Employer's Works Information

Engineering, Procurement and Construction of a fixed tilt Rooftop Photovoltaic Power Facility at the CSIR Campus in Pretoria

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Contents

1 Introduction

This *Employer's* Works Information describes the Engineering Procurement and Construction *works* to be executed according to the associated Engineering Construction Contract (ECC) as well as the minimum expected technical requirements. The Works Information also describes the requirements for Operations and Maintenance (O&M) during the O&M Period as well as the Training Programme for the CSIR's staff.

This Works Information also contains the Site Information.

For the purposes of the Works Definition, the following general definitions apply:

The Works means all Engineering, Procurement and Construction and related activities described in this Works Information to deliver a defect-free Solar Photovoltaic (PV) Facility with a design lifetime of 25 years and installed capacity of at least 900 kWp which occupies approximately 8 000 m² within the Site Boundaries.

PV Facility means the functional and operating unit consisting of the materials, equipment and activities in the *works* able to generate and export electricity. The PV Facility remains an element of the *works* until Final Completion.

Completion of the *works* occurs in two stages:

Practical Completion means the *works* have passed the Practical Completion Test and the Facility is accepted for the purposes of Commercial Operation. The *defects period* and O&M Period of 36 months each begins.

Final Completion means the *works* have passed the Final Acceptance Test and the Facility has demonstrated guaranteed performance expectations and is defect-free. The *defects period* and O&M Period conclude.

2 Site Information

2.1 Location

The 5 buildings are located within the CSIR Pretoria Campus in Gauteng South Africa.

Figure 1 : Location of the site within the CSIR Campus

2.2 Clearing of the Site and survey

The employer provides all rooftops survey of the buildings in Schedule 6 of the tender documents which are available. This information provided is general, detailed investigation can be done on discretion.

The sites will require some degree of movement on aircon and obstacle on the roof. These movements will be in scope of CSIR and will be discussed after the final PV design layout is approved.

2.3 The Point of Connection

The Point of Connection (PoC) will be the low voltage switchgear inside the buildings. The Contractor will be responsible for the procurement of replacement LV switchboard panel as specified in Appendix C and the additional switchgear required to integrate the PV Facility.

The Plant shall have separate metering for export and import.

2.4 Perimeter fence

No perimeter fence is required for the rooftop PV.

2.5 Topographical pictures

Figure 2: Building 3 Top view

Figure 3 : Building 10 Top view

Figure 4 : Building 22 Top view

Figure 5: Building 23 Top view

Figure 6 : Building 33 Top view

3 General Requirements

3.1 *Contractor*'s Scope of Work

3.1.1 Engineering, Procurement and Construction

The *Contractor* is responsible for:

- surveying, setting-out, clearing
- design, detailed drawings, design sign-offs, as-built sign-offs and electrical & structure certifications;
- purchasing, transportation and offloading of all equipment and materials;
- construction, erection, installation, assembling;
- testing, commissioning and performance testing;
- preparing operations & maintenance manuals;
- identifying and remedying defects for a *defects period* of 36 months after Practical Completion;
- O&M services for 36 months following Practical Completion of the whole Works.

3.1.2 Operations and Maintenance

The *Contractor* shall be responsible for the effective day-to-day monitoring, operating and maintaining of the plant for 36 months after Practical Completion. See Section 8.

3.1.3 Training Plan

The *Contractor* is required to develop and effect a training programme for CSIR's Facilities Maintenance staff for the duration of the O&M Period. CSIR's staff will assist with basic operations, maintenance and safety related tasks of the Facility. See Section 9.

For the purposes of Tender, the bidder is required to submit a proposed plan for Training Programme.

3.2 Programme

The *Contractor* is to submit a Preliminary Programme as the appropriate schedule in the Invitation to Tender which proposes the scheduling of tasks necessary to achieve the Milestones by the Key Dates provided in the Contract Data. A more thorough description of the criteria is provided in Table 1.

Table 1: Key Milestones and descriptions

Ref.	Milestone	Qualifying Criteria
KD 1	**Tender submission**	Submission of a qualifying binding Tender
KD 2	**Tender award**	Upon decision to award, the *Employer* shall issue a Letter of Acceptance to the *Contractor*
KD 3	**Contract signing**	The *Employer* and *Contractor* shall sign of the ECC contract with suitably amended Contract Data
KD 4	**Delivery of designs and drawings**	The *Contractor* shall deliver to Delivery of the updated design documents to the *Project Manager* for his review and acceptance
KD 5	**Submission of preliminary documents to Municipality**	Those drawings and information required shall be submitted to Tshwane Municipality for their review. The Works progresses in the meantime.
KD 6	**Starting Date**	The *Contractor* may occupy the *Site* and commence with the Works subject to the required security arrangements.
KD 7	**Site clearance**	CSIR is responsible for the *site's* preparation to their satisfaction.
KD 8	**Delivery of Modules to Site**	Delivery of all PV modules to the *site*.
KD 9	**Delivery of Inverters to Site**	Delivery of all inverters to the *site*.
KD 10	**Delivery of mounting structures to site**	Delivery of all mounting structure and associated mounting hardware to the *site*.
KD 11	**Mechanical completion**	Mechanical completion is achieved when the Works have passed the Mechanical Completion Test (see Section 7.2.1)
KD 12	**Commissioning**	The Facility is energised and successful Grid Connection Test has been passed (see Section 7.2.2)

Ref.	Milestone	Qualifying Criteria
KD 13	**Provisional Acceptance Test**	Works have passed all tests and the Facility has demonstrated adequate performance to pass the Provisional Acceptance (PAC) Test (see Section 7.2.3)
KD 14	**Training Program**	Provide a detail training program as per 3.1.3 Training Plan
KD 15	**Practical Completion**	Works have passed all tests, the Certificate of Compliance is issued and the Facility has demonstrated adequate performance to pass the PAC Test (see Section 7.2.3). The Contractor has delivered the Warranty Bond to the Employer. The Employer issues the Completion Certificate and releases the appropriate retention value
KD 16	**Submission of final documentation to Municipality**	Submission of final as-built drawings to Tshwane Municipality
KD 17	**Start of O&M period**	*Contractor* begins operations (monitoring) and maintenance obligations. The Training Programme begins.
KD 18	**Defects date**	End of *Defects period* in which the *Contractor* is responsible for correcting of defects. Remedied defects are dealt with as per Clause 44 or 45 in the ECC
KD 19	**Final Completion**	The Works have passed all tests and the Facility has demonstrated adequate performance to pass the Final Acceptance Test (FAT) (see Section 7.2.5)
KD 20	**End of O&M period**	The operations and maintenance period is concluded. The Training Programme is also concluded.

3.3 Conduct on *site*

3.3.1 Health and safety

All staff working on CSIR premises must adhere to the Occupational Health and Safety Act (85 of 1993) and its regulations, as amended from time to time.

3.3.2 Security

3.3.2.1 Site Security

The *Employer* shall supply security services for the duration of construction. Security staff shall be provided with a complete list of *Contractor*'s Staff (including subcontractors' staff) and the *Contractor*'s *Project Manager* shall inform security about expected activities, especially by Others (e.g. for deliveries of materials or equipment).

