. Security Access Control Building

- a. The Security Access Control Room shall be located and positioned at the Sere Wind Farm entrance gate at DR2225. The security building to conform to Eskom Security Standards.
- b. It shall include, but not be limited to:
  - i. Workstation for monitoring and controlling the Intruder Detection system.
  - ii. Workstation for the trunking radio base station of the security department.
  - iii. Workstation to display the CCTV
  - iv. Building to be powered with suitably sized Rooftop solar system with battery backup (Off the grid solution)
  - v. Potable water to be supplied via suitably sized elevated tank
  - vi. Suitably sized conservancy tank
- c. The proposed building layout to be as indicated in drawing 0.95/61 Sere Power Station Building Layout Unit 0 Solar Farm Security Access Control Building and consist of at least the following:
  - i. Guard room,
  - ii. 2 Offices,
  - iii. Two ablution facility
  - iv. One small kitchen
  - v. Space to house server (CCTV), Rooftop solar inverter and batteries (24 hour standby time)
  - vi. Covered parking space for 4 vehicles surfaced with the same surfacing material utilised in the access road surfacing.

### 34. Fencing and Gates

- a. The PV Facility perimeter fence to be constructed according to the specifications detailed in 562/2 High Risk Security Mesh Fence: System Technical Specification for Sere Solar PV Plant Phase 1a.

### 35. Existing Sere Wind Farm Fire protection pumphouse

- a. The existing Sere Wind Farm Fire protection pumphouse to be bricked up and appropriate doors and windows to be installed. The room is to be equipped with appropriate lighting and extraction fan that will be suitably rated and designed such that possible accumulation of gasses is mitigated. Water drainage from the floor and out of the pump house is catered for in the design and construction.

### 36. Cable, Pipe Trenches, Ducts and Manholes

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- a. Design of service trenches, tunnels, ducts, manholes and cable pulling pits.
- b. Design of all power evacuation structures.
- c. Underground cable runs, including communication cables and earth conductors, shall be located at an appropriate depth to meet the applicable Standards and any other Employer's requirements as provided in the EPC Contract and Good Industry Practice.
- d. Underground cables shall be laid on a clean layer of sand, always covered with warning tape. Mechanical protection shall be provided and installed for LV and MV trenches. Backfilling materials shall be free of rocks, vegetation or any element that could damage the cables or create cavities after compaction. Bedding material should be tested and aligned with the thermal resistivity assumptions used in the cable sizing calculations.
- e. The cable trench study shall consist in determining:
  - i. The final trench design based on the final DC and AC collection system layout
  - ii. The final trench design based on:
  - iii. Geotechnical study
  - iv. Thermal resistivity measurements
  - v. The surrounding conditions
  - vi. The soil conditions and obstructions in the soil
  - vii. Filling material
  - viii. Existing infrastructures
  - ix. DC cables, AC MV cables, FO cable and earth conductors' characteristics
- f. Earthing connections and splices that are directly buried in the soil must be permanently bonded using exothermic connections (where copper earthing is used) to equalize the potential differences and avoid joint corrosion over time. Cable joint specifications shall be of the water block type.
- g. Both physical and digital markers shall be provided at any direction change, any cable joint and every 100 meters for each cable run. Subject to the Employer approval, the requirement for physical markers for DC cabling may be waived after the final layout has been reviewed.
- h. Trenches with mixed AC medium / low voltage circuits shall be avoided if possible. In case strictly necessary, higher voltage circuits shall be buried deeper than lower voltage circuits. The following depth of cover (distance between edges of conduit or cables to ground level and trenches edges) shall be as per SANS 10198 and be adhered to the following among others:
  - i. Cables laid at the bottom of the trench will lay on a 100mm sand layer. Contractor shall only be allowed to reduce the 100mm sand layer requirement under prior approval from the Employer and under proper technical justification based on the Thermal Resistivity (TR) of the backfill material. In any case, a sand layer thickness of less than 50mm shall not be approved for MV cables.
  - j. MV cables will lay at the bottom of the trench, at a minimum depth of 800mm.
  - k. LV (DC and AC) cables to be a minimum of 300mm above the MV cable layer and laid at a minimum depth of 600mm.
  - l. The depth of signal tape must be at least 200mm above cables and 300 mm below the surface to warn contractors of the presence of cables. Trenches greater than 1 m wide should have two or more equally spaced warning tapes above the cables.

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- m. Distance between DC and AC cables will be a minimum of 200mm (from nearest duct or cable edge).
  - n. Fibre optic cables must be separated 125 mm from low voltage cables and medium voltage cables.
  - o. In LV and MV crossings with roads, cables shall be laid in cased ducts concreted along their entire length. The depth from the top of the protection tube to the surface shall be not less than 0.80 m.
  - p. Conductive (copper) signal cables will lie at least 200mm apart from LV cables.
  - q. Minimum separation from the cables (LV or MV) to the excavation walls, shall be not less than 50 mm.
  - r. The contractor shall displace cables horizontally through the different layers (MV cables should be accessible for repair without causing damage to the cables above).
  - s. All cables to be surrounded by soft sand backfill (a fine-fill material to be used for LV cables). The thickness of the sand backfill above the cables shall align with the requirements of the trench design study and the TR of the sand backfill shall be per the requirements of the trench design study.
  - t. DC main cables to be armoured and buried directly in the ground.
  - u. DC string cables to be fixed to the back of the PV mounting structure such that independent cable movement is arrested. Sharp edges to be protected. Where string cables must travel between rows, the cable should be buried in ducting. Where ducts are installed, they are to be sealed at both ends with rodent and waterproof filling material.
  - v. Earthing, where applicable, will be laid at the lowest layer of the trenches.
  - w. LV AC cables and MV cables should be mechanically protected and buried appropriately within the trench as above.
  - x. Trenches shall be backfilled with clean fill material free from aggregate, debris, organic material and stones. Trenches shall be backfilled in layers of no more than 150 mm each and mechanically compacted to 90%- 93% of maximum density at optimum moisture content, in order to avoid cavities that may cause collapse of trench top due to settling of the soil or sand. Backfilling material will have a five 50 mm size as a maximum.
  - y. When filling the channel, marking tapes shall be placed and earth shall be compacted.
  - z. Waste Storage Area (Domestic Waste)
    - i. Install concrete floor with bund wall where waste skip bins can be placed (to accommodate 4 x 6m<sup>3</sup> waste bins).
    - ii. Waste area to have surrounding brick walls and/or fencing and and gate to ensure all waste is contained.
    - iii. Close existing wheely bin area with fence & gate to ensure all waste is contained.

#### 4.2.4 Construction

The scope of work includes all civil, structural and architectural works.

1. General infrastructure and utilities. The Contractor shall be responsible for the following, but not limited to:
  - a. Provide and install all necessary signalization on the Site and for the access of the Site.

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- b. Maintain security on Site 24/7 from when granted access to Site until Date of Completion, including the installation of security system, video surveillance and guards' posts if necessary.
- c. Installation of temporary lighting posts if necessary.
- d. Provision of first aid facility and medical facilities on Site in accordance with legislation and local regulations.
- e. Provision of changing facilities for both sexes.
- f. Supply of electricity and water and any other required supplies during construction and commissioning.
- g. Sheltered eating areas and sheltered areas for trainings and meetings, properly sized for the respective number of workers including a communal kitchen and canteen services.
- h. Supply of shaded areas with fresh water.
- i. Site temporary firefighting supplies and systems.
- j. Erosion and sedimentation control.
- k. Site industrial effluent handling (i.e., concrete mixer cleaning water) and removal.
- l. Maintenance and operation of clean site conditions facilities including change areas, ablutions and common areas in line with the regulations. The Employer's authorised personnel shall have access as and when required.
- m. Housekeeping and Site establishment.
- n. Emergency lighting and signage to enable its personnel to evacuate Site in the event of an emergency.
- o. At laydown areas and temporary areas external to the Site, any temporary fencing, lighting and guarding and all other materials and services necessary for the safety and security of persons and property.
- p. A temporary car park and its maintenance for use by the Contractor's and its sub-contractors' personnel and the Employer's personnel.
- q. Temporary roads, hardstanding and parking areas.
- r. Provision of telephone and uncapped high-speed internet connections to any Site offices (both temporary and permanent) and such other places as it considers necessary for the efficient performance of its operations.
- s. Site offices for the Contractor including main offices for the PV Cluster and dedicated offices at each of the PV Plant Site
- t. Dedicated fully furnished, equipped (including air conditioning, heating, printer, fridge, microwave, drinking water, washing facilities and toilets), functional and ready to use Site offices for the Employer and its representatives including main offices shall have a capacity for at least 4 people. Offices shall be made available at the earliest after Notice to Proceed and shall be regularly and systematically maintained and cleaned by the Contractor
- u. Solid waste disposal facilities.
- v. Sanitary facilities and sewage disposal.
- w. Catering services during construction, considering the necessary hygienic measures with regard to all processes involving food: manufacture, processing, packaging, storage, transport, distribution, preparation, handling, sale and deliver.
- x. Temporary storage facilities for spares until the warehouse is operational.

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- y. Backup diesel generators and one stand-alone PV system to supply as much as practically possible the energy needs of the temporary facilities.
- z. Those facilities must be in place prior to the start of the construction activity, equipped with internet connection, lights, air conditioning, heating and with a proper housekeeping, from the start of the construction period. Contractor must ensure lights, air conditioning from the beginning using the temporary generators if necessary.

## 2. Preparatory Works

- a. Prior to the start of construction, preparatory works shall be performed by the Contractor, including but not limited to:
  - i. Create, modify, extend or upgrade the access routes needed for the construction and operation of the Plant. Access roads shall be protected, maintained, and repaired if damaged during construction. A condition assessment prior to use is recommended.
  - ii. Install fencing.
  - iii. Install access control and security.
  - iv. Install Site offices.
  - v. Install infrastructure for the provision of utilities (electricity, water, uncapped high-speed internet, solid and other waste removal, and sewage)

## 3. The Contractor provides all Building Services.

- a. Building Services - lighting, power supply, ventilation services and fire protection. Provision of all scaffolding, site crane, lifting equipment, etc. which are required by the Contractor. Detection, verification, and adjustment/diversion of existing services. The Contractor is responsible for identification and demarcation of all existing underground and overhead services within the Project Site. If encountered during the course of the Works, all live pipes, mains cables, transmission lines and services of any kind are to be maintained in position or diverted to a location reviewed by the Employer, protected and kept in working order unless otherwise directed by the Employer. No works in this regard shall commence without the prior approval in writing by the Employer of the Contractor's proposed method statement and programme.

## 4. Site Clearance and Protection of existing Services

- a. The Contractor is responsible for all site preparation and site establishment required for the construction. Prior to the commencement of any construction works, the Contractor shall clear the Site of all rubbish, debris, building, vegetation and unwanted materials of any description and remove and dispose in line with the local Environmental requirements, through licensed contractors permitted by the local approving authorities. The Contractor shall carry out a topographical survey and evaluate if relevant slopes are observed within the minimum and maximum recommended slopes.
- b. The preparation of the Site and the levelling work shall also be done to ensure that the PV modules will, once installed and fastened, stand at their lowest level (at maximum tilt) at a height that enables ease of cleaning, free movement and operating safely in case of flooding, for the minimum return period and storm duration specified in this Employer's Requirements, being aligned with the specifications of the tracker supplier. Furthermore, the bottom edge of the PV modules shall at all times be more than 0.5m from the ground at all locations in order to allow for unplanned movement of fauna below the PV modules.
- c. No slope greater than 15% shall exist on the Site, in cases of more restrictive slopes being required by the manufacturers, such as tracker system or MV station manufactures, these shall prevail. Special attention shall be given to the manufacturer requirements of the tracker system, regarding N-S and E-W slope tolerances

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- d. The Contractor liaises with third parties that have access to site.
- e. 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
5. Construction Phase Earthworks
- a. If tracking system slope limitations requires a generalized earthwork on the Site, this shall be equilibrated for minimizing the amount of terrain to move in order to save costs.
- b. Levelling and grading of the Site, if required for the Contractor's design, shall match the existing surrounding ground levels to facilitate free drainage of the Site. Additional fill material required to achieve the falls necessary for free draining shall be a suitable imported fill material. The finished Site shall be well compacted in layers according to the SANS 1200 & SANS 2001.
- c. Cutting and filling slopes shall be indicated as (H:V).
- d. Finished ground floor level of technical and non-technical buildings/enclosures shall be at least
- e. 0.25m higher than the 1:100 year return period maximum water level, in order to ensure free drainage of the surrounding grounds away from the buildings. For any case where the flood risk assessment / hydrological report will specific higher ground floor levels, these shall be prioritised. The Contractor shall also refer to the recommendations of the hydrological studies in terms of finished ground floor levels as well as SANS 10400.
- f. The Contractor shall carry out its construction activities in such a manner as to avoid damage to, or deterioration of, the final surfaces of excavations. The Contractor shall not allow water to lie in any part of the Works unless required to do so under the Contract; water arising from or draining into the Works shall be drained or pumped to an approved disposal container/area. Any contaminants whose presence would render water unsuitable for discharge into water courses or drains external to Site shall be effectively removed prior to discharge and, where appropriate, such extracted contaminants shall be transported to a licensed facility. The stormwater management plan should include the aforementioned considerations and actions.
- g. All excavated materials for reuse (especially all excavated topsoil) or disposal off site shall be placed in stockpiles prior to processing and final classification in accordance with the Soil / Material Management Plan. Where required, unacceptable material shall be processed by mechanical or chemical testing or other means to render the material acceptable for use in the permanent Works. Classification and disposal of any contaminated material shall be the responsibility of the Contractor, with the agreement of the Employer and in line with Environmental Legislation.
- h. The Contractor shall provide to the Employer documentation to prove the source of materials brought into the Site and that sufficient chemical testing has been performed to demonstrate beyond reasonable doubt that these materials are free of pollutants.
- i. The Contractor shall prepare and re-dress the Site as necessary with free-draining granular material to facilitate the efficient movement of personnel during the construction of the Works and
- j. shall maintain the surfacing as required such that construction is not interrupted nor water is allowed to collect on the surface.
- k. The Contractor shall establish temporary Site drainage system including settlement/attenuation ponds, depending on the flooding risk during construction, to be evaluated by the Contractor. Oil interceptors and wheel washes shall be required, if applicable under the EA and EMP. Any contaminants whose presence would render water unsuitable for discharge into water courses or drains external to the Site shall be effectively removed prior to discharge and, where appropriate, such extracted contaminants shall be transported to a licensed disposal Site.