3.3.2.2 Site Access

All *Contractor*'s staff requiring regular access to the *site* will require access permits and valid identification. The *Contractor* shall submit to the *Employer* a full list of all staff (including subcontractors) who will access the *site*.

Once a permit is in-hand, *Contractor*'s staff and Subcontractors' staff may access the *site* freely weekdays between 7:00 – 18:00. Access outside of these times and on weekends and public holidays will require prior arrangement with the *Project Manager*.

3.3.3 Environmental Management

The *Contractor* is responsible for the removal of all waste from the *site*. This includes rubble, packaging etc.

4 The Works

4.1 Works Definition

The Works (defined in further detail in Section 5) shall include the following:

1. Major Equipment
    1.1. Photovoltaic modules
    1.2. Inverters
    1.3. Mounting structure
2. Electrical System
    2.1. DC Reticulation
        2.1.1. Cables
        2.1.2. Ducting / trays
        2.1.3. Termination
        2.1.4. Connection of modules in strings
        2.1.5. Connection of strings to combiner boxes or directly to inverter (as appropriate)
    2.2. AC Reticulation
        2.2.1. LV
            2.2.1.1. Cables
            2.2.1.2. Ducting / trays
            2.2.1.3. Termination
            2.2.1.4. Switchboard(s)
            2.2.1.5. Protection devices

2.2.1.6. Metering

2.2.1.7. Connection inverters to switchboard

2.2.1.8. Connection of switchboard to transformer

2.3. Combiner boxes (if appropriate)

2.4. Lightning protection & Earthing

3. Main DB

3.1. Metering system

3.2. Switch gears

3.3. Transformer protection (optional)

3.4. Protection devices

4. Monitoring and communication system

4.1. Data logger

4.2. Cabling

4.3. String monitoring

4.4. Pyranometer

4.5. Soiling sensor

4.6. Modem

4.7. UPS

5. Spare parts

4.2 Engineering / Design

The *Contractor* shall develop the detailed design in full compliance with local and international standards related to electrical works and specifically PV works (where local codes are insufficient) A list of minimum applicable standards is provided in Appendix C. The *Contractor* assumes full liability for the design. The PV facility shall have a design life of 25 years. The Chief Designer shall be named in the list of Key People and shall demonstrate at least 5 years of PV design related experience.

The design shall be in accordance with the appropriate portions of the South African Grid Code.

The *Contractor* shall submit his designs to the *Employer*'s *Project Manager* for review and comment prior to procurement and construction of the PV Facility.

4.3 Procurement

The *Contractor* shall be responsible for the procurement, transportation, offloading and care and custody of all equipment, materials and consumables as well as procuring of services required to complete the Works.

In addition, the *Contractor* shall procure (and maintain for the duration of the O&M period) spare parts sufficient to maintain a Facility adequately. The *Contractor* shall ensure that spare parts inventory is fully stocked at the end of the O&M period.

Spare parts (to be deliver and stored at the CSIR campus in Pretoria)

- 30 x solar modules
- 2 x Inverter
- 40 x MC4 connectors and DC cable
- Mounting structure spare parts to installation 10 solar modules

4.4 Site Establishment

The *Contractor* shall supply all temporary tools, equipment, vehicles, materials, consumables, machinery, infrastructure, professional services and labour required to set-out, clear and establish the *site*.

4.5 Construction

The *Contractor* shall supply all temporary tools, equipment, vehicles, materials, consumables, machinery, infrastructure, professional services and labour required for the construction of the Works.

The *Contractor* shall comply with the Occupational Health Act (85 of 1993) and its regulations as applicable. The *Contractor* shall have a Health and Safety officer present throughout the duration of the construction period.

4.6 Commissioning

The *Contractor* shall supply all equipment and tools necessary to commission and test the Facility according to the Tests defined in this *Works Information*.

5 Technical Specifications and requirements

5.1 Civils

Civils works shall be in accordance with SANS 1200.

5.2 Major Equipment

5.2.1 Photovoltaic Modules

5.2.1.1 Technical requirements

The *Contractor* is allowed to make use of the following photovoltaic module technologies:

- Monocrystalline silicon
- Polycrystalline silicon
- Thin film

Crystalline silicon modules are required to be IEC 61215 certified, thin film modules are required to be IEC 61646 certified. Detailed specification sheets and certificates of compliance to these

standards are to be provided. **The *Contractor* may use locally assembled modules on condition that proof of these certifications specific to the local assembly facility can be provided.**

In addition, the modules shall feature the following qualities:

- Normal Operating Cell Temperature (NOCT) is at maximum 46°C with a tolerance of ±2°C.
- The panel operating temperature range is to be at least -40 to 85°C.
- The temperature coefficients for power is to be at least -0.44%/°C (i.e. >= -0.45%/°C)
- All modules are required to have a positive output tolerance and the tolerance range is not to be larger than 0 to +3%, preferably 0...5Wp.
- Modules shall have anti-reflective coating, The PV panels must have frames sufficiently resistant to potentially corrosive environment (Aluminium Alloy, Anodized Aluminium, etc.); these modules must have valid IEC certifications.
- The PV panels shall be able to support a maximum PV system voltage of 1000V (or 1500V in case of new module generation). When a panel type is certified as per IEC61730 standard, it implies it has been tested and has passed this requirement.
- The panel's ability to withstand up to 5400Pa must have been proven through the IEC61730 certification being obtained with this load;
- Typical efficiency reduction of maximum 5% at 200 W/m2 according to IEC 60904-1.
- Junction box shall be IP 67 rated.

5.2.1.2 Flash Tests

A comprehensive IV flash test report for each PV module procured shall be provided to the *Project Manager* in Excel format prior to commencement of construction (this is not required for tender). The data must have the following information:

- Product name and number (external and internal)
- The test condition the measurement is carried out
- Serial number of the tested panel, including which panels are in which shipping containers and pallets
- Power at maximum power point (Pmpp)
- Voltage at MPP (Vmpp)
- Current at MPP (Impp)
- Fill factor
- Open circuit voltage (Voc)
- Short circuit current (Isc)
- Panel surface temperature (measured by temperature sensor, corrected and uncorrected if possible)

This information shall be provided by latest two (2) weeks prior to the arrival of PV modules on the *Site*.

5.2.1.3 Installation

The *Contractor* is responsible for the installation of modules according to the manufacturer's specifications. The PV module installation manual must be provided as part of the as-built documentation. The manual shall contain all the necessary requirements and specifications for proper module installations such as (but not limited to):

- Types of mounting structures including physical requirements for securing mechanisms (screws, clamps, dimensions, tightening force, locations) and useful information such as recommended mounting types, recommended spacing to guarantee sufficient air circulation, restrictions to certain environments etc.
- Mechanical and electrical configuration guidelines (landscape, portrait, string and array sizing, grounding etc.).
- Earthing requirements.

5.2.1.4 Guarantees and Warranties

Modules shall carry a defect warranty of at least 10 years and a linear 25 year performance guarantee of 80%.

The warranties offered by the module manufacturer shall be transferrable to the *Employer*. Other terms and conditions for warranties transferability must be clearly defined.