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## 6. Permanent earthworks

- a. In anticipation of the difference in the existing ground levels across the Site, the Contractor shall carry out the earthworks within and in the immediate vicinity of the Plant. The earthworks shall be designed to minimise the amount of cut and fill. The slope of the access roads shall also be given consideration. Excavated materials shall be disposed of in line with the environmental requirements and legislation.
- b. The filling for foundations purpose will be done in layers of no more than fifteen (15) cm and compacted at 98% of maximum density at optimum moisture content.
- c. Adequate laydown areas suitable for the Plant, equipment and/or vehicles using them shall be provided for the proper operation and maintenance of the Plant.
- d. Laydown areas shall be provided to permit storage of equipment as may be required during overhauls as well as areas for the outage contractor's cabins and car parking, these areas shall be included in the layout drawing.
- e. If design of platforms is required due to earthworks, as well as the slopes, it shall comply with the required bearing capacity, either for a foundation or roads, and will depend on the geo-mechanical parameters obtained from the geotechnical report. The minimum layer of topsoil specify in the geotechnical report shall be removed and used / spread over other free areas and perimeter for later environmental restoration activities.

## 7. Excavation and Trenching

- a. The Principal Contractor shall ensure that all excavation and trenching operations shall be performed under the adequate supervision construction management team and in compliance with all requirements including excavation plan and the material disposal authorizations.
- b. Contractor shall ensure that, in addition to the Statutory requirements. the following minimum requirements are met during every excavation and trenching operation:
- c. Protected measures aimed to avoid falls, dislodgment of materials, person buried or trapped in, as well as fenced measures shall be taken into consideration.
- d. Sides of excavations must be clean and neat.
- e. Drilling holes must be covered, signalized and fenced.
- f. Locations of cables, communication wires and other underground hazards such as pipelines shall be established and marked prior to beginning excavation or trenching operations.
- g. In case of excavation at the edge of a track/road, that has an impact on the movement of the vehicles, the traffic must be managed with two flagmen or with traffic lights.
- h. If an excavation or trench is greater than 1.5m in depth shoring, bracing, or under pinning will be provided.
- i. Access and egress must be provided adequately dependant on the size of the trench.
- j. All excavations must be on register and inspected daily before Work commences and after inclement weather by Contractor, declared safe and his findings noted in the daily register.
- k. No work shall commence in an excavation unless the excavation has been declared safe by the Contractor.

## 8. General

- a. The Contractor is responsible for providing site drainage and sewage drainage systems;

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- b. The Contractor is responsible for providing construction facilities including to, but not limited to, provision for temporary Contractor's office, warehouse, toilets, workshop for site construction purpose, vehicles, mobile equipment, temporary power generators, electricity, water and any other provisions required for site preparation and construction. Temporary facilities with offices for the Contractor team and the Employer's representatives.
- c. The Contractor performs surface grading (if required) for site establishment and construction of facilities.
- d. The Contractor demolishes and removes all temporary facilities upon the Completion date including restoration of areas.
- e. Manage and accommodate traffic during construction of the work. The contractor shall develop a traffic management plan.
- f. Maintain temporary water supply and services during construction.
- g. Integrating and interfacing on all existing civil engineering works and various items of mechanical and electrical plant.
- h. The EPC Contractor must perform all testing and commissioning of the Civil, Structural and Architectural Works.
- i. Reinstatement of roads, kerbs and all other surfaces and services affected by the works.
- j. Liaison with property owners, residents and authorities as required for the execution of the works.
- k. Liaison with the Employer and his representative.
- l. The EPC Contractor to co-ordinate and plan the tie in of all civil works and connections where required.
- m. The EPC Contractor is responsible for the disposal of all surplus, disposable material and waste material from the Site. The contractor shall develop a waste management plan.
- n. Perform all Site survey and setting out of the work.
- o. The Contractor shall be responsible for the safe transport of all goods and materials to the Site and for obtaining any necessary approvals and permits from the relevant authorities for such transport.
- p. An Environmental and Storm water management Plan shall be provided by the Contractor.
- q. The EPC Contractor provides the required level of construction monitoring in order to ensure that the construction is completed in accordance with the approved design, scope of work and specifications.
- r. Provides adequate protection to existing and completed works to prevent damage during construction.
- s. The EPC Contractor is responsible for the complete construction process and methodology for his design and scope of work.
- t. The EPC Contractor carries out the civil, structural and building portion of the works in accordance with the Occupational Health and Safety Act (85/1993): Construction Regulations, 2014, the National Building Regulations and the relevant codes and standards.

#### **4.2.5 Deliverables**

- 1. The contractor will be required to submit documentation including but not limited to the following items:
  - a. Investigation Phase
    - i. Geotechnical investigation and report.

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- ii. Topographical survey of the site.
- iii. Hydrological Study
- b. Preliminary Design Phase
  - i. As a minimum a preliminary design report indicating PV site layout, PV mounting structures, road network layout, store and workshop layout, cable/services routing, O&M building layout, sewage disposal and water supply/storage preliminary design. The preliminary design for the mounting structure foundations and other foundations. A layout showing the security/access control building at the main access road. Fencing/gates, security lighting masts/towers layouts. Drawings showing cross-sections and elevations.
- c. Detail Design Phase
  - i. Civil Engineer Design indicating final site layout, layout and routing of cabling trenches/ducts, cross sections, elevations, details of all Civil, Structural and Architectural Works.
- d. Drawings (All Civil, Structural and Architectural)
  - i. General arrangement layouts
  - ii. Foundation layouts
  - iii. Layouts and sections of the different components
  - iv. Reinforcement drawings and schedules
  - v. Construction joint schedules
  - vi. Details of embedded parts
  - vii. Details of the PV mounting structure and fixing
  - viii. Structural steel detailing and corrosion protection
  - ix. Details of all plinths, openings, box-outs, holding down arrangements, grouting, connections etc. required for plant and equipment.
- e. Design Report and calculations relating to the civil work.
- f. Scope of work
- g. Technical Specifications

#### **4.2.6 Pre-implementation**

1. The Contractor provides the following prior to implementation:
  - a. Geotechnical report
  - b. Topographical survey
  - c. Hydrological Study
  - d. Design Report
  - e. Detailed design as per the design requirements detailed (Design report, construction drawings, specifications, etc.)
  - f. Method Statements
  - g. Quality Control Plans and Inspection Check Sheets
  - h. Installation Procedures
  - i. Testing Procedures

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- j. A Corrosion Protection Specification for coating.
- k. A bar chart program (preferably in Microsoft Project format) detailing all scope of work activities.

#### 4.2.7 Post-implementation

1. The Contractor supplies the Employer with Instruction/Technical/Operating and Maintenance Manuals that includes:
  - a. As-built drawings
  - b. Signed-off test certificates.
  - c. Signed-off Quality Control Plan and Inspection Check sheets.
  - d. Operating and Maintenance Manual including the following:
    - i. Operating instructions (start-up check list)
    - ii. Fault finding and maintenance instructions supported with a fault tree.
    - iii. Maintenance plan (detailing frequency of preventative maintenance)
    - iv. The manufacturer's name, model and number of PV modules, central inverters, transformers, batteries, SCADA and all other major components.
    - v. List of recommended spares
    - vi. Warranty information for major components such as panels and inverters and the SCADA system.

#### 4.2.8 Codes and Standards

1. All civil engineering design and construction work complies with the standard in Appendix C.

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## 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.
2. The electrical works shall include the following items, but not limited to:
  - a. The generation equipment including cabling and connection and all auxiliary systems.
  - b. Protection and control equipment for the whole system, connection, interlocking and inter-tripping.
  - c. Inverter stations (where applicable), operational meters, LV/MV transformer, MV switchgears and auxiliary transformers
  - d. Temporary construction power supplies
  - e. Installation of power supply for trackers (where applicable)
  - f. Electrical building services to all buildings and LV auxiliary distribution board for power, lighting, emergency lighting, ventilation, etc
  - g. Electrical distribution system at voltages suitable for the layout and power requirements
  - h. Internal and external normal and emergency lighting
  - i. Small power systems
  - j. UPS systems
  - k. Lightning protection system and Plant Earthing
  - l. Underground evacuation line for the Plant to its respective substation, according to the Plant layouts, Applicable Laws, Permits and National Regulations and Codes
  - m. Security and surveillance systems and equipment
  - n. Site lighting compliant with the Applicable Laws, Permits, Codes and Standards
  - o. 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:
  - a. Load flow studies to assess equipment ratings, voltage profiles and losses.
  - b. Fault level studies - short circuit current levels and flows to assess equipment capabilities.

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- c. 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).
- d. Harmonic studies to assess harmonic distortion levels and penetration and effectiveness of any potential mitigation measures.
- e. Electrical protection studies.
- f. Equipment rating selection calculation.
- g. Insulation co-ordination in accordance with SANS 60071.
- h. Earthing study.
- i. Interlocking system study in accordance with industrial good practices.
- j. Grid Code compliance study, in accordance with all requirements of the National Standards, all Applicable Laws, Permits and Codes.
- k. Any other studies to prove the validity of the design.

#### **4.3.2 Electrical HV interconnection**

1. The battery limit is located at the 22kV MV voltage level in the Solar PV Collector Substation.
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 HV 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 EPC's HV Contractor will be responsible for the underground routing, including the construction of troughs and electrical raceways, of the incoming MV power cable and Communication cables from the PV Plant 22kV collector Substation to the POC at 132kV Sere Substation.
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. The Contractor shall liaise with the HV Contractor to define the space requirements for the installation of these cabinets during the detailed engineering phase.
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. The make and model for the power quality and metering equipment shall be provided by the Contractor to the HV Contractor at due time.
7. 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:
  - a. 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.
  - b. The Plant shall be designed for 1,500 VDC configuration.

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- c. 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.
  - d. 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.
  - e. 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:
    - a. Indoors only in totally enclosed rooms with provision for limiting ingress of dust: IP31.
    - b. Indoors, except as noted otherwise: IP54.
    - c. Indoors in areas subject to water spray, or heavy condensation: IP55 or better.
    - d. 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 16.8 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.

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6. The Contractor provides the PV capacity information according to requirements set in the Tender Technical Schedules.

#### 4.3.5 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, monofacial or bifacial.
3. The PV Modules shall 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:
  - a. The photovoltaic cells of the PV modules shall be activated in the solar spectrum as defined by STC within SANS 61215-1.
  - b. PV modules shall comply with a minimal safety class II according to IEC 60364-4-41:2005+AMD1:2017, SANS 61140 & SANS 61204.
  - c. 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.
  - d. PV modules shall have a positive initial power tolerance.
  - e. 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.
  - f. 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.

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- g. The PV module connectors must be protected against dust and water while waiting to be plugged with PV cable connectors.
  - h. All PV module connectors shall be same type and make.
  - i. PV modules independent PID testing, and verification tests should be performed, and results provided in accordance with SANS 61215 and SANS 61730-1.
  - j. 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.
  - k. 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.
  - l. 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.
  - m. 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).
  - n. 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.
  - o. 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.
  - p. To avoid galvanic corrosion, any contact between the PV module frame (if applicable) and an incompatible material must be fully electrically isolated.
  - q. 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:
- a. Name of manufacturer
  - b. Type or model number
  - c. Serial number
  - d. Polarity of terminals or leads (colour coding is acceptable)
  - e. Maximum system voltage which module is suitable for
  - f. Safety class
  - g. Date and place of manufacture on label or traceable from serial number
  - h. 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:
- a. Module efficiency, greater than or equal to 20%

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- b. Bifaciality Factor (if applicable) where:
    - i. Minimum Bifaciality factor for p-type bifacial module greater than or equal to 70%  $\pm$ 5%
    - ii. Minimum Bifaciality factor for n-type bifacial module greater than or equal to 85%  $\pm$ 5%
  - c. Minimum cell temperature of -40 °C
  - d. Operating temperature between -40 °C and 85 °C
  - e. PV Module design lifetime greater or equal to 25 years
  - f. Nominal Module Operating Temperature (NMOT) lower than or equal to 44 °C  $\pm$ 2 °C (NMOT @800 W/m<sup>2</sup>, 20 °C, AM 1.5, Wind speed 1 m/s)
  - g. Temperature coefficient greater or equal to -0.37%/°C
  - h. Guaranteed light induced degradation lower or equal to 2%
13. The PV modules minimum guarantees from the manufacturer are:
- a. Guaranteed minimum power output of 98% during the first year of operation.
  - b. Linear maximum degradation coefficient guarantee of 0.55 % per year from year 2 to year 25
  - c. Guaranteed minimum output of 90% of the nominal power after 10 years of operation
  - d. Guaranteed minimum output of 80% of the nominal power after 25 years of operation
  - e. Workmanship Product guarantee against manufacturing defects for a minimum of 10 years
14. The PV module manufacturer shall comply with the following:
- a. ISO 90001 — Quality management system
  - b. ISO 14001 — Environmental management system
  - c. 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:
- a. SANS 61730-1: Photovoltaic (PV) module safety qualification, Part 1: Requirements for construction
  - b. SANS 61730-2: Photovoltaic (PV) module safety qualification, Part 2: Requirements for testing,
  - c. SANS 61215: Crystalline silicon terrestrial photovoltaic (PV) modules — Design qualification and type approval
  - d. IEC 61701: Photovoltaic (PV) modules – Salt mist corrosion testing
  - e. IEC 60068-2-78: Environmental testing - Part 2-78: Tests - Test Cab: Damp heat, steady state
  - f. IEC 60068-2-68: Environmental testing — Part 2-68: Tests — Test L: Dust and sand
  - g. Module flash test data from manufacturer, measurement according to IEC 60904- 1: Photovoltaic Devices- Part-I: Measurement of Photovoltaic Current-Voltage Characteristic
  - h. IEC TS 62804: Photovoltaic (PV) modules - Test methods for the detection of potential-induced degradation
  - i. CE Certification
  - j. 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.