The sales agreement with the module manufacturer shall clearly define the claiming procedure of defective modules, the required additional specific independent party involvement and any other conditions that might influence the honouring of the warranty and guarantee.

5.2.2 Inverters

5.2.2.1 Technical Requirements

The *Contractor* may make use of Central or String inverters.

The Inverters shall comply with safety requirements according to IEC 62109 and feature anti-islanding according to IEC 62116.

The selection of inverters shall be based on the PV installation design and functional requirements, including the integration requirements into the PV system and the compatibility to the selected PV modules for the installations.

The inverter supplier has to approve the stringing chosen for the project. Inverters must be designed for PV application and include:

- At least one MPP tracker
- A display showing the faults and the performances
- An advanced system to allow power control and efficiency (maximum efficiency) must be at least 97% (excluding transformer)
- Remote monitoring and control capabilities

- Isolation fault detection
- Anti-islanding
- Ability to start and stop function automatically
- Variable power factor setting
- The ratio of the input DC power to output AC power must be between 80% and 120% at STC
- The MPP voltages of the strings are to be verified to lie in the MPP voltage range of the inverter for temperatures between 0°C and 70°C. The maximum inverter input voltage is not to be exceeded at temperatures of -10°C.
- An IP protection class of at least 54 is required for outdoor mounting and an IP grade of at least 21 is required for indoor mounting of the inverters
- If inverters are installed outdoors must have to be protected from direct sunlight
- The inverter requires an external DC switch

In cases where applicable, there may special grounding requirements for inverters. These are stipulated by the PV module manufacturer. In such cases, it is the *Contractor*'s responsibility to notify the *Project Manager* and implement these requirements.

5.2.2.2 Guarantees and Warranties

Inverters shall have a warranty of at least 10 years. The contract sales agreement with the inverter manufacturer shall clearly define the claiming procedure of defect inverters or parts. The required testing, independent verification requirements and any other conditions that might influence the honouring of the warranties.

Any extension and the full scope of that extension to the standard limited warranty that is included in the price should be indicated clearly.

Upon request by the *Project Manager*, the *Contractor* must provide proof that the inverter manufacturers have sufficient financial backup that covers manufacturers in bankruptcy or insolvency procedures.

The conditions which void the warranties shall be clearly stated.

The warranties offered by the Inverter manufacturers shall be transferrable to the *Employer*. Other terms and conditions for warranties transferability must be clearly defined.

5.2.3 Mounting structure

The supporting structure of the modules and all other PV components on the roof shall be designed and installed in line with the relevant South African standards more in particular applicable for PV installations.

- SANS 10160 Part 2- Self weight and imposed loads
- SANS 10160 Part 3- Wind actions

The wind load on the modules should be calculated (prior to the selection of the supporting structure) for each specific location depending on wind zone of the site, surroundings of building, roof altitude, inclination of roof and modules, location of modules on the roof (corners, roof edge, etc.), load of PV installation, distance between rows of modules, presence of wind shield, etc.

The amount of connection points will be calculated based on the applied loads and the static behaviour of the system. The connection points may not harm the position of or the sealing in-between the roofing.

Wind load stability calculations will be provided to the Employer.

Structures are typically made out of steel and aluminium; those materials should be new and conform to the current norms in terms of characteristics (quality, tolerance…). All used screws and clamps need to be resistant to corrosion.

The mounting of other components should not be done by penetrating the structure (e.g. drilling holes) as this might void the galvanization layer. A clamping method is preferred or adequate measures are to be taken to ensure a corrosion protection.

5.3 Module mounting

The way of mounting the modules onto the mounting structure shall be in accordance with the requirements of the module manufacturer and mounting structure manufacturer as described in the instruction manual of both components. If not, written approval on the way of mounting shall be provided by the Contractor from the module manufacturer or/and mounting structure manufacturer.

If modules are clamped onto the mounting structure, at least 4 clamping points should be used. The minimal torque for screwing the modules as stated in the instruction manual shall be respected.

The Contractor shall foresee a minimum inclination of the modules in order to assure the self-cleaning effect by the rain, i.e. at least 15° from the horizontal.

The sheds are to be designed so that the shadow angle is to stay below winter solstice. The shadow angle is defined as the angle between the horizontal and the line connecting the highest point of one row to the lowest point of the following row of modules.

5.3.1 PV Mounting structure

The supporting system of the PV system and the connections to the roof may not have an impact on the function of the roof. In all circumstances the building's weather tightness must be maintained.

The supporting structure and the choice of its location on the roof may not block the water drainage on the roof. Special attention should be paid because some supporting structure

manufacturers mention a minimum inclination of the roof of approximately 3%. The drainage system shall be well maintained and clean.

The roof clearance around the perimeter of the array has to allow safe O&M activities. It shall be considered corridors to allow the easy access to the module arrays for cleaning activities.

Alignment between all modules planes should be guaranteed.

The roofs where the PV Plants are to be installed are mainly flats. On flat roofs, the PV installation can be attached to the roof by using ballast or by anchoring onto the roof supporting structure.

5.3.1.1 PV Ballast system

Ballast will be placed on certain positions to attach the PV system onto the roof. There will be no penetrations though the roof. The ballast will be dimensioned based on the conclusions of the stability study. The maximal resistance of the thermal insulation material against pressure shall be taken into account when dimensioning the ballast system.

Creep resistance shall be taken into account. E.g.; an aluminium frame of 6 meter shall deform 8 mm with a temperature difference of 50°C.

A protection layer shall be foreseen between the ballast tiles and the roofing in order to prevent damage of sharp edges onto the roofing and to act as buffer for thermal expansion of the supporting structure. The material of the protection layer needs to be compatible with the roofing material and high UV resistance. The protection layer shall have a minimum thickness of 1.5 mm.

For the position of the module ballast, the Contractor should take into account the position of the supporting beams under the roof. The load of the PV system on the roof should be equally distributed over the roof.

5.3.1.2 Anchoring system

The perforation of the module supporting structure through the roofing material can have a direct impact on the water tightness and thermal isolation, which shall be kept as low as possible. All roof penetrations must be durably sealed using purpose-made products capable of accommodating the movement and temperatures to which they may be subjected.

Besides the tensile and pressure force also the horizontal component of the wind force need to be taken into account in the design.

5.3.1.3 Warranties

The structure shall have at least 10 years warranty but shall be designed for a minimum lifetime of 25 year. Special attention should be paid to warranty conditions against corrosion. Corrosion prevention must start at the design stage considering Site and soil specific parameters.

5.4 Balance of Plant

5.4.1 Protection and control devices

The protection and switching methodology shall be determined by the *Contractor*'s proposed design and technology but the degrees of protection shall comply with the applicable standards associated with PV and electrical works in general. Overcurrent and overvoltage devices shall be

required on the DC and AC sides. Switchgear used in any switchboards shall comply with SANS (IEC) 60947 and SANS (IEC) 62271.

5.4.2 Lightning Protection and Earthing

The *Contractor* is to conduct a risk mitigation study of lightning damage as per SANS 10313 and IEC 62305 and implement sufficient Lightning Protection System (LPS).

Earthing shall comply with SANS 10142 Parts 1 (LV) and 2 (MV), SANS 10292 and SANS 10199. A neutral earthing design is required.

Lightening protection devices should be also included on the communication lines.

All structures, enclosures, PV modules and cabinets shall be earthed appropriately.

5.4.3 Cabling

5.4.3.1 General

All cabling shall be installed in accordance with manufacturers' requirements and to meet the design conditions used in the sizing calculations.

The combined cable DC and AC losses shall not exceed 3%. The *Contractor* shall submit detailed calculations prior to commencement of construction.

5.4.3.2 DC cables

The DC cables of the PV installation must have the following characteristics as minimum:

- Cables used outside shall be UV resistant and ozone protected
- Cables should have Class II rating for insulation
- Cables must be rated for temperatures from -15°C to +90°C. This requirement is also applicable to all materials used in the installation (such as cable conduits).
- The cable shall be made of double insulated component and shall have a minimal life span of 25 years.
- Cables shall comply with SANS 1507 and TÜV 2 Pfg 1169
- All DC solar cable shall be halogen free, flame resistant & fire retardant
- Cables shall be terminated with MC4 connectors
- The cable bending radius shall be at minimum four times the cable diameter or as specified by manufacturer, if different.
- Cables have to be sized to allow a current up to 1.25 Isc and up to 1.2 Voc

Cables must be installed in conduits and hooded cable trays. The cable return path should follow the same way to avoid induction loops.

Cables must be dimensioned according to CEI 20-40 and CEI 20-67. Norm CEI 64-8 should be followed to prevent short-circuit-induced current. Norm CEI 82-25 should be followed regarding arrangement of cables and cables trays.

Combined DC cable losses are to be less than 2% at Standard Test Conditions.

5.4.3.3 AC cables

The AC cables of the PV installation must have the following characteristics as minimum:

- All AC cables may be XLPE or PILC with aluminium or copper stranded wire conductors;
- All cable construction shall be according to SANS 97 or 1339, SANS 1507 and IEC 60502;
- All AC cables shall be suitable for direct buried (armoured) or ducted installation;
- All joints and terminations be completed and tested in accordance with the manufacturer's recommendations;
- AC cables are to be terminated in suitable lugs;

5.4.4 Monitoring system

The main standard applicable is the IEC 61724.

A logging tariff meter is to be installed at the delivery point compliant with SANS 474/NRS 057. The meter shall be compatible and integrated into the monitoring system recordings.

The monitoring system must be designed and implemented in such a way to have a lifetime of 25 years. The monitoring system is to continuously measure data, electrical parameters and status of the PV plant components. Updated conglomerated data is to be available online at least every 30 minutes.

The monitoring system shall feature a UPS with 24 hour capacity to continue monitoring in times of grid outage.

The monitoring system shall have an online platform with different levels of access control.

The minimum data to be monitored are:

- DC current and voltage at the inverter input, per string
- Inverter behaviour
- DC current and voltage input
- Output active and reactive power
- Phase voltage and current
- Grid frequency
- Grid status
- Energy output
- Alarms and faults
- Energy output at the export meter
- Auxiliary consumption at the import meter
- Status of the equipment (protection devices, inverters etc.)

Additional monitoring system:

- String monitoring for all PV installation
- 2 x Soiling sensors (Kipp & Zonen)
- 4 x Pyranometer (Kipp & Zonen)

6 Battery Storage System

6.1 Technical requirements

The battery energy storage system must be capable of capturing and managing all historic data and data generated on current systems, including operated cycle, discharged capacity, instrument data in various forms for general information security and controlled access.

The location of the battery storage system should be at building 10 on the ground level outside the building.

Parameters	Specifications
Voltage	400 V, 3 phase 4 wire
Nominal capacity	min. 100 kW
Energy Rating	Adequate for 2-10 hrs of discharge at rated power
System efficiency (AC, round-trip)	> 85%
Battery efficiency (DC, round-trip)	> 96%
Reactive Power	Dynamic VAR support available at all times
Planned Islanding	Peak shaving using time of use tariffs(TOU) (may also be stacked with energy arbitrage and T&D deferrals)
Power Quality	At rated power
Total harmonic distortion	< 5%
Maintenance	Less than 0.5 % of installed cost per year
Calendar life	15 years
Cycle life	>4000 cycles at rated power
Disposal Cost	Less than 3 % of the installed cost.

The battery inverter features should include:

- Grid-forming and bi-directional
- Provision of short-circuit power and reactive power
- Overload capacity
- Compensation of asymmetric loads
- Cooling: air flow

Remote monitoring:

1 & 15 min data resolution available; real-time & historical data at cellular level. Control and monitoring via external interface.

7 Tests and Acceptance

7.1 Acceptance Criteria

7.1.1 Practical Completion

The criteria for Practical Completion are:

- Mechanical Completion Test is passed;
- Commissioning Test is passed;
- The Certificate of Compliance is issued;
- Provisional Acceptance Test is passed;
- Delay liquidated damages are paid;
- The final punch list of minor finishing works is agreed;
- The Final Documentation are provided;
- The O&M contract is signed;
- The Training Plan is provided.

Following the successful fulfilment of all criteria, the Project Manager shall issue the Certificate of Practical Completion to the Contractor.

The 36 months *Defect Period* and O&M period commences.

7.1.2 Final Completion

- Final Acceptance Test is passed or
- Performance Liquidated Damages are paid;
- The Plant is free of defects;

At the completion of a successful FAC Test, the *Project Manager* issues the *Contractor* with a Certificate of Final Completion. This signifies the end of the *defects period*.

7.2 Tests

7.2.1 Mechanical Completion Test

The purpose of the Mechanical Completion Test is to ensure that all parts of the Facility have been physically completed and installed correctly and according to the As-built documents.

The checks shall be compiled for each section of the *Works* as defined in the Works Definition (Section 4.1) focusing on physical installation, connection and compatibility and safety.

The Contractor submits a schedule of checks for the Project Manager's approval at least 2 weeks prior to planned Mechanical Completion.

7.2.2 Commissioning Test

The *Contractor* shall be responsible for all pre-commissioning and commissioning tests including the Grid Connection Test to ensure safe energisation and synchronisation with the grid. Unless otherwise stated prior to commencement of the tests, Eskom's Distribution Standard for Interconnection for Embedded Generation (DST 34-1765) shall be followed.

It shall be confirmed as a minimum that following are acceptable:

- Insulation resistance of all components
- String Voc, ISc, Vmpp and Impp are as expected
- String I-V curves are as expected
- Thermographic imaging detects no hot-spots on modules, combiner boxes and switchboards
- All inverters are functional and export power
- Power factor settings are correct
- Isolation switches are effective
- Protection devices are correctly calibrated, set and operating
- Communications are functional (internally and externally to Monitoring System)
- Alarms and signals are function correctly
- Monitoring system is functioning and remotely accessible
- Monitoring system UPS is functioning

The Contractor submits a schedule of checks for the Project Manager's approval at least 2 weeks prior to commencement of the Commissioning Tests.