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#### 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:
  - a. 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.
  - b. Cables' insulation material and cable routing method should be in accordance with any applicable Site restrictions.
  - c. If using bifacial PV modules, 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:
    - i. Highest possible albedo on Site.
    - ii. Highest bi-faciality gain considering the whole tracker motion range, sun geometry and irradiance.
  - d. 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.
  - e. 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.
  - f. 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.
  - g. All cable/wires shall be clearly marked with permanent and UV resistant markings identifying type, place of manufacture, and date of manufacturer.
  - h. Enhanced resistance to heat and fire, with low smoke emissions, and halogen free.
  - i. DC voltage maximum rating of 1,500 V.
  - j. 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.
  - k. 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.
  - l. 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.
  - m. 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.
  - n. 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.

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- b. Outer sheath: Low smoke zero halogen (LSZH) polyolefin DMO1 type according to HD 603-1,
  - c. Ambient temperature: -40 °C to +90 °C
  - d. Short circuit temperature 250 °C (Five second maximum)
  - e. 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:
  - a. Shall be metallic with appropriate environmental protection (plastic combiner boxes will not be accepted) with proper sunshade / sun protections.
  - b. Protection class IP 65 or above.
  - c. 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:
  - a. Accessible without opening the combiner box.
  - b. Lockable door switch interlock.
  - c. Double pole to isolate both the positive and negative PV array cables.
  - d. Capable of breaking under full load.
  - e. Equipped with safety signs.

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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 disconnect 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 monitoring 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 2 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. The cable labelling and single line diagram of connections inside the combiner box is kept in each combiner box.
15. 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.

#### 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:
  - a. Inverters can be central or string type
  - b. The inverters shall be designed and constructed for continuous operation under the most extreme climatic and environmental conditions on Site
  - c. The inverters shall be designed to provide the required Maximum Capacity at the Point of Connection with power factor 1 and 50°C of operational temperature.
  - d. Any grounding of negative/positive pole shall be done according to the PV module manufacturer's requirements.
  - e. 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
  - f. The harmonic distortion (THD) shall be less than 3%.
  - g. The Inverter shall be capable of providing reactive power compensation at night
  - h. The inverter shall meet all relevant Laws, Consents, and Standards including but not limited to the following requirements and international standards:

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- i. Protection type IP (SANS 60529)
  - ii. SANS 62109-1, IEC 62109-2
  - iii. Equipment safety and protection class (SANS 62103 or EN 50178)
  - iv. DC overvoltage protection
  - v. Surge protection (SANS 61643-11/-12)
  - vi. Anti-islanding protection
  - vii. CE declaration to conformity
  - viii. DIN VDE 0126-1-1
  - ix. EMC guideline SANS 61000-6-1, SANS 61000-6-2, SANS 61000-6-3, SANS 61000-6-4
  - x. Voltage guideline SANS 62103, EN 50178
  - xi. Electrical safety SANS 60950-1
- i. The protection system shall be selected and coordinated in line with the requirements of the Grid Operator
  - j. 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
  - k. Incorporate display which shows performance values and faults
  - l. For string inverters, active string monitoring is required
  - m. Each inverter shall be connected to the earthing protection system by an appropriate arrangement
  - n. Inverters shall have at least One MPPTs.
  - o. Inverter shall have a minimum European efficiency of 98%
  - p. Maximum system DC voltage should be 1,500 VDC
  - q. IP Protection shall be at least IP54 in case of central inverters and IP65 for string inverters, and shall be suitable for the Site-specific environmental conditions.
  - r. Inverters are provided with lockable DC disconnect switch and AC disconnect switch for isolation
  - s. If outdoor type inverters are considered these shall be designed to withstand the most extreme climatic and environmental conditions on Site
  - t. 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.
  - u. 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.
  - v. 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.
  - w. 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.

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4. In case bifacial PV modules are used, the string inverters cannot be installed under the trackers 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:
  - a. All inverters to be supplied shall have been in operation in at least three (3) commercial plants totalling 50 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
  - b. The inverter manufacturer shall conform to the following requirements:
    - i. Manufactured inverters for more than 5 years
    - ii. Capacity installed is more than 1,000 MW
    - iii. Production capacity is more than 500 MW per year
    - iv. 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:
  - a. ISO 9001 – Quality Management Systems
  - b. ISO 14001 – Environmental Management Systems
9. 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 Tender Technical Schedules.

### **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 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.
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.

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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. 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.
8. The protection class shall be at least IP55 for outdoor transformers and at least IP4X for indoor transformers.
9. Vibration and noise levels of all transformers shall be in accordance with best commercial practice. 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.
10. 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.
11. The anti-vibration mountings shall be of oil and weather resisting rubber or other approved material, capable of operation at temperatures from -10 °C to +80 °C. 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.
12. 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.
13. The transformers are designed with adequate transformer protection with the following as minimum:
  - a. restricted earth fault protection
  - b. over current protection
  - c. thermal overload protection
  - d. Over voltage protection
14. 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.
15. 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.

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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 °C.
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:
  - a. climatic class C2
  - b. insulation class F
  - c. environmental class E2
  - d. 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

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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:
  - a. Three phase
  - b. 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
  - c. Equipped with cooling system suitable for intended installation
  - d. Designed, procured, and tested in compliance with SANS 60076
  - e. Rated MV voltage level: to be determined by the Contractor according to MV grid rated voltage or MV/HV transformer rated voltage
  - f. Rated LV voltage level: to be determined by the Contractor according to PV inverter AC rated output voltage
  - g. Off load tap changer with minimum five positions -5%, -2.5%, 0, +2.5%, +5%
  - h. Protection against overload, short-circuit up to inverter, internal failure, over-temperature, overpressure
  - i. Suitable for the environment at the Project Site
  - j. Specific data of transformer shall be guaranteed: load and no-load losses, impedance (%)
  - k. Condition monitoring shall be provided (e.g., oil temperature, oil level, pressure, etc.)
  - l. All documentation, certificates and test protocols shall be provided

#### **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.

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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:
  - a. Service
  - b. Disconnected-test
  - c. Disconnected
  - d. 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:
  - a. Switch disconnectors on cable feeder circuits
  - b. breaker, IDMT, definite time overcurrent and earth fault protection on transformer feeder circuits

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- c. LV phase rotation meter
  - d. Voltage presence indicator
  - e. Cable Clamping facilities
  - f. 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:
    - a. MV Circuit Breakers for transformer protection.
    - b. Position indication of each RMU switching device shall be integrated to the plant SCADA system.

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- c. 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.
  - d. 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.
  - e. 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):
  - a. Restricted earth fault
  - b. Overcurrent

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- c. Buchholz Transformer Tank
- d. Pressure relief device tank
- e. Oil Temperature Alarm & Trip
- f. Winding Temperature Alarm & Trip
- g. 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:
  - a. Feeders shall be provided with Overcurrent Protection and Earth Fault (GFT) Protection
  - b. Auxiliary transformers shall be installed in controlled environments and encased in naturally air ventilated enclosures.
  - c. A winding temperature indicator shall be provide having contacts for temperature high alarm and trip functions.
  - d. 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:
  - a. XLPE or HEPR cables shall be used
  - b. MV cables shall comply with the corresponding codes and standards
  - c. MV cables shall be flame retardant as per SANS 60332-1 and SANS 60332-3
  - d. MV cables shall withstand the expected maximum electrical voltages during the lifetime of the Plant
  - e. All MV cables shall be permanent marked and properly identified
  - f. AC cables shall be designed with a maximum operation temperature of:
    - i.  $\geq 90$  °C under normal operation
    - ii.  $\geq 250$  °C under short circuit circumstances (five second maximum)
2. Instrument and data cables shall have conductors and insulation appropriate for their duty/location.

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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:
  - a. Between main switchboards (i.e., supplied by a transformer) and sub switchboards: 2%
  - b. Between main switchboards (i.e., supplied by a transformer) and static load terminals: 5%
  - c. 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:
  - a. 2 cores: red – black.
  - b. 3 cores: red - yellow – blue.
  - c. 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.

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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:
  - a. Switch disconnecter
  - b. 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.

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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;
  - a. PV Plant, taking Grid Code limitations into account or,
  - b. Dedicated PV string for the purpose of providing power to the re-purposed existing buildings.
  - c. Provision to be made for battery backed-up emergency power that is suitably sized to supply (1) admin building lights, (2) security camera's/alarms and related equipment required to monitor the plant, (3) perimeter lights, (4) communication equipment (e.g. servers and related HVAC), (5) Sub-station electrical protection equipment/devices and (6) Fire systems. Battery back-up time to be 24 hours. These batteries can be recharged from the PV Plant or the Dedicated PV string.
2. Provision to be made for the Wind Farm administration building to be provided with a diesel generator power socket. Suitable interlocking to be installed to prevent paralleling of un-synchronised supplies.
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.

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#### 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:
  - a. Lightning ground potential rise (GPR) in the context of wire-line technology
  - b. Lightning ground potential difference
  - c. Step and touch voltages
  - d. Electro-magnetic zoning
  - e. Soil resistivity variation across the site
  - f. Earth electrode resistance - resistance is a low frequency parameter whilst the assessment and analysis called for lightning with higher frequencies involved
  - g. Large earth electrodes (example PV field)
  - h. LEMP (All electromagnetic effects of lightning current via resistive, inductive, and capacitive coupling, which create surges and electromagnetic fields.)
  - i. 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.

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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:
  - a. 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  $\mu$ s), limited peak voltage 94 kV at 10 kA (8/20  $\mu$ s)
  - b. Sub Distribution (AC Boards): Overvoltage arrestors (SPD Type II) limited surge voltage: 4 kV at 10 kA (8/20  $\mu$ s)
  - c. Control and monitoring system (CMS): Overvoltage arrestors (SPD Type II) limited surge voltage: 1.5 kV
  - d. 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  $\mu$ s), limited surge voltage: 4 kV at 25 kA (8/20  $\mu$ s)

#### 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 maximum 20 MVA falls under Category B of the Grid code definition, that is, a plant sized between 1 MVA and 20 MVA connected at MV level. 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.

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2. The Sere 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 Sere PV SCADA 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 Sere PV SCADA system shall consist of the following main components:
    - a. **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.
    - b. **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.
    - c. **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 Sere PV Plant.
    - d. **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).
    - e. **Engineering Station** – The PV Plant SCADA system shall provide an engineering station where engineering applications for building, configuring, and maintaining the Sere PV Plant SCADA system.
    - f. **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.
    - g. **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.

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- h. **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.
  - i. **Interfacing to Ancillary Systems** - The Sere 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.
  - j. **Selected Software Related functions of the SCADA System:**
    - i. HMI Application– The HMI display shall provide as minimum display diagrams, monitoring, event and alarming, supervisory control, trending, tagging, data entry and communication monitoring.
    - ii. 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 Sere 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.
  - a. The Scope of Supply shall consist of:
    - i. SCADA Servers, PLC/RTU hardware and software.
    - ii. Controls and Monitors hardware and software.
    - iii. Network Panels, switches, and fibre communication technologies.
    - iv. Configuration, Installation and Commissioning of Systems.
    - v. Factory Acceptance Tests.
    - vi. Compliance and Acceptance Tests.

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- vii. Grid Code Model development, testing and validation. Modelling shall be performed in compliance with the grid code requirements.
- viii. The Contractor shall perform SCADA and control systems engineering.
- ix. The PV SCADA solution shall comply with cyber-security requirements.
- x. 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 (see Figure 3: Sere 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 Sere PV Plant and is based on two systems, namely, the Automation Controllers and the Local Plant SCADA systems.

#### 4.4.5 Sere Wind and PV Combined Operating and Control Philosophy

1. Operating Philosophy
  - a. The Sere PV1a plant shall be modeled and designed to track the Sere Wind Power Reference/ Setpoint feedback value and/or the actual Wind generated MW Sent-out (output). For the total Sere Wind Farm and Solar PV plant to remain within its regulated MEC value, the PV1a plant determines its own generated MW setpoint value based on the status of the Wind MW generation output.
  - b. In principle, as illustrated on the graph below, the PV1a plant is designed to occupy the top part of the sent-out range within the MEC value in order to maximize the capacity factor of the overall Sere (Gx) Wind Power Station.