7.2.3 Provisional Acceptance Test

The purpose of the Provisional Acceptance (PAC) Test is to confirm the correct functioning and operation of the PV Facility. These tests shall commence once Mechanical Completion and Commissioning has been achieved. The tests consist of:

- Performance Ratio (PR) Test of the entire Facility to confirm quality of design, construction and correct operation as per Appendix A.1
- Visual Inspection to confirm quality of materials and construction and confirm the plant is defect free for the purposes of commercial operation
- Functional Test to confirm correct operation not directly related to performance

7.2.4 Intermediate Acceptance Testing

The purpose of Intermediate Acceptance (IAC) testing is to detect early poor performance and performance impacting defects during the *defects period.* The Contractor shall conduct the following at the end of the 1st and 2nd years of operations:

- Annual Performance Ratio (PR) Test of the entire Facility as per Appendix A2.3 to confirm long-term quality of design, construction and correct operation against guarantees.
- Visual Inspection to confirm wear and tear are within acceptable limits and not attributable to defects.
- Functional Test to confirm correct long-term operation not directly related to performance.

This shall be conducted simultaneously with the major annual O&M preventative maintenance activities to minimise impact on performance.

7.2.5 Final Acceptance Test

The purpose of the Final Acceptance (FAC) Test is to confirm that the Facility has functioned and operated consistently with expectations and guarantees during the *Defects period*. The tests will consist of the following to confirm the Facility is defect free:

- Performance Ratio (PR) Test of the entire Facility as per Appendix A2.3.2 to confirm long-term quality of design, construction and correct operation against guarantees
- Visual Inspection to confirm wear and tear are within acceptable limits and not attributable to defects
- Functional Test to confirm correct long-term operation not directly related to performance

8 Operations and Maintenance

The *Contractor* shall develop an O&M plan to manage his obligations in delivery the guaranteed performance in the O&M Period. A preliminary plan is submitted with the Tender in the appropriate Schedule. The *Contractor*'s minimum Scope of Work shall include the following tasks bearing in mind the obligation to work cooperatively with CSIR Staff in effecting the Training Plan.

8.1 Monitoring

a) The *Contractor* commits to remotely monitor the Facility for 7 days a week, 365 days a year within hours where Global Horizontal Irradiation exceeds 50 W/m².

b) The *Contractor* maintains a log of all anomalies, faults, failures, safety incidents, maintenance interventions and status of the spares list.

c) The goal of the monitoring is to remotely identify and troubleshoot faults, failures, incidents and anomalies and to coordinate the intervention with CSIR Staff (once suitably trained) prior to launching a corrective maintenance intervention.

d) The *Contractor* compiles monthly, quarterly and annual performance reports indicating achieved vs expected and guaranteed performance and trends in performance.

8.2 Preventative Maintenance

The following is a minimum prescribed list of activities and frequencies. Should the equipment manufacture require an increased frequency of interventions then those shall supersede those proposed.

Component / Area	Type of activity	Description	Frequency
Module	Cleaning	Cleaning module of dust and debris	Bi-annually
	Visual	Damage to frame, hot spots, browning, delamination etc. backsheet undamaged, junction box damaged, Cables damaged, tightness of modules clamps and screws	Bi-annually in year 1 thereafter annually
Mounting structure	Visual	Corrosion, tightness of bolts, integrity of welds, signs of stress, galvanic coating	Annually
Cables	Visual	Signs of damage, exposure to sharp edges	Annually
Inverters	Visual / non-intrusive cleaning	Display is functioning, vents are clean, no signs of damage, mounted firmly, noises, fans are working, excessive heat, cables are connected correctly	Bi-annually in year 1 thereafter annually
	Testing / intrusive cleaning	Thermographic imagery, earthing, check state of fuses, internal cleaning of vents and fans, clean PCBs and heatsinks Measure AC/DC conversion efficiency	Annually
Combiner boxes	Visual / non-intrusive cleaning	Door seal condition, handle / lock operates correctly, safety signage , signs of overheating or sparks, condition of cables,	Bi-annually

Component / Area	Type of activity	Description	Frequency
		connections	
	Testing / intrusive cleaning	Thermographic imagery, insulation resistance, earthing, stat of fuses and SPDs, String IV testing, Voc, Isc, Vmpp Impp.	Annual
Switchboards	Visual / non-intrusive cleaning	Door seal condition, handle / lock operates, safety signage , signs of overheating or sparks, condition of cables, connections signs of moisture	Bi-annually
	Testing / intrusive cleaning	State of circuit breakers, SPDS, insulation resistance, thermographic imagery	Annually
Monitoring system	Visual / non-intrusive cleaning	Inspect meter, inspect cables, antennae, clean housings	Annually
	Testing / intrusive cleaning	Test communication protocols, test UPS, remove on-site data for permanent backup	Annually
Battery Storage	Visual / non-intrusive cleaning	Inspection, testing and cleaning	Annually

8.3 Corrective Maintenance

a) Any fault, failure, defect, anomaly or incident (generally referred to as a “fault”) arising that cannot be resolved remotely within the current Business day of occurrence by the *Contractor* shall require an onsite corrective intervention;

b) In such events, the *Contractor* notifies the *Project Manager* as soon as is reasonably practicable after becoming aware of such an issue but no later than within the current Business Day or at the beginning of the next Business Day if it is weekend or public holiday of:

   i. The nature of the fault

   ii. The measures taken to correct or troubleshoot it remotely

   iii. The intended plan of action when on *site*

c) The *Contractor* shall then attempt to rectify the fault within 1 (one) Business Day;

d) If the *Contractor* is unable to remedy the fault within the allowed time, he shall notify the *Project Manager* and submit a binding plan and programme to correct the fault for the *Project Manager*'s approval;

e) If the fault remains unresolved after the expiry of the programme, then delay damages are paid;

f) The period between the occurrence of the fault until the Facility becomes fully operational shall be considered as Facility Unavailability;

g) If the *Contractor* identifies, with reasonable evidence, that the fault was caused by the action of Others or Force Majeure then they shall be deemed to be excluded from Facility Unavailability;

h) If a fault is found to be a Defect claimable under a valid equipment warranty, the *Contractor* shall undertake the warranty claim proceedings on the *Employer*'s behalf;

i) Following the resolution of fault or remedying of a defect, the *Contractor* shall compile a report detailing the nature of the problem, the actions taken to correct it, the likelihood of reoccurrence and recommendations on a strategy to prevent reoccurrence;

8.4 Reporting

The *Contractor* shall compile quarterly reports of preventative and corrective maintenance activities occurring in that period describing the activities conducted, faults / defects identified and remedied and actions taken to prevent further faults / defects. The time taken, costs incurred and spares used shall be stated. The report shall describe scheduled maintenance visits to occur in the next period.

9 Training Program

To fulfil CSIR's internal human development obligations, the *Contractor* is required to accommodate three different types of training interventions during the planning/design, installation and the O&M period.

For the purposes of Tender, the bidder is required to submit a proposed plan for Training Programme.

9.1 Training programme

The *Contractor* is required to develop and provide a training programme for CSIR's facilities maintenance staff for the duration of the O&M Period. CSIR's staff will assist with basic operations, maintenance and safety related tasks of the *Facility*.