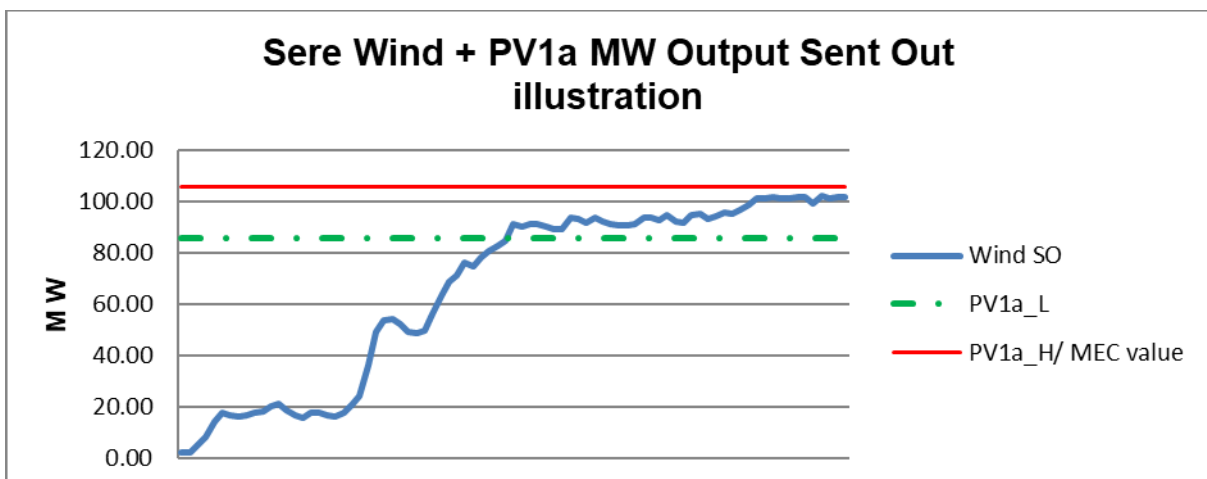


Figure 3: Sere Wind Output Illustration 1

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## 2. Control Philosophy

- a. The EPC Contractor shall model, design, and demonstrate how the control will be managed for the PV1a plant, to comply with the set maximum power evacuation limit of 105.8 MW from the blended Sere plant.

## 3. Automation Controllers (RPP Controller)

- a. The Automation Controllers shall be based upon PLC/RTU technologies or equivalent and shall be redundantly configured at the automation controller level.
- b. Power supplies shall also be redundantly configured.
- c. The Automation Controller hardware shall run standard packaged software and control libraries for all grid control functions required for RPPs.
- d. The systems shall be delivered with standard communication protocols such as Modbus TCP/IP, DNP3, IEC60870-6-101, and others to allow for interfacing with any third-party interfaces.
- e. High-Level functions of the Automation Controllers:
  - i. Active power constraint functions
  - ii. Reactive power and voltage control functions
  - iii. Remote/Local Control Mode
  - iv. Remote Control Mode – in this mode of control, the controller response to either external references from the System Operator or external reference.
  - v. Local Control Mode – in the mode, the Plant Operator is allowed to change the set point manually.
  - vi. Coordination and management of the active power and reactive power of the inverters.
- f. Starting and Stopping of the inverters via the HMI graphics based upon the Local Plant SCADA.
- g. Besides, the Automation Controllers shall collect set points, measurements and statuses to implement control algorithms for regulating process plant control loops and the communication of information to all functional interfaces.

### 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).

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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 reported to the same control suite following the Sere Wind Farm's Fire Detection alarm philosophy., i.e. where 24-hour surveillance of the site is maintained. 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.

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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;
  - a. 240-55410927 Cyber Security Standard for Operational Technology
  - b. 240-79669677 DMZ Designs for OT Systems
  - c. 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.

#### 4.4.9.2 Codes, Standards, and Guidelines

1. 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:
  - a. PV inverter systems
  - b. PV string combiner boxes
  - c. Electrical MV switchgear
  - d. Electrical MV and LV transformers
  - e. Electrical protection relays
  - f. Electrical energy measurement and metering
  - g. Electrical battery tripping units (BTU)
  - h. Uninterruptable power supplies (UPS)
  - i. Internal environmental sensors of equipment panels, network cabinets, inverter stations/cabins
  - j. PV meteorological system (weather station)
  - k. Balance of plant (BoP) potable water and sewage tank levels
  - l. BoP Fire detection system (FDS)
  - m. 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.

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6. The Contractor provides the following hardware for each server machine of the redundant pair:
  - a. redundant central processing units (CPU)
  - b. redundant array of independent disks (RAID) configuration
  - c. redundant power supplies with dual power input ports
  - d. redundant case fans
  - e. two (2) 19" (inch.) rack-mountable type enclosure for the servers and power supplies installed in the plant server room
  - f. all redundant equipment is split across two (2) cabinets
  - g. on-board database to continuously process and store all real time plant data for the lifespan of the plant
  - h. 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:
  - a. hosting the Microsoft Windows operating system suitable for industrial process plant applications
  - b. hosting the CMS application software for operating and monitoring of all equipment
  - c. hosting the anti-virus software
  - d. performing comprehensive operating and monitoring functionality of the plant in real time via the thin clients
  - e. performing network configuration, logic development, mimic development, antivirus, and software updates
  - f. storing and processing of plant data via the redundant information servers' database
  - g. storing of all engineering logic and CMS network configuration settings
  - h. performing of online engineering and diagnostics of the plant via the thin clients
  - i. 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
  - j. 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)
  - k. running the back-up and recovery application in an event of a disaster to the CMS network
  - l. copying of data automatically from the information servers onto the removable media at pre-configured intervals
  - m. 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**

1. 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.

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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:
  - a. managed type with online management and configuration via the thin clients using a network management software installed on the SCADA/CMS servers
  - b. compatibility with Simple network management protocol version 3 (SNMP v3) and Internet protocol version 6 (IPv6)
  - c. online monitoring of the port connections, communication link status, bandwidth, and device health status indicating alarms and faults to the server and remote users
  - d. power supply from dual redundant power sources (230 Vac or 24 Vdc)
  - e. dual power input ports
  - f. 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
  - g. optical fibre and Ethernet ports
  - h. 10% unused ports (rounded up)
  - i. wide operating temperature range
  - j. auto negotiation capability
  - k. auto crossover (MDIX) capability
  - l. 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:
  - a. device state
  - b. link and connection state of each connection
  - c. bandwidth utilization of each connection
  - d. network performance and traffic statistics (latency, throughput, errors, dropped packets)
  - e. 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.

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#### 4.4.11.1 Codes, Standards, and Guidelines

1. 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:
  - a. SANS 10139 Fire detection and alarm systems for buildings — System design, installation, or an accepted equivalent standard
  - b. 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.
  - a. 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.
  - b. The Contractor provides a dedicated network switch to communicate with the BMS equipment.
  - c. The Contractor provides the BMS server to host the application software and the information database to monitor the equipment.
  - d. The Contractor provides a local thin client for the BMS network.
  - e. 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.
  - f. The Contractor provides a dedicated 19" floor standing network cabinet for the BMS equipment.
  - g. The Contractor ensures that redundant equipment and servers are split over across two cabinets.
  - h. 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

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

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#### 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

1. 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.

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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:
  - a. Availability of each inverter
  - b. Energy produced per inverter
  - c. Energy sent out at the point of connection
  - d. Auxiliary power consumed
  - e. Performance ratio of the plant
  - f. Average Irradiance (GHI and DNI)
  - g. Capacity factor
  - h. Specific Yield
  - i. 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:
  - a. 240-55410927 Cyber Security Standard for Operational Technology
  - b. 32-373 Information Security – IT and OT Third Party and Remote Access Standard
  - c. 240-79669677 DMZ Designs for OT Systems

#### **4.4.14.3 Codes, Standards, and Guidelines**

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

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#### 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:
  - a. 3 x 24"(minimum) liquid crystal display monitors (LCD)
  - b. 1 x 40"(minimum) LCD monitor
  - c. Built-in optical drive/BU-ray writer (online backup system)
  - d. 1 x USB type keyboard and mouse
  - e. 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: -
  - a. Alphanumeric characters:
    - i. Text, except for labels, is presented using upper- and lower-case characters.
    - ii. Capitalization is used to start sentences, and to indicate proper nouns and acronyms.
    - iii. Labels are displayed in upper case.
    - iv. 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.
    - v. 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
    - vi. 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.
  - b. Numeric data:
    - i. Numeric values are displayed using the decimal number system.

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- ii. 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.
  - iii. 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.
  - iv. Each numeric display must be able to accommodate all the values in the range of its variable.
  - v. All numeric data is oriented upright.
- c. Abbreviations and acronyms:
- i. Abbreviations are avoided, except when terms are commonly referred to by their initials or abbreviations.
  - ii. Abbreviations and acronyms do not include punctuations. For example, CMS is preferred over C.M.S.
  - iii. 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.
  - iv. When arbitrary codes use both letters and numbers, the letters are grouped together, and numbers grouped together rather than interspersing letters with numbers.
- d. Labels:
- i. Label formats are consistent across and within displays.
  - ii. Labels are worded consistently, so that the same item is given the same label wherever it appears.
  - iii. Labels are separated from one another by at least two standard character spaces.
  - iv. Labels are oriented horizontally.
- e. Icons and symbols:
- i. Icons in graphic displays are primarily used to represent actual objects or actions.
  - ii. Icons and symbols are used consistently throughout the displays for all plant areas.
  - iii. Icons are designed to look like the objects, processes, or operations they represent, by use of literal, functional, or operational representations.
  - iv. Icons must be closed i.e.; they must have a continuous outside border
  - v. 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.
  - vi. 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.
  - vii. Icons and symbols are oriented upright.
  - viii. Icons and symbols are large enough for the user to perceive the representation and discriminate it from other icons and symbols.
  - ix. An icon or symbol is highlighted when it is selected by a user.

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- x. 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.
- f. Colour:
  - i. The colours used for coding is readily distinguishable from each other.
  - ii. 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.
- g. Highlighting:
  - i. Highlighting methods (e.g., flashing, and brightness) associated with emergency conditions is not used in association with normal conditions.
- h. Flashing:
  - i. 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.
  - ii. 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.
  - iii. Flash suppression or event acknowledgement keys are provided.
- i. Pointing cursors:
  - i. The pointing cursor is always visible to the user.
  - ii. The pointing cursor does not blink.
  - iii. The position of the pointing cursor is clearly visible during movement from one screen position to another.
  - iv. The pointing cursor maintains its size across all screens and display locations.
  - v. The pointing cursor does not move in the absence of any input from the user.
- j. Display pages:
  - i. Displays are configured in a clear and unambiguous manner to provide the operator with information relevant to the task.
  - ii. Every display contains a title positioned suitably at the top, which briefly describes the contents or purpose of the display.
  - iii. Displayed information, which temporarily overlays and obscures other display data, must not erase the overlaid data.
  - iv. In a multi-page display, each page must be labelled to show its relation to the others.
  - v. 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
  - vi. 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
- k. Menus:
  - i. Navigation is clear, simple, and unambiguous.
  - ii. All menu items are visible to the user without scrolling.

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- iii. Menu options is ordered and grouped logically. If no logical structure is apparent, the menu options must be ordered alphabetically.
  - iv. The order of the menu options is fixed.
  - v. Menus clearly indicate which options are selectable.
  - vi. When the same options appear on several different menus, consistency of wording and ordering on all the menus is maintained.
  - vii. 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.
  - viii. When hierarchic menus are used, the user must have some indication of current position in the menu structure.
  - ix. Users are able to return to the highest-level menu in the hierarchic menu structure by a single key action.
- I. Windows:
- i. Windows are identifiable by a label consistently located at the top of the window's border.
  - ii. Users are able to select separate windows that share a single display screen.
  - iii. 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.
  - iv. The system keeps track of the windows that are open and provide a means of displaying the list of open windows to the user.
  - v. Caution and warning windows are positioned front most on the display.
  - vi. User control of windows is consistent from one display to another for each type of window.
  - vii. Users must be able to close windows with a single action.
  - viii. The users must be able to move windows to different areas of the display.
  - ix. It is not possible to position windows such that they obscure menu bars, access to the command area, or caution and warning messages.
  - x. The action that opens a window automatically makes that window active.
  - xi. Windows have a default location on the display screen.
  - xii. Users must be able to change the horizontal and vertical dimensions of a window independently and together.
  - xiii. The user must be able to scroll through the contents of a window both horizontally and vertically.
  - xiv. Display data that is temporarily obscured by a window object reappears when the object is removed.
  - xv. There is a maximum limit to the number of windows allowed to be open at one time.
- m. Display efficiency:
- i. Response time for acknowledgement of any display control command is no longer than 2 seconds.

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- ii. Any display selected or requested by the operator, including trend displays and dynamic data, is completed within 2 seconds.
  - iii. 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.
  - iv. 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.
- n. Operational requirements:
- i. General:
    - 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.
    - 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
    - Uniformed signal descriptions and abbreviations are used through-out the entire SCADA/CMS and physical plant interface.
  - ii. Errors:
    - No set or sequence of keystrokes causes the operator systems and SCADA/CMS servers to fail or freeze.
    - Any incorrect operation is indicated to the operator by audible signal or suitable text message.
    - 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.
  - iii. Alarms:
    - A comprehensive and integrated alarm handling system is employed, which clearly distinguishes between different alarm types.
    - 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.
    - Faults or operational failure detected on each individual string, or the network raises an alarm to the control room operator.
    - Alarm handling and management system is designed in accordance with international standards, Eskom's standards and guidelines, and best engineering practice.

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#### 4.4.17 SCADA/CMS Plant Information Server (PIS) Requirements

The Contractor provides the following requirements:

1. General:

- a. 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.
- b. 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:
  - i. Alarm data
  - ii. Sequence of Events (SoE)
  - iii. Field and other system's readings (inputs and outputs)
  - iv. Calculated variables
  - v. Control variables
  - vi. SCADA/CMS system settings
  - vii. Operator inputs (key logging)
- c. 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.
- d. 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.
- e. 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.
- f. The software application stores historical plant information on-line for the lifespan of the plant at maximum resolution.
- g. 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.
- h. 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:
  - i. Trends
  - ii. Chronological lists
  - iii. Reports
  - iv. Process graphics
  - v. Performance calculations and analysis

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- vi. Event history and analysis
  - vii. Importing/exporting of information from/to Microsoft Excel®, and via SQL and OPC
  - i. Data stored in the Historian database are appropriately time stamped.
  - j. Comprehensive prioritising, grouping, filtering and database sorting is provided from the SCADA/CMS servers.
  - k. The historian databases are open to queries from OPC Clients
  - l. 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:
- a. From the SCADA/CMS thin clients, trends are configurable. The user, as a minimum, is able to configure the following:
    - i. Select the tags to view.
    - ii. Specify the start and stop date of each trend.
    - iii. Specify the start and stop time of each trend.
  - b. 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:
- a. Binary Events:
    - i. From the SCADA/CMS thin clients, the user views binary events in the form of a chronological list. The chronological list includes:
      - event date
      - event time
      - tag name
      - tag description
      - tag value
    - ii. The user filters the binary events, as a minimum, according to:
      - unit
      - tag name
      - tag description
      - time period
    - iii. The user saves the binary event history as a .CSV or .XLS file type.
  - b. Alarm Events:
    - i. 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:
      - event time
      - tag name
      - tag description

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- tag value
- ii. The users filter the alarm events, as a minimum, according to:
  - unit
  - tag name
  - tag description
  - priority
  - entry/exit
- iii. The users save the alarm event history as a .CSV or .XLS file type.
  - Operator Events:
- iv. 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:
  - unit
  - operator system
  - time period
  - event type
- v. The user saves the Operator event as a CSV or .XLS file type.
- c. Reports:
  - i. A report generator that builds and schedules reports is provided at the SCADA/CMS thin clients
  - ii. From the SCADA/CMS thin clients, the users, as a minimum, are able to configure the following:
    - create, edit, and store reports.
    - create, edit, and store report formats.
    - Schedule the automatic creation of reports at periodic intervals, elapsed times or on the occurrence of an event (e.g., alarm or event message)
  - iii. The following reports are to be generated by the system for each PV installation and collectively:
    - Availability of each inverter
    - Energy produced per inverter.
    - Energy sent out at the Point of Connection
    - Auxiliary power consumed
    - Performance ratio of the plant
    - Average irradiance (GHI and DNI)
    - Capacity factor
    - Specific yield
    - Alarms, faults, and trips

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- iv. Remote client users create and save a report of selectable parameters via a standard web browser in .CSV or .XLS file formats.
  - v. The users create reports and report formats without any software programming. The report generator provides total control over report format similar to spreadsheet packages.
  - vi. The users include both near real-time and historical plant information.
  - vii. Users produce lists of totals and averages and apply arithmetic functions to plant information.
  - viii. The types/classes of data used by the report generator includes the following:
    - analogue variables
    - status of multi-state variables
    - alarm and event messages
    - calculated variables
    - batch-end information for sequence control
    - historical data values and status
    - any other retrievable tagged items
  - ix. Users are provided data in the form of:
    - current values
    - batch values
    - database query value
    - operator entry values
  - x. Users save reports CSV, .XLS and HTML files.
  - xi. 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
- d. Process Graphics:
- i. The process graphics are configurable by a user at the SCADA/CMS thin clients. The user, as a minimum, configures the following:
    - create, edit, and store graphical displays
    - select the tags to be displayed in the process graphic displays
  - ii. The user is able to include both near real-time and historical plant information in the displays.
  - iii. 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:
  - a. a global positioning system (GPS) antenna and a time server

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- b. implement the network time protocol (NTP) via an Ethernet connection to the SCADA/CMS network switch.
- c. time stamping with an accuracy of 10 milliseconds (UTC+2)
- d. on loss of the GPS signal, the accuracy of the GPS clock, i.e.: deviation from UTC is less than 1 minute per day.
- e. determine its installation position automatically by self-calibrating.
- f. retains critical data (by means of non-volatile memory or battery back-up) in the event of power supply failure.
- g. automatic time synchronisation to the plant, after recovery from any GPS time sync system failure or power supply failure
- h. the GPS antenna and receiver system provided are highly resistant to electrical surges from sources such as lightning.
- i. an on-board display and function keys
- j. monitoring and alarming of the time server at the SCADA/CMS thin clients
- k. 19" rack or DIN rail enclosure
- l. 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:
  - a. network protocol convertors
  - b. network medium convertors
  - c. digital or analogue input and output (IO) modules
  - d. programmable logic controllers (PLC) with on-board IO cards, communication processors and protocol convertors
  - e. dc power supplies (12 V or 24 V)
  - f. 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.

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#### 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:
  - a. grommets are installed where panels are cut for communication and power cable entry.
  - b. Internal cable channels or traces to neatly route cables inside the cabinet.
  - c. Removable blanking panels on all unused slots or sections
  - d. Adequate depth (> 200 mm free space) to allow air circulation around cables in the rear.
  - e. Perforated front and rear door and side panels to allow circulation of air.
  - f. Flexible brushes to be used to prevent air leakage via cable entries or cut-out.
  - g. Include 19" racks and DIN rails to mount equipment.
  - h. Removable perforated front and rear door panels
  - i. Doors with manual locking mechanism and automatic open/close detection
  - j. Internal lights for illumination
  - k. 10% uninstalled space on the racks and DIN slots to install spare equipment.
  - l. blanking panels on un-used slots
  - m. 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

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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 as a guide to size the SCADA/CMS power supplies.

**Table 4: 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
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 to the

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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:
  - a. CMS network cabinet/s (servers, thin clients, switches, splice trays, etc.)
  - b. Building management system (BMS) network cabinet
  - c. Redundantly configured CMS UPS system cabinet/s
  - d. Plant security system network cabinet/s
  - e. 1 x 19" IT network cabinet
  - f. 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.

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#### 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.
  - a. Detailed CMS network single line diagram of the complete CMS works.
  - b. Detailed field wiring schematics
  - c. Site specific equipment locations and cable route diagrams
  - d. Instrument and equipment list
  - e. Cable schedule and cable specifications (power and communication)
  - f. 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.)
  - g. CMS signal list
  - h. All instrument and equipment datasheets, manuals, specifications
  - i. CMS load list (Power supply and distribution SLD including design calculations, battery sizing, etc.)

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- j. Server room network cabinet and CMS equipment panel specifications and general arrangement diagrams (2D and 3D)
- k. Control and server room specifications and general arrangement diagrams (2D and 3D)
- l. Calibration and Factory acceptance test certificates
- m. Site acceptance test (SAT) procedure and check sheet.
- n. Site integration test (SIT) procedure and check sheet.
- o. Commissioning procedure and check sheet.
- p. 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
- q. 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

1. 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:
4. 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.

#### 4.5.1 Codes, Standards, and Guidelines

1. 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.

#### 4.6.1 General Requirements for the Security System

1. The Sere Solar PV Functional Specification for the Security Fence is attached in Appendix I.

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2. The Sere Solar PV power plant shall provide a security solution to protect the PV Plant from any security breach (such as theft of PV modules).
3. 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.
4. All sensitive areas shall be protected by physical barriers (openings and doors shall be secured, protected, and alarmed).
5. Alarms shall be centrally enunciated (within the Admin Building Control Room and Security Building or remotely communicated).
6. 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.
7. Therefore, it is essential to protect the PV infrastructure, and precautions shall be taken to protect the power plant's safety and security.
8. Security measures may include anti-theft bolts, CCTV Cameras, alarms, and security fencing (see functional specification 562/2 High Risk Security Mesh Fence: System Technical Specification for Sere Solar PV Plant Phase 1a). These measures shall be designed to reduce the risk of security breach, theft or tampering with Sere Solar PV systems and equipment.
9. 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.
10. 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:
  - a. The protection and security systems shall be operating at greater than 95% availability.
  - b. The security system shall provide support to the security personnel should any potential risk or threat materialize.
  - c. 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.
  - d. The security system shall be an integrated solution.
11. Security planning undertaking with all relevant security stakeholders and shall not be undertaking in isolation (planning with Eskom's Group Security).
12. The EPC Contractor shall be responsible for the supply, design, installation, and commissioning of all power supplies for the electronic security systems.
13. 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.
14. The security system shall be in line with the latest security standards and shall be accepted by the insurance provider.
15. The security systems shall satisfy as a minimum several of the following security elements:
  - a. Permanent Security Fencing
  - b. Permanent Security System
  - c. Temporary onsite security during construction
  - d. CCTV Cameras
  - e. Access Control

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- f. Video Analytics Software and Digital Video Recorder
- g. Security Sensors
- h. Warning Devices (such as warning signs or use of CCTV cameras and site monitoring to dissuade intrusion).
- i. Security Staff
- j. Remote Alarming
- k. Interfacing between the security systems, SCADA, CCTV, Building Management Systems, Access Control, and monitoring centres where applicable.

#### 4.6.2 Codes, Standards, and Guidelines

1. 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:
  - a. Direct expansions air conditioning units, air handling units, ductwork, pipework, condensers, evaporators, and its associated subsystems with new energy efficient systems.
  - b. Mechanical ventilation system, complete with fans, grilles, louvres, and ducting.
  - c. Associated electrical works and related controls & monitoring of complete HVAC system.
  - d. Complete HVAC related building and civil works.
  - e. Interfacing with SCADA/CMS for monitoring of complete HVAC system.
  - f. Provision of painting and corrosion protection for complete Works.
  - g. Provision of training, operation & maintenance manuals.
  - h. 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  $\pm 5\%$  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 5.

**Table 5: Required indoor conditions**

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

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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.
  - a. Summer: 43,2°C DB
  - b. Winter: 0°C DB
  - c. Altitude: 32 m

#### **4.7.2 HVAC System Description**

1. The O&M Control desk shall be accommodated in the existing Sere Wind Farm facility Control Room. The Contractor shall confirm that the required indoor design conditions can be maintained by the existing HVAC system, and provide any required modifications accordingly.
2. One (1) closed office and ten (10) open plan work stations shall be accommodated in the existing Sere Wind Farm Exhibition area. The Contractor shall confirm that the required indoor design conditions can be maintained by the existing HVAC system, and provide any required modifications accordingly.
3. Six (6) open plan work stations shall be accommodated in the existing Sere Wind Farm Workshop and Stores building, on the slab above Office 1 and Office 2. The Contractor shall confirm that the required indoor design conditions can be maintained by the existing HVAC system, and provide any required modifications accordingly.
4. The PV Server and Equipment Room shall 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.
5. The Security Access Building is to be serviced by dedicated direct expansion split units, 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.
6. 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 and Equipment 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.
7. Outdoor filtered air shall 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.
8. The PV Spares Storeroom should have a natural ventilation system with filters installed to ensure sufficient air circulation and limit the ingress of dust.

#### **4.7.3 HVAC System Commissioning**

1. 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:

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- 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

1. 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 existing Sere Wind Farm has a fire protection system installed around the O&M building, and Workshop and Stores building, including a fire water storage tank, fire water pumps, fire hydrants, and sprinkler systems (refer to Appendix G). The Contractor shall evaluate, modify (if required), and extend the existing fire protection systems to adequately cover any new installations.
6. The Fire Protection System works include the following:
  - a. 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.
  - b. SABS symbolic signs are to be installed to clearly indicate all firefighting equipment, fire escape routes, and exit doors in accordance with SANS 1186.
  - c. Provision of training, operation, and maintenance manuals.
  - d. Plant codification and labelling for the complete works.
  - e. The Contractor makes provision for spares and maintenance support for the Operation and Maintenance period.
7. 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:
  - a. Ensure protection of occupants (life safety)

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- b. Minimize the spread and intensity of fire
  - c. Minimize and control the generation of fire and spread of smoke
  - d. Ensure sufficient building stability is retained in a fire
  - e. Provide adequate fire detection and fire extinguishing equipment, and access for fire brigade services
8. 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.
  9. 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 banded. Cable entries into the band shall be piped up above the band level using non-combustible materials. All band drains shall be fitted with fire traps.
  10. Door sets to all enclosed fire risk areas shall have a minimum two-hour fire rating and shall be fitted with self-closing devices.
  11. The Contractor shall be responsible for fire protection on the entire site in the Contractor's scope during the construction period.

#### **4.8.1 Codes, Standards, and Guidelines**

1. 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 five (5) Security Staff stationed at the Security Access Building.
3. The Contractor shall evaluate the option for installing a sewage conservancy tank system and infrastructure at the Security Access Building.
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.