The intention of the training is to allow CSIR staff:

- to assist the Contractor in basic O&M activities and thereby reducing call-out time for minor interventions, fault-finding and troubleshooting;
- to demonstrate the Facility; and
- to operate the plant beyond the Contractor's O&M period.

The Training Programme shall encompass, at least:

- The basic concepts and technology of Solar PV technology
- The purpose and functionality of the equipment installed in the Facility
- Safety procedures for working in and around the Facility
- The basic operating and control procedures of the Facility
- Basic fault-finding and troubleshooting
- Replacement of minor parts (e.g. fuses)
- How to monitor, interpret and report performance

The knowledge transfer shall be through a phased approach beginning with the staff shadowing the Contractor during maintenance visits and eventually the Contractor supervising the staff while they conduct the inspections, tests and interventions. These phases shall be adopted on a quarterly basis with a review of the activities and key learning arising in that quarter.

10 Quality Assurance Plan

The *Contractor* shall submit a Quality Assurance Plan (QAP) for the Project Manager's approval. This need not be an ISO 9001 compliant plan but such certification shall be deemed favourable. The QAP shall detail as a minimum:

- Management philosophy and structure of the business
- Supply chain management
- Subcontractor management philosophy (indicating split of in-house and subcontracting)
- Quality of materials and equipment management
- Staff training and development philosophy
- Project quality standards
- Ethics

For the purposes of Tender, the Bidder shall submit a high level overview of their QAP.

Appendix A Facility Performance

A.1 Provisional Acceptance Test

1.1. Test duration and conditions

The duration of the PAC Test shall be 5 consecutive full days, for the whole plant.

The PAC Test will only commence upon successful completion and certification of the Tests on Completion referred to in the previous sections. On each day of the test, the test will be deemed to have commenced at the earlier of commencement of inverter operation or 50 W/m^2 irradiance measured by the plane-of-array pyranometer.

The following irradiation conditions apply;

- For the period from the start of February to the end of July the test shall be undertaken so that for a period of no less than 20 hours the modules shall be exposed to an irradiance of 400 W/m^2 or greater.
- For the period from the start of August to the end of January the test shall be undertaken so that for a period of no less than 20 hours the modules shall be exposed to an irradiance of 700 W/m^2 or greater.
- The PR shall be measured in accordance with IEC 61724 **with the exception that Global Horizontal Irradiation shall serve as the reference as measured by the calibrated secondary-standard pyranometer and not Global Inclined Irradiation**

The sampling period each day will cease when no further energy from the inverters is being received and irradiance is below 50W/m^2.

Each sampling period, j, will be 30 min. i.e. Ts = 30 min.

1.2. Requirements for successful completion of the PAC Test

The PAC Test will be considered as successfully completed if the following conditions are met:

- PR_{PAC} > Guaranteed PR as agreed and defined in the Contract
- Duration = 5 consecutive days
- Plant availability = 100% (during hours when horizontal pyranometer irradiance reading is ≥50W/m^2)
- Pyranometer and temperature sensor availability = 100% (during daylight hours)

1.3. PAC Test Calculation Methodology

In calculating the Performance Ratio (PR), data shall be measured over 30 minute intervals. Whenever the inverter is not functioning for all or part of the 30 min. Where horizontal irradiation is less than 50 W/m^2 the data is disregarded. Where the irradiation is greater than 50W/m^2 the inverter will be considered as unavailable.

Pyranometers and dataloggers shall be capable of measuring to a granularity of 30 second intervals which will be averaged over the 30 minute sampling period.

The PR shall be measured in accordance with IEC 61724 **with the exception that Global Horizontal Irradiation shall serve as the reference as measured by the calibrated secondary-standard pyranometer and not Global Inclined Irradiation.**

The PR is a measure of the quality of the design, components and installation of the PV plant. It is the relationship between the actual energy produced, i.e. the energy measured at the appropriate meter, and the energy theoretically produced by the PV Modules (before any losses).

The PR during time period j is calculated as follows and is based on the net exported energy:

$$PR_j = \frac{E_{Prod_j} - E_{cons\_j}}{E_{PV\_j}}$$

Where;

PR_j	Is the performance ratio measured over time period "j" where the inverter has been operational for the full 30 min
E_{prod_j}	Is the sum of all energy (kWh) produced by the Plant at the export meter in timeframe j
E_{cons_j}	Is the sum of all energy (kWh) consumed by the Plant at the import meter in timeframe j
E_{PV_j}	Energy theoretically produced by the PV modules (kWh) in timeframe j $$E_{PV\_j} = P_{nom} * (\frac{H_j}{G})$$

Where;

P_{nom}	Is the nameplate or datasheet capacity of the modules kWp
H_j	Is the irradiation measured by the reference horizontal pyranometer in timeframe j (kWh / m2)
G	Is the irradiance under Standard Test Conditions = 1,000 W / m2

A single PR figure will then be generated for the 5 day test by using the following equation.

$PR_{PAC\_overall}$	Single PR value for all valid readings over the PAC Test period for the whole plant.

$$PR_{PAC\_overall} = \frac{\sum_{j=1}^{z} E_{prod\_j}}{\sum_{j=1}^{z} E_{PV\_j}}$$

Where;

Z	Is the number of sampling periods (j) in the total PAC Test duration

1.4. Monthly Correction Factor

For comparison against the guaranteed PR, the PAC Test PR value from the test must be adjusted to account for variation between seasonal and annual conditions using the Monthly Correction Factor (MCF).

At the signing of the EPC Contract, a table of MCF factor values shall be agreed between the parties based on the *Contractor's* PVSyst model.

1.5. Provisional Acceptance Test PR result

The result of this adjustment is the Provisional Acceptance Test PR result.

$$PR_{PAC} = \frac{PR_{PAC\_overall}}{MCF}$$

The PAC Test period will conclude with a review meeting. If unsatisfactory test results are obtained, this meeting will be used to determine the course of action required.

1.6. Data Format

Processed data shall be prepared in an Excel spreadsheet of at least 2 readings per hour with the following columns:

- Time and date
- All pyranometer readings
- Pyranometer average
- Pyranometer deviation range
- Ambient temperature
- Module temperature
- Each string inverter or string combiner box power
- Total inverter power
- Availability
- Expected production
- Export meter energy
- Import meter energy
- PR

Each day of the test will be represented on a separate worksheet with a summary of data over the course of the day. An additional summary sheet will combine data over the whole test period.

1.7. Check of Data Quality

The *Contractor* will supply raw data before any manipulation and highlight any gaps in the data to the Employer and Employer's Representative. All recorded data shall be checked for consistency and gaps to identify obvious anomalies before any detailed analysis is conducted. A reasonable set of limits shall be defined for each recorded parameter, based on the known characteristics of the parameter, the PV plant and the environment.

1.8. Safety during testing

The Contractor shall be responsible for safely conducting all Tests. The Contractor shall provide a safety briefing for all personnel on the Site who will be involved in or witnessing any Tests, and shall ensure that such personnel comply with all applicable safety procedures at all times during performance of the Tests. The Contractor shall discontinue performance of any Tests in the event of any unsafe conditions.

1.9. Extension of testing

- There shall be at least 3 hours of Admissible data per day else that day is excluded entirely and PAT is extended by an additional day
- If the minimum threshold of Admissible data cannot be achieved solely due to the average Global Horizontal Irradiation being less than 400W/m² then testing may be extended up to a maximum of 5 days. If the maximum extension is reached and the minimum threshold of Admissible Data has not been achieved then the *Project Manager* may either:
    - Accept the PAT PR based on the lesser amount of Admissible Data or
    - Choose to reduce the average irradiation threshold to 300W/m² and calculate the PAC PR on the increased number of Admissible data
- If the minimum threshold of Admissible data cannot be achieved due to Unavailability of the Facility, regardless of the irradiation, then PAC Test shall be extended indefinitely until 5 consecutive days of Admissible Data are achieved.

1.10. Stopping and Restarting of the PAC Test

- If, for any reasons beyond the *Contractor*'s control, the Facility or part thereof becomes unable to operate then the PAC Test shall be suspended until proper operation resumes and the *Contractor* may resume with the PAC Test until the required 5 consecutive days of operation have been achieved.
- The *Contractor* shall notify the *Project Manager* of any such suspensions and resumptions and maintain a log of the causes of such events.
- If, after the occurrence of such a suspensive event, the *Contractor* can reasonably justify the likely occurrence of repeat events within the next 5 days, the *Contractor* may request permission from the *Project Manager* to discontinue the PAC Test.
- If the Project Manger accepts the justification, he grants the *Contractor* permission to discontinue the PAC Test else instructs the *Contractor* to continue.
- If the PAC Test is discontinued, the *Project Manager* and *Contractor* agree on the Date to begin a new PAC Test.

A.2 Tests after Completion

2.1. Duration and conditions of the IAC and the FAC Test

The *Contractor* shall conduct an Intermediate Acceptance (IAC) Test at the end of the 1st and 2nd years following Practical Completion.

The *Contractor* shall conduct a Final Acceptance (FAC) Test at the end of the 3rd year following Practical Completion.

2.2. IAC and FAC Test Availability

Availability will be measured at the inverter. The individual availabilities calculated for each inverter are averaged to obtain the plant availability; this average is to be weighted by the installed DC capacity of each inverter.

$$A_{IAC\ or\ FAC} = \frac{T_{Energy\ output}}{T_{Total\ test\ time}}$$

Where;

$T_{\text{Energy output}}$ = total time of operation (inverters are exporting energy) during hours of daylight of the relevant inverter (for a whole 30 minute sample period).

$T_{\text{Total test time}}$ = total time in which either inverters are operating or the horizontal array pyranometer irradiance reading is ≥50W/m^2 (for a whole 30 minute sample period).

There is no unavailability allowance i.e. all period of downtime due to faults, defects or failures shall be regarded as performance losses.

The downtime during following periods will be excluded from $T_{Total\ test\ time}$:

- Force Majeure;
- Events beyond the *Contractor's* reasonable control;
- Grid outage and/or instability under which conditions the Facility must cease to operate;
- Preventative maintenance activities requiring shutdown of the Facility (provided that these activities are strictly scheduled and not due to reactive maintenance).

2.3. IAC and FAC Test PR calculation methodology

In calculating the Performance Ratio (PR), data shall be measured over 30 minute intervals. Whenever the inverter is not functioning for all or part of the 30 min. where the irradiation is less than 50 W/m^2 the data is disregarded. Where the irradiation is greater than 50W/m^2 the inverter will be considered as unavailable.

Pyranometers and dataloggers shall be capable of measuring to a granularity of 30 second intervals which will be averaged over the 30 minute sampling period.

The PR shall be measured in accordance with IEC 61724 **with the exception that Global Horizontal Irradiation shall serve as the reference as measured by the calibrated secondary-standard pyranometer and not Global Inclined Irradiation**

2.3.1. IAC Test PR Equations

The IAC PR is calculated each year for years 1 and 2 following Practical Completion and is based on the net exported energy.

PR_{IAC} = The Intermediate Performance Ratio (will be evaluated in accordance with the following equation:

$$PR_{IAC} = \frac{E_{prod\_IAC} - E_{cons\_IAC}}{E_{PV\_IAC}}$$

Where:

E_{prod_IAC} = The total energy (kWh) produced by the plant as measured at the export meter during each 12 month period from the date of the Practical Completion.

E_{cons_IAC} = The total energy (kWh) consumed by the plant as measured at the import meter during each 12 month period from the date of the

Practical Completion.

$$E_{PV\_IAC} = A_{IAC} * P_{nom} * \left(\frac{H_n}{G}\right) * (1-d)^n$$

Where:

n = the year of operation following Practical Completion

d = Agreed degradation [0.8]%

Hn = Measured horizontal irradiation in the year *n* in kWh/m^2

G = Standard irradiance 1000W/m^2

Pnom = the Nominal Peak Power of the Plant measured in kilowatt peak

The test will be deemed to have passed if;

$PR_{IAC} > PR_{guaranteed}$

If the Facility fails to pass the test, the Facility shall be regarded as defective and the *Contractor* shall implement remedial works to rectify the cause for underperformance at their expense.

2.3.2. FAC Test PR Equations

The FAC PR is calculated at the end of the third year following Practical Completion and is based on the net exported energy.

PR_{FAC} = The FAC Performance Ratio is defined in accordance with the following equation:

$$PR_{FAC} = \frac{E_{prod\_FAC} - E_{cons\_FAC}}{E_{PV\_FAC}}$$

Where:

E_{prod_FAC} = The total energy (kWh) produced by the plant as measured at the export meter during the whole 36 months operation period following Practical Completion.

E_{cons_FAC} = The total energy (kWh) consumed by the plant as measured at the import meter during the whole 36 months operation period following Practical Completion.

$$E_{PV\_FAC} = A_{FAC} * \left(\frac{P_{nom}}{G}\right) * \sum_{n=1}^{3} [H_n * (1-d)^n]$$

Where :

n = the year of operation following Practical Completion

d = Agreed degradation = [0.8]%

Hn = Measured horizontal irradiation in the year *n* (kWh)

G = Standard irradiance 1000W/m^2

P_{nom} = The Nominal Peak Power of the PV plant measured in kilowatt peak

FAC will be deemed to have been passed if;

$$PR_{FAC} > PR_{guaranteed}$$

Should FAC not be passed, liquidated damages will be payable in accordance with A.3.

A.3 Performance Liquidated Damages

The Contractor guarantees a FAC Performance ratio (PR_{FAC}) of not less than the Guaranteed PR ($PR_{guaranteed}$) for the Plant as specified in the financial model submitted in the tender.

Should the FAC Test not be passed, liquidated damages will be payable in accordance with the Contract.

If the FAC Performance Ratio is less than the Guaranteed PR, the Contractor shall pay to the *Employer* by way of liquidated damages specified in the financial model submitted in the tender.

The parties agree that the liquidated damages payable represent a genuine pre-estimate of the losses the *Employer* may suffer as a result of any failure in the performance of the PV plant.