##### **4.9.1 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.

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#### 4.9.2 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:
3. Complete design in accordance with the requirements of this specification.
4. Sizing and optimizing of the different components.
5. Design of the sewage conservancy tank and all other associated supporting structures.
6. The Contractor ensures the sewage conservancy tank is functionally and efficiently located and that it is sized for optimum space usage.

#### 4.9.3 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.

#### 4.9.4 Codes, Standards, and Guidelines

1. 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:
  - a. Irradiance:
    - i. 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.
    - ii. 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
    - iii. For bifacial modules, minimum of six (6) in-plane rear-side irradiance or, optionally, spectrally matched in-plane rear-side irradiance albedometers.

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- b. PV module temperature:
    - i. Minimum of six (6) thermal sensors (according to IEC 61724-1) to measure module surface temperature with a measurement resolution  $\leq 0.1^{\circ}\text{C}$  and uncertainty of  $\pm 1^{\circ}\text{C}$  at the PV module back sheet.
    - ii. 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 and allow determination of an effective average.
  - c. Ambient air temperature:
    - i. Minimum of two (2) shielded ventilated thermocouples, appropriately distributed around the PV Plant, to measure the ambient temperature with a measurement resolution of  $\leq 0.1^{\circ}\text{C}$  and uncertainty of  $\pm 1^{\circ}\text{C}$  (according to IEC 61724-1).
  - d. Soiling:
    - i. 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).
  - e. Wind speed and direction:
    - i. 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).
    - ii. 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.
  - f. Rainfall:
    - i. Minimum of two (2) rainfall measurement sensors, appropriately distributed around the PV Plant.
  - g. Humidity:
    - i. Minimum of one (1) relative humidity measuring sensor.
  - h. Tracker system:
    - i. 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.

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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:
- a. Tests before Installation;
  - b. Tests after Installation;
  - c. Tests after Completion; and
  - d. Tests after Operational Acceptance.

##### **4.11.1 General Requirements**

1. The Contractor:
- a. Refers and complies with the following Standards:
    - i. IEC 62446 - Grid connected photovoltaic systems - Minimum requirements for System documentation, commissioning tests & Inspections" to complete the minimum requirements for a PV Plant commissioning.
    - ii. IEC 60364-6 - Low Voltage Electrical installations.
    - iii. IEC 62337 - Commissioning of Electrical, Instrumentation and Control systems.
    - iv. Grid Connection Code for Renewable Power Plants (RPPs) connected to the Electricity Transmission System (TS) or the Distribution System (DS) in South Africa.
    - v. SANS 10173 Code of Practice for the Installation, Testing and Balancing of Air Conditioning Ductwork, or CIBS Commissioning Code A: 1996 or latest revision.
    - vi. Automatic Controls: CIBS Commissioning Code B: 1996 or latest revision.
    - vii. Refrigerating Systems: CIBS Commissioning Code R: 2002 or latest revision.
  - b. Uses Commissioning best practice methods and any other relevant standards.
2. Personnel and Facilities:-
- a. 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.
  - b. 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.
  - c. Provides staff with the relevant skills and competence for the inspection, testing, commissioning, performance testing and witnessing required.
  - d. Provides an ECSA registered professional engineer to declare the installation complies with all standards & requirements.
  - e. Ensures that the supervising commissioning engineer has a minimum of 3 years' experience in the commissioning and performance testing of utility scale PV installations.

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- f. 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 arise.
- g. 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.
- h. 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.
- i. Commences commissioning activities respecting all legal, environmental, and administrative requirements.
- j. Co-operates with the respective authorities for verification of their requirement during project installation, commissioning, and operation.
- k. 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:-

- a. Provides any instruments or other equipment for the Employer and Employer's representatives to review the accuracy, quality, and performance of the PV Plant.
- b. Provides any assistance required by Employer and Employer's representatives in the use of instruments and measuring equipment.
- c. 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.
- d. 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:-

- a. 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.
- b. 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:-

- a. 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:
  - i. Definition of each test type and test methods

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- ii. List of equipment to be used for each test along with technical specification, measurement uncertainties and relevant certificates
  - iii. Duration of each test
  - iv. Test evaluation method (including equations – wherever applicable)
  - v. Acceptance/Rejection criteria for each test type
- b. Provides the report to the Project Manager upon the successful commencement of any tests during commissioning. The report includes, but not limited to:
- i. Final test protocol
  - ii. Raw data (un-processed)
  - iii. Evaluation of raw data (processed data)
  - iv. 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:-
  - a. Factory Acceptance Test
  - b. Independent Laboratory Test
  - c. 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:-
  - a. Date of commencement of each test type
  - b. Detailed description of inspections/test types
  - c. Component certificates, technical data sheets
  - d. Manufacturer's quality certificates
  - e. Standards to be followed during testing/inspection
  - f. 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:-
  - a. Definition of each test type and test methods
  - b. Technical data along with the component certificate of the tested components
  - c. Test evaluation and technical data of tested components, including relevant certificates
  - d. Compliance with the requirements for the Project and/or Industry practice
  - e. Summary and conclusion with regard to acceptance or rejection of equipment

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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:-
  - a. The Contractor verifies that all PV modules that are delivered for the Project have been quality checked and complies with the Employer's requirement.
  - b. 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:
    - i. Nominal vs. Manufacturer Flash Test Power Comparison
    - ii. Independent Laboratory Test – Counter Check
  - c. Nominal vs. Manufacturer Flash Test Power Comparison:
    - i. 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.
    - ii. 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.
  - d. Independent Laboratory Test – Counter Test:-
    - i. 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.
    - ii. 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.
    - iii. The counter test consists of two major inspections: Visual inspection and Power measurement.
    - iv. 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.
    - v. 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  $\pm 3\%$  (for c-Si modules). The measurements are carried out with AAA class sun simulator according to IEC 60904-9.

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- vi. 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 6 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 6: 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

- vii. 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.
- viii. 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.
- e. Upon the completion of power comparison test and counter test, PV modules fulfil the following conditions for delivery for the Project.
- i. Manufacturer flash test data confirm that every module to be delivered for the Project has MPP power within the provided tolerance ranges
  - ii. Visual inspection carried out on sample module according to IEC 61215 does not detect any damages or abnormalities; and
  - iii. 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.
- f. 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:
- a. 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 7.

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**Table 7: Inverter certificate standards**

Standard	Description
<b>Minimum required standards</b>	
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

- b. 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:
  - i. Visual inspection
  - ii. Cabling checks
  - iii. Protective conductor test
  - iv. High Voltage test
  - v. Configuration of assembly components
  - vi. Functional test
  - vii. Long term test
  - viii. Safety and protection test
- c. The Contractor only delivers the inverters to site upon submission and acceptance of its factory acceptance test results.
- d. The Contractor delivers inverters to the site with all relevant documents (test reports, relevant certificates, technical data sheet, warranty, installation manuals etc.).

10. Transformer:

- a. 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.
- b. 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:
  - i. Transformer Ratio Test
  - ii. Insulation Resistance Test
  - iii. DC Winding Resistance Test
  - iv. Temperature Rise Test
  - v. Load Loss Measurement
  - vi. Power Frequency Voltage Withstand Test
  - Lightning Impulse Test

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- c. Transformer Ratio Test:
- i. 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.
  - ii. 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.
  - iii. The results are recorded on a test sheet.
- d. Insulation Resistance Test:
- i. This test is carried out with all cables disconnected; a 5kV insulation resistance test is to be applied:
    - between primary winding and earth.
    - between secondary winding and earth.
    - between primary and secondary winding.
    - The results are recorded on a test sheet.
- e. DC Winding Resistance Test:
- i. The winding resistance is checked on all taps of the tap changer to verify there is no high resistance on the tap changer and windings. A DC winding resistance test set is used for this test. This test is carried out in accordance with IEC 60076-1.
  - ii. The results are recorded on a test sheet.
- f. Temperature Rise Test:
- i. To be carried out in accordance with IEC 60076-2, at rated voltage, rated frequency and with rated power of the secondary winding.
  - ii. The winding temperature is ascertained by using the resistance method. The hot spot temperatures rise is performed in accordance with the SANS 60354.
  - iii. Full details of the test arrangements, procedures and conditions are supplied with the test certificates.
- g. Load Loss Measurement:
- i. The Employer does not allow any tolerances on load losses above those stated in IEC 60076-1.
  - ii. The load losses on every transformer is measured on the principal tapping position and corrected to the reference temperature specified in IEC 60076-11.
- h. Power Frequency Voltage Withstand Test:
- i. Both a separate-source AC withstand voltage test and an induced AC withstand voltage test are performed in accordance with IEC 60076-11.
  - ii. The basic insulation levels and corresponding test voltages will be in accordance with IEC 60076-3.
- i. Lightning Impulse Test:
- i. This test is carried out in accordance with IEC 60076-11.
  - ii. The basic insulation levels and corresponding test voltages will be in accordance with IEC 60076-3.

## 11. Switchgear and Ring Main Units:

- a. 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.
- b. Routine tests for RMUs are according to the requirements in SANS 62271-200.
- c. Internal arc classification test for RMUs are according to the requirements in SANS 1874.
- d. 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:
  - i. 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.),
  - ii. 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,
  - iii. 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.
  - iv. RMUs for indoor applications shall be tested in accordance with SANS/IEC 62271-200. The following requirements for these tests shall apply:
    - The tests shall be performed on each RMU manufacturer type and design offered (i.e., same material, dimensions, manufacturing method, manufacturer, manufacturing location, etc.),
    - 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.
- e. 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.
- f. The following Site Tests are performed:
  - i. Visual Inspection
  - ii. Timing and Contact Resistance Tests on Circuit Breaker
  - iii. Insulation winding resistance and Ratio test on voltage/current transformers
- g. Visual Inspection:
  - i. 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.
- h. Circuit Breaker:
  - i. 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.

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- ii. Timing Test: The circuit breaker is to be electrically operated and verified that the opening and closing times fall within the designed parameters.
    - iii. 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.
  - i. Voltage and Current Transformers:
    - i. 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:
      - Insulation Winding Resistance Test
      - Ratio Test
      - Type Test
12. The Contractor complies with the following mandatory type tests as per SANS 62271-200:
- a. Test to verify the insulation level of the equipment
  - b. Test to prove the temperature rise of any part of the equipment and measurement of the resistance of circuits
  - c. Prove the capability of the main and earthing circuits to be subjected to the rated peak and the rated short time withstand currents
  - d. Tests to prove the making and breaking capacity of the included switching devices
  - e. Tests to prove the satisfactory operation of the included switching devices and removable parts
  - f. Tests to verify the IP protection code
  - g. Tests to verify auxiliary and control circuits
13. SCADA/CMS Test:
- a. 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.
  - b. The Contractor provides the following factory acceptance tests for SCADA/CMS equipment, but not limited to:
    - i. 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.
    - ii. Redundancy and single fault tolerance checks will be performed on network equipment, servers, thin clients, switches, power supplies, etc.
    - iii. Application software checks will be performed as required.
14. Low Voltage Installations:
- a. All low voltage installations including distribution boards are tested in accordance with SANS 10142-1.

#### 15. Site Acceptance Test:

- a. Site Acceptance Test refers to the inspections and document verification of all components immediately after the delivery of components on site.
- b. 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.
- c. 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:
  - a. Completeness of the mechanical and electrical construction works
  - b. Correctness of the assembly and installation
  - c. Safety and reliability of the works under all operating conditions
  - d. Inspection and functional tests
  - e. 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:
  - a. 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.
  - b. 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:
  - a. Basic system information:
    - i. Project location and installation date
    - ii. Rated system capacity (DC and AC)
    - iii. PV modules and inverter – manufacturer, model, and quantity
    - iv. Installation date
    - v. Commissioning date (to be updated later if time schedule of tests not met)
  - b. System designer's information (name, affiliate, contact details)
  - c. System installer/Contractor information (name, affiliate, contact details)
  - d. 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.

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- e. General specifications of array:
    - i. Module type
    - ii. Module number
    - iii. Number of modules per string
    - iv. Number of strings
  - f. PV string information:
    - i. String cable type, size, and length
    - ii. Specification (current and voltage rating) of overvoltage protection device
  - g. Electrical characteristics of array:
    - i. Array junction box location
    - ii. Array main cable specification
    - iii. Location, type, and rating of over voltage protective devices
  - h. 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
  - i. A single line diagram including DC and AC isolators location, type and rating along with similar information for AC over-current protection device
  - j. Plant safety regulation following all MCB's, MCCB's, Isolators employed in the AC electrical boards with a padlocking facility
  - k. Technical data sheet of all components
  - l. Full documentation of the SCADA
  - m. Description and documentation of all mechanical structures including details such as material type, structure mounting solution, foundation design, and geotechnical study
  - n. 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
  - o. Documentation of all required legal and administrative permits, if any
  - p. Confirmation on project design and installation compliance with all permits (Environmental, Water Use license and grid code)
  - q. Documentation of module flash test data
  - r. The complete C&I design, network diagram, test certificates and test results.
7. Mechanical Completion Test:
- a. 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.

- b. 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.
- c. The Contractor undertake the following, but not limited to, to verify the physical installation is completed according to the design:
- i. General:
    - Verify all parts of the PV Plant are in line with the Final Design
    - Verify the PV Plant construction is according to the provisions of the Contract
    - Verify all equipment and parts have been installed according to their manufacturer's installation manuals
  - ii. PV Modules:
    - 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
    - Verify that Modules have been sorted according to their Flash Test Data
    - Verify that serial number of each module is documented according to installation location on site
    - Verify that the installation was done according to manufacturer's recommendation and/or requirements
  - iii. PV String Combiners:
    - Verify that PV String cables have been permanently marked and numbered
    - Check cable Pulling Test records
    - 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
    - Verify the integrity of Surge Protection Devices and all Earthing connections
    - Verify the installation according to design and manufacturer's recommendation
    - Verify that the string monitoring system have been installed according to design and requirement for communication to SCADA/CMS system
  - iv. PV Mounting Structures:
    - Verify correct Orientation and Inclination angles for the PV Modules
    - Verify that the installation is free from any corrosion
    - Verify fastening with recommended torque, overall set-out distances, surfacing, alignment and completeness of the assembly
  - v. Foundation and Civil works:
    - Verify all civil works (O&M building, foundation, security systems, internal roads) are completed according to design and according to permits for the Project

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- Verify that security system (fences, video surveillance) are installed according to Employer's requirement
  - Verify HVAC, drainage and sewage systems installed according to as built design
- vi. PV Inverters:
- Verify that all cables and switches have been marked and numbered permanently
  - Inspect all DC & AC cabling and verify that cable types, sizes and lengths are in accordance with the design
  - Verify all inverter parameters are set up within Manufacturer's recommendations, grid requirements and local regulations
  - Verify the ventilation of inverter cabin is installed according to design and inverter manufacturer's recommendation (if any) for operation in project location
- vii. Inverter stations/cabins containing inverters, transformers, and switchgear:
- Verify that all cables and switches have been marked and numbered permanently
  - Inspect AC cabling and switches and verify that types, sizes and lengths are in accordance with the design
  - Verify Voltage Controls
  - Inspect Insulation Test records on all cables and circuits
  - Proper Installation and safety during operation
  - Verify the physical installation of energy meters, protections, earthing and lightning
- viii. Control and Monitoring System:
- Verify all system components and respective electrical and data connections are according to design
  - Verify all Calibration Certificates are available
  - Verify broadband equipment and connections
- ix. Labelling and Identification:
- Verify all circuits, protective devices, switches and terminals are suitably labelled
  - 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
  - Verify the main AC isolating switch is clearly labelled
  - Verify dual supply warning labels are fitted at point of interconnection
  - Verify a single line wiring diagram is displayed on site
  - Verify the inverter protection settings and installer details are displayed on site
  - Verify the emergency shutdown procedures are displayed on site
  - Verify all signs and labels are suitably affixed and durable
- x. 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:

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- 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
  - Automatic controls: CIBS Commissioning Code C: 2001 or latest revision
  - Refrigerating Systems: CIBS Commissioning Code R: 2002 or latest revision
- d. Upon the successful completion of Mechanical Completion Test, the Mechanical Completion Certificate will be issued by the Employer.
8. Electrical Completion Test:
- a. 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.
- b. The Contractor undertake the following, but not limited to:
- i. Tests on AC circuits in accordance with IEC 60364-6:
- Continuity of conductors
  - 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
  - Insulation resistance of the electrical installation
  - The insulation resistance is measured between live conductors and the protective conductor connected to the Earthing arrangement
  - Protection by SELV, PELV or by electrical separation
  - Insulation resistance/impedance of floors and walls
  - Protection by automatic disconnection of the supply
  - Polarity test
  - Check of phase sequence
  - Functional tests
  - Verification of voltage drop
- ii. Tests on DC circuits in accordance with IEC 62446-1:
- 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
  - 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

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- 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
- iii. The following functional tests be performed:
    - Switchgear and other control apparatus to be tested to ensure correct operation and that they are properly mounted and connected
    - 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
  - iv. 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
  - v. 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
- c. Certificate of Compliance
- i. 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).
  - ii. 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
  - iii. 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
  - iv. The Contractor submits test reports of all electrical installations as per the sample test report (Certificate of Compliance) in SANS 10142-1
  - v. CoC and test report is issued only by electrical tester, installation electrician or master electrician for single phase installation
  - vi. CoC and test report is issued only by installation electrician or master installation electrician for three phase and DC installations
  - vii. The CoC is also accompanied by as-built design package documentation
- d. Functional Test of Meteorological System and C&I system:
- i. Functional test procedure and check sheets are provided to ensure that the SCADA/CMS meets the requirements as specified in the Scope of work
  - ii. All meteorological stations signal be working properly, and the data are being recorded into the monitoring system

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- iii. Commissioning of C&I system is according to IEC 62337 - Commissioning of Electrical, Instrumentation and Control systems
  - iv. Test communications with string combiner boxes and inverters
  - v. Verify format and handling of acquired data set
  - vi. Check threshold alarm controls
  - vii. Inspect all system displays, event recording and timing synchronization regime and data storage and upload from local to remote
  - viii. Inspect the site communication systems - broadband cable distribution and GSM (backup, if provided)
  - ix. Inspect operation of display and data-processing software and check visualization from local to remote
  - x. Control of remote system access and data downloading
  - xi. Handover of access rights and passwords
- e. Infrared Thermography:
- i. 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<sup>2</sup>.
- f. Grid Code connection test:
- i. 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
  - ii. The Contractor provides an ECSA registered professional engineer or technologist to declare the installation complies with all standards and requirements
  - iii. 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
- g. Reporting:
- i. Once the Electrical Completion tests are successfully performed, the Contractor provide the report to the Employer, for review and acceptance, including the following:
    - A report, signed by the Contractor, summarizing each test performed and their acceptance or rejection according to the test protocol, relevant standards and requirements
    - Test raw data and processed data
    - Final Test protocol along with list of measurement equipment considered during testing and their specification
    - Certificate of Compliance (COC) for all electrical installations
    - 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

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- ii. 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:
  - a. Mechanical Completion Certificate, Certificate of Compliance (COC) for electrical installations, safety clearance certificates for Plant installations, Completion Certificate have been issued
  - b. 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:
  - a. 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.)
  - b. Safety Guidelines including emergency shutdown/isolation procedures
  - c. Preventive and corrective maintenance procedures including site inspection checklist for each component including power evacuation line and security systems
  - d. Scheduling of routine maintenance
  - e. A checklist of what to do in case of system failure
  - f. Documentation on stock of spare parts and spare parts management including contact information and procedures for replacement of defective components
  - g. Inverter O&M Manual (troubleshooting for error codes, repair, software for inverter, Fault finding on the DC Plant)
  - h. Data Acquisition System and CMS O&M Manual (troubleshooting, equipment descriptions, repair, metering equipment downloading, weather station)
  - i. Method of PV module cleaning
  - j. Operation and maintenance manual for inverter, transformer and module from respective manufacturers
  - k. Performance monitoring and reporting procedures
4. The Provisional Acceptance Test (PAT):
  - a. The Contractor executes the PAT and is witnessed by the Employer and the Employer’s representative.
  - b. The Contractor prepares a detailed test program and test protocol based on requirements described in this document and submits to the Employer for approval.
  - c. The Test program and the test protocol must be accepted by the Employer/Employer’s representative before the commencement of the test.
  - d. 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.
  - e. 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.

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- f. 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<sup>2</sup>, 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.
- g. 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 to be made only for available valid days.
5. The PAT Procedure:
- a. Parameters and Instrumentation:
- i. 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:
- AC Energy output at the Point of Connection (PoC): [kWh]
  - Global solar irradiation on plane of array: [kWh/m<sup>2</sup>]
  - Global solar irradiation on horizontal surface (GHI): [kWh/m<sup>2</sup>]
  - Module temperature: [°C]
  - AC Energy output from each inverter: [kWh]
  - Ambient air temperature: [°C]
- ii. 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.
- b. PAT Stopping and Restarting Procedure:
- i. The PAT is stopped and restarted:
- 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.
  - 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.
- ii. 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.
- iii. 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.
- c. Performance Ratio (PR) Evaluation Procedure during PAT:
- i. The Plant Performance Ratio (PR) is evaluated according to equations below:

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

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<sup>2</sup>

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

d. Plant Availability Evaluation Procedure during PAT:

- i. The Plant Availability is measured for a consecutive 15-day period, for the PAT.
- ii. 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.
- iii. 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/m<sup>2</sup>. This level of irradiation is considered as the minimum level of irradiation required to overcome the inverter's threshold power.
- iv. The stoppage of the Plant due to events caused by the following is not considered while evaluating the Plant availability:
  - events caused by faults that are not attributed to the Contractor (e.g., manual shut-down, inspections not attributable to the Contractor)
  - required by third parties (e.g., insurance companies, authorities)
  - attributable to the grid operator/the Employer
  - the result of Force Majeure events
- v. The Plant Availability  $[AV]$  is defined as average of individual inverter availability, as shown in the equations below:

$$[AV] = \frac{\sum_{i=1}^{i=n} [AV]_i}{n}$$

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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<sup>2</sup>, 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<sup>2</sup>).

- e. Criteria for PAT Acceptance:
- i. The provisional Acceptance Test is considered successful if:
- Measured Performance Ratio (PR) is greater than or equal to Guaranteed Performance Ratio during PAT, and
  - Measured Plant Availability is greater than or equal to Guaranteed Plant Availability during PAT
- f. Criteria for Issuance of Operational Acceptance Certificate:
- i. The Operational Acceptance Certificate is issued by the Employer, if:
- PAT requirements are successfully completed
  - The complete O&M manual is provided by the Contractor and accepted by the Employer
  - Punch List is reviewed and accepted by the Employer
  - All Guarantees and Warranties are successfully transferred to the Project Manager and the Plant is substantially handed over to the Employer
  - The Contractor has stored on-site the minimum required spare parts for the Project

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- The site is free from any wastes, residues from site establishment and construction
- 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 8.

**Table 8: 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 Completion Certificate)
	Plant availability test during year 1 of operation (month 1 to month 12 - after issuance of Completion Certificate)
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)
	Visual Inspection at end of year 2 of operation (end of month 24)
	Electrical Measurement Tests at end of year 2 of operation (end of month 24)

2. Performance Ratio (PR) Test during IATs and FATs:
  - a. The Contractor performs annual performance ratio tests for the Plant operation during the O&M period. There are two performance ratio tests during the O&M period; Performance Ratio Test for IATs (year 1) and Performance Ratio Test for FAT (year 2).
  - b. Performance Ratio test is performed for the operational Plant parameters measured during one complete year period.
  - c. There are no irradiation threshold and valid day’s criteria for performance ratio evaluation during the O&M period.
  - d. The Performance Ratio is only evaluated for the period during which the Plant is available.
  - e. Performance Ratio (PR) Evaluation Procedure during IATs and FATs:
  - f. 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

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

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<sup>2</sup>

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

- g. 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.
  - h. 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 10).
  - i. The Performance Ratio tests during the O&M period is considered successful if:
    - i. 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 9).
  - j. 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:
- a. The Contractor performs annual availability tests for the Plant operation during the O&M period. There are two availability tests during the O&M period; Availability Test for IATs (year 1) and Availability Test for FATs (year 2).
  - b. Availability test is performed for complete one year period during each availability test.
  - c. 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/m<sup>2</sup>. This level of irradiation is considered as the minimum level of irradiation required to overcome inverter's threshold power.
  - d. Plant Availability Evaluation Procedure during IATs and FATs:
    - i. 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.
    - ii. The stoppage of the Plant due to events caused by the following is not considered while evaluating the Plant availability:
      - events caused by faults that are not attributed to the Contractor (e.g., manual shut-down, inspections not attributable to the Contractor)

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- required by third parties (e.g., insurance companies, authorities)
  - attributable to the grid operator/the Employer
  - the result of Force Majeure events
- e. 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<sup>2</sup>, 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

- f. 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<sup>2</sup>).
- g. 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.
- h. 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.

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- i. 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.
  - j. The Availability tests during the O&M period will be considered successful if:
    - i. 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 9).
  - k. 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:
- a. Visual Inspection of the Plant is performed in order to verify correct installation and functioning.
  - b. The visual inspection is performed for following major components but not limited to:
    - i. PV Module,
    - ii. Foundation and Mounting structure
    - iii. Security System and Civil structures (O&M building, etc.)
    - iv. DC Cables, cable routing, electrical connections,
    - v. Junction boxes, fuses, isolation switches, protection device
    - vi. Inverter and Inverter station/cabin
    - vii. Transformer and Switch gear
    - viii. Power evacuation line and point of connection
    - ix. Energy meter
    - x. Meteorological Stations
    - xi. Monitoring and C&I system
    - xii. Remote communication
    - xiii. Security system
    - xiv. And any other Plant components
  - c. The Contractor verifies that the Plant is free from any defects and the Plant does not pose any risk for safe operation.
  - d. The Contractor verifies that the site is free from any wastes, residues from construction, operation, and maintenance.
  - e. The Contractor verifies that the minimum level of spare parts is available on site according to the Employer's requirement.
5. Electrical Measurements:
- a. The Contractor performs:
    - i. 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.

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- ii. 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/m<sup>2</sup>.

6. Criteria for Acceptance of IATs:

- a. The Intermediate Acceptance Tests are considered successful if:
  - i. Measured performance ratio during the year of operation is equal to or greater than the respective performance ratio guaranteed by the Contractor.
  - ii. Measured Plant availability during the year of operation is equal to or greater than the respective availability guaranteed by the Contractor.
  - iii. Any applicable liquidated damage payable to the Employer by the Contractor is completed.
  - iv. The O&M training is successfully completed.
  - v. The complete Plant O&M manual and component O&M manual are delivered to the Employer.
  - vi. The minimum level of spare parts have been stored on site and transferred to the Employer.
  - vii. All guarantees and warranties of components are successfully transferred to the Employer.