The *Employer* may deduct and/or set off any sum due pursuant to this Schedule from any monies due to the Contractor under this Contract or the Employer may recover the same from the *Contractor* as a debt.

In the event that, for any reason, the right of the *Employer* to recover Liquidated Damages pursuant to this Appendix is held to be unenforceable in whole or in part and the *Employer* is therefore not entitled to the relevant liquidated damages, the parties acknowledge and agree that the *Employer* shall be entitled to bring a claim for breach of contract against the *Contractor* to recover (without double recovery) the losses suffered and/or incurred by the Employer as a result of the failure by the *Contractor* to achieve the Guaranteed Performance (provided that the *Contractor's* liability under this clause shall in no circumstances exceed the total amount of the liquidated damages (or part thereof) held to be unenforceable).

Appendix B Site Photos

Figure 7 Building 10

Figure 8 Building 22

Figure 9 Building 23

Figure 10 Building 33

Figure 11 Building 3

Appendix C Point of Connection

The Facilities shall connect into the low voltage distribution board inside the building s which is to be replaced under the scope of this Project. The Single Line Diagram and corresponding switchgear specifications are provided in the Annexure, respectively.

The *Contractor* is required to supply, install and commission the distribution board, including that required for the integration of the PV Facility under the scope of work.

Each switchgear shall feature its own meter.

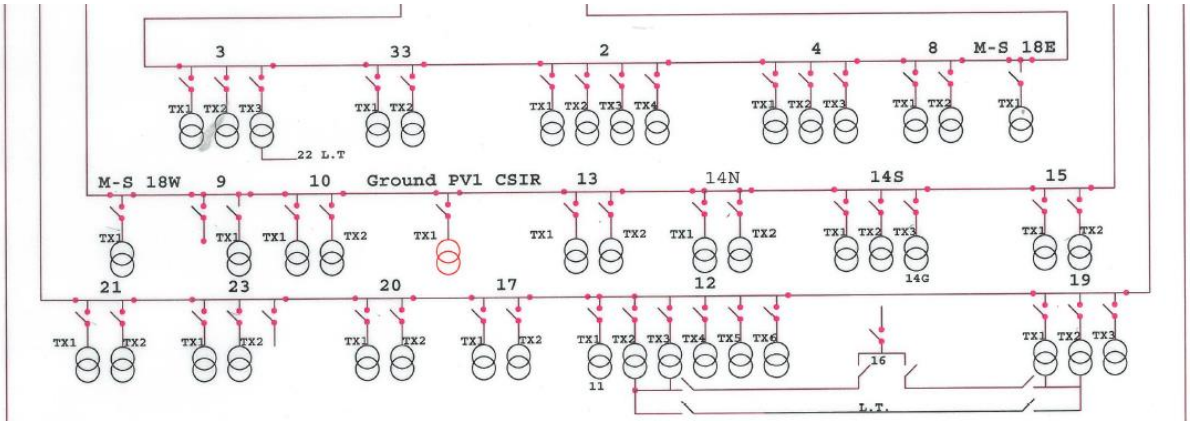

Figure 12: single line diagram CSIR network

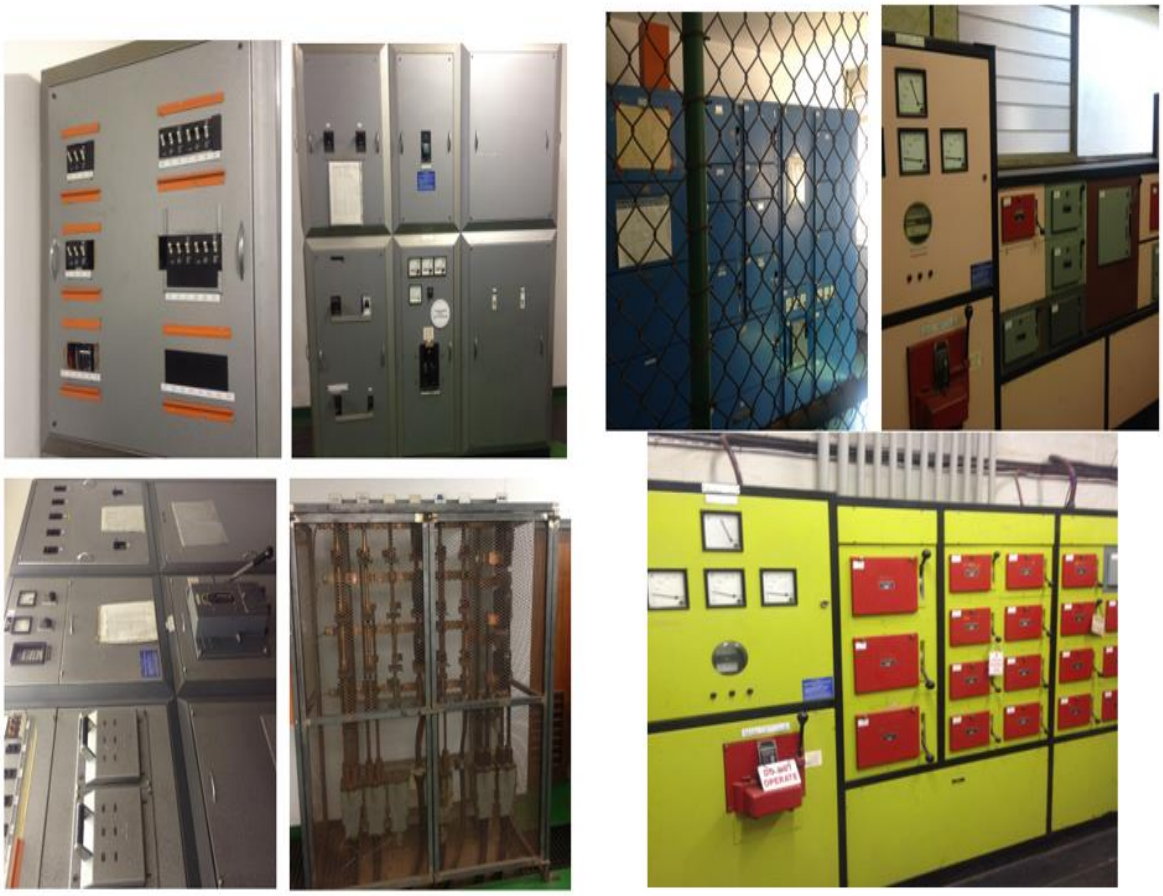

Figure 12 : Low voltage distribution boards for different buildings

Appendix D Applicable Standards and Guidelines

The following is a non-exhaustive list of standards and guidelines. It is the responsibility of the Reasonably Experienced Solar PV *Contractor* to be familiar with these and other standards.

South African National Standards (SANS)

SANS 97 (Electric cables-Impregnated paper-insulated metal-sheathed cables for rated voltages 3.3/3.3 kV to 19/33 kV)

SANS 474/NRS 057 Code of practice for electricity metering

SANS 780 (Distribution Transformers)

SANS 1029 (Miniature substations for rated a.c. voltages up to and including 24 kV)

SANS 1063 (Earth rods, couplers and connections)

SANS 1213 (Mechanical