7. Criteria for Acceptance of FATs:

- a. The Final Acceptance Tests are considered successful if:
  - i. Measured performance ratio during the year of operation is equal to or greater than respective performance ratio guaranteed by the Contractor.
  - ii. Measured Plant availability during the year of operation period is equal to or greater than respective availability guaranteed by the Contractor.
  - iii. Any applicable liquidated damage payable to the Employer by the Contractor is completed.
  - iv. The visual inspection is successfully completed, and the Plant is free from any defects.
  - v. Electrical measurements are successfully completed.
  - vi. The O&M training is successfully completed.
  - vii. The complete Plant O&M manual and component O&M manual are delivered to the Employer.
  - viii. The minimum level of spare parts have been stored on site and transferred to the Employer.
  - ix. 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:
  - a. Performance Ratio (PR)
  - b. 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 9.

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**Table 9: 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 Final Acceptance Test	77.5 %	
	Guaranteed annual average Plant Availability for year 2 of operation for 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 9, 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 10.

**Table 10: 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 <sup>2</sup> )
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 10) 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

- The Contractor provides equipment warranty according to minimum requirement set in Table 11.
- 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.

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3. The Contractor transfers the ownership of all manufacturer equipment warranties to the Employer during the Operational Acceptance of the Project.

**Table 11: 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:-
  - a. Maintenance spares and consumables: These are items for which the Contractor anticipates that demands will arise in normal operation of the Plant.
  - b. 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.

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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:
- a. PV modules – Minimum of 0.2% of the total installed PV modules per Plant.
  - b. 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 be held onsite.
  - c. 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.
  - d. String DC Cable – Minimum 500 m.
  - e. Main DC Cable – Minimum 500 m.
  - f. AC Power cables – Minimum 500 m.
  - g. Communication cables – Minimum 500 m.
  - h. MV transformers – Minimum one (1) unit.
  - i. MV switchgear / RMU – Minimum one (1) unit.
  - j. 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.

#### 4.14.1 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.

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#### 4.15 Operation and Maintenance

1. 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 [12] 240-53113685 Design Review Procedure.
2. The Contractor is responsible for following, and conducts all the reviews as specified in [12], including:
  - a. Design Freeze Review
  - b. Integrated Design Review
  - c. Construction Completion Review
  - d. Acceptance Testing Review
3. The following process is followed during submission of documents:
  - a. The Contractor submits the documents/drawings to the Employer.
  - b. The Employer's Document Controller registers the documents.
  - c. The Employer's Document Controller will supply the documents/drawings to all relevant parties within the Employer's project team.
  - d. 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.
  - e. 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.
  - f. The Employer reviews the documents/drawings and if no major deficiencies are found, the Contractor organises a Design Review session.
  - g. The Contractor conducts the Design Review session and invites the Employer to attend/participate.
  - h. 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.
  - i. The Contractor organises a Design Review session once all designs were revised according to the concerns raised by the Employer.
  - j. 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.
  - k. 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.
  - l. 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.

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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:
  - a. Complies with the Functional Specification Document.
  - b. Has been checked and dated.
  - c. Has been co-ordinated in sequence and physical relationship with the work of others.
  - d. 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
  - a. The Contractor shall use the latest versions of application software.
  - b. The Contractor shall provide all information in an electronic format as shown Table 12, or otherwise compatible with the project electronic data management system, as agreed.

**Table 12: 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

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## 17. Format &amp; Copies of Submissions

- a. All Documents shall be equipped with an index where applicable. Such index shall be hyperlinked in electronic formats of the Documents.
- b. The Contractor shall submit the Documentation in electronic format and on paper copies as shown in Table 13.

**Table 13: 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.

**All Contractor's Documents selected for review will be given a status mark as shown in**

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20. Table 14.

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**Table 14: 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

- The Contractor submits all design, documents, and drawings in compliance with the requirements indicated in the Functional Specification Document.
- All design, equipment, materials, fabrication and tests conforms to the latest applicable standards indicated in the Functional Specification Document.
- All design and equipment are entirely suitable for the use under the site conditions.
- 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.
- The Contractor provides, but not limited to, documents, drawings, design information in the time manner indicated in Table 15 to ensure the finalization of design within agreed timelines.

**Table 15: Documents related to design phase**

No.	Document / Drawing	Review Type
Within 1 week after issue of <i>Contract Date</i>		
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 <i>Contract Date</i>		
5	List of Permits, Approvals required for the Project	I/A
Within 3 weeks after issue of <i>Contract Date</i> (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 <ul style="list-style-type: none"> <li>• Road: Internal Road, perimeter road and access to inverter cabin, O&amp;M building, PV Plant substation, meteorological station, and any other civil infrastructures</li> <li>• Foundation: type, layout, design, and material</li> </ul>	A

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No.	Document / Drawing	Review Type
	<ul style="list-style-type: none"> <li>• O&amp;M building: layout, design, and material</li> <li>• PV Plant Substation: layout, design, and material</li> <li>• Parking Area: layout, design, and material</li> <li>• Drainage and Sewage System: layout, design, and material</li> <li>• Concrete mix design</li> <li>• Method statement for civil engineering works</li> </ul>	
9	Cable routing layout: <ul style="list-style-type: none"> <li>• DC: String Configuration, String to Combiner box and to Inverter Cabin</li> <li>• AC: Inverter Cabin to 22kV switching station</li> <li>• MV Cables (underground and overhead)</li> </ul>	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: <ul style="list-style-type: none"> <li>• Fencing</li> <li>• Perimeter lighting and security systems according to specification</li> <li>• Construction method</li> </ul>	A
13	C&I System according to specification: <ul style="list-style-type: none"> <li>• Detailed CMS network single line diagram of the complete CMS works</li> <li>• Detailed field wiring schematics Site specific equipment locations and cable route diagrams</li> <li>• Instrument and equipment list</li> <li>• Cable schedule and cable specifications (power and communication)</li> <li>• 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.)</li> <li>• CMS signal list</li> <li>• All instrument and equipment datasheets, manuals, specifications</li> <li>• CMS load list (Power supply and distribution SLD including design calculations, battery sizing, etc.)</li> <li>• Server room network cabinet and CMS equipment panel specifications and general arrangement diagrams (2D and 3D)</li> </ul> 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: <ul style="list-style-type: none"> <li>• PV module</li> <li>• Mounting structure</li> <li>• DC, AC and Communication Cables</li> </ul>	A

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No.	Document / Drawing	Review Type
	<ul style="list-style-type: none"> <li>• Combiner Boxes</li> <li>• Inverter and MV Cabins</li> <li>• LV/MV Transformer, Auxiliary transformer, and switchgear</li> <li>• Switchgear type test certificate including arc flash, proof of type test laboratory accreditation, copy of RMU factory routine test certificate.</li> <li>• MV Cables (Underground and Overhead)</li> <li>• Meters and protection devices</li> <li>• C&amp;I System</li> <li>• Meteorological system</li> <li>• System studies report (Dynamic studies using Powerfactory model)</li> </ul>	
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: <ul style="list-style-type: none"> <li>• Factory Acceptance Test</li> <li>• Site Acceptance Test</li> <li>• Mechanical Completion Test</li> <li>• Electrical Completion Test</li> <li>• Completion Test</li> </ul>	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 <i>Contractor</i>	I/A
Within 5 weeks after issue of <i>Contract Date</i> 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 <i>Contract Date</i>		

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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 16.

**Table 16: Documents related to procurement phase**

No.	Document / Drawing	Review Type
Within 2 weeks after issue of <i>Contract Date</i>		
1	List of product type and manufacturer that the <i>Contractor</i> is intending to consider for the Project: <ul style="list-style-type: none"> <li>• PV Module</li> <li>• Inverter</li> <li>• Combiner/Junction box</li> <li>• Inverter Station/Cabin</li> <li>• LV/MV transformer type and Auxiliary transformer</li> <li>• Switchgear</li> <li>• Meters</li> <li>• C&amp;I system</li> <li>• DC cabling</li> <li>• AC cabling</li> <li>• Communication cable</li> <li>• C&amp;I System</li> <li>• Security Components</li> <li>• Meteorological System/ Weather Stations</li> </ul>	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: <ul style="list-style-type: none"> <li>• detail description of inspection test types</li> <li>• components certificates, technical data sheets</li> <li>• manufacturers' quality certificates</li> </ul>	A

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No.	Document / Drawing	Review Type
	<ul style="list-style-type: none"> <li>components to be used during test/inspections</li> <li>standards to be followed during tests/inspections</li> <li>acceptance and rejection criteria of each test</li> <li>Test results from previous inspections/tests, if available</li> </ul>	
9	For PV modules <ul style="list-style-type: none"> <li>Flash Test Data Sheet from manufacturer for all PV modules to be delivered on site in compliance to specification</li> <li>Independent Laboratory Test location for counter test including ISO/IEC 17025 certificate according to specification</li> </ul>	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

- The Contractor provides, but not limited to, documents as indicated in Table 17 before, during, the site establishment and construction phase.

**Table 17: 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 Plan	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

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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 <ul style="list-style-type: none"> <li>• Construction <i>Contractors</i> at the site,</li> <li>• <i>Contractor's</i> engineering service support team</li> <li>• Sub-<i>Contractors</i> (if any) at the site</li> <li>• No. of workers on site</li> </ul>	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 <i>Contractor</i> wishes to include in the report upon discussion with <i>Employer</i> .	I
Within one week after the test during construction		
20	Concrete test report for 7 days, 28 days	A

## 5.5 Mechanical Completion

- The Contractor provides, but not limited to, documents as indicated in Table 18 before, during, and after mechanical completion.

**Table 18: 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
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

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No.	Document / Drawing	Review Type
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 <i>Employer</i> and the <i>Employer's</i> 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/ <i>Contractor's</i> 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 <ul style="list-style-type: none"> <li>• Module type</li> <li>• Tracking of module serial numbers</li> <li>• No of modules per string</li> <li>• Number of strings per combiner boxes and per inverter</li> </ul>	A
21	Cabling information <ul style="list-style-type: none"> <li>• DC Cable: cable type, size, length and expected losses calculation</li> <li>• AC Cable: cable type, size, length and expected energy losses calculation</li> <li>• Specification (current and voltage ratings) of all protection devices used in DC and AC system</li> <li>• Cable schedules</li> </ul>	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
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

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No.	Document / Drawing	Review Type
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 <i>Contractor</i> 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	<i>Contractor's</i> internal inspection report (signed by the <i>Contractor's</i> 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 signed by the <i>Contractor</i> and Accepted by the <i>Employer</i>	A
37	Final Punch List signed by the <i>Contractor</i> and Accepted by the <i>Employer</i>	A

## 5.6 Electrical Completion

- The Contractor provides, but not limited to, documents as indicated in Table 19 before, during, and after electrical completion.

**Table 19: 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
4	Test evaluation method (including equations-whenever 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		

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No.	Document / Drawing	Review Type
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 <i>Employer's Project Manager</i>	I
Within 1 weeks after completion of Electrical Completion Test		
13	Electrical completion test report (to be signed by the <i>Contractor</i> ) 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 20 before, during, and after the Provisional Acceptance Test.

**Table 20: 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
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		

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No.	Document / Drawing	Review Type
13	Proof of Mechanical, Certificate of Compliance and Commissioning Certificate, accepted by the <i>Employer's Project Manager</i>	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 <i>Employer's Project Manager</i>	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 <i>Contractor</i> ) 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 <i>Employer</i>	A
32	Proof of transfer of all guarantees and warranties to the <i>Employer</i>	A
33	Punch List, if any pending accepted by the <i>Employer's Project Manager</i> and schedule for the correction	A
34	Schedule for Training on Operation and Maintenance of the Facility	A
35	<i>Contractor's</i> document verifying that the site is clean and free from any waste materials from construction and commissioning	A

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## 5.8 Intermediate Acceptance Tests and Final Acceptance Tests

1. The Contractor provides, but not limited to, documents as indicated in Table 21 during and after the Intermediate Acceptance Tests and Final Acceptance Tests.

**Table 21: 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 <i>Contractor</i> )	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 <i>Employer</i>	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 <i>Contractor</i> )	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 <i>Contractor</i> ) 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 <i>Employer</i>	A
22	The Complete Plant O&M manual and Component O&M Manual	A
Within 4 weeks after the Final Acceptance Tests		

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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 <i>Employer</i>	A

### 5.8 Operation and Maintenance

1. Refer to Appendix D of this document.

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## APPENDIX A: PV PLANT INDICATIVE SITE LAYOUT DRAWINGS

Please refer to separate file attached to this document.

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**APPENDIX B: PV PLANT INDICATIVE ELECTRICAL SINGLE LINE  
DIAGRAM**

Please refer to separate file attached to this document.

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## APPENDIX C: PV PLANT CODES AND STANDARDS

Please refer to separate file attached to this document.

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**APPENDIX D: PV PLANT OPERATION AND MAINTENANCE  
REQUIREMENTS**

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## APPENDIX E: PV PLANT LIQUIDATED DAMAGES

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## APPENDIX F: PV PLANT ELECTRICAL POINT OF CONNECTION REQUIREMENTS

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## APPENDIX G: SITE INFORMATION

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## APPENDIX H: SERE WIND FARM FACILITY GENERATION PROFILE

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**APPENDIX I: SERE SOLAR PV PHASE 1A FENCING FUNCTIONAL SPECIFICATION**

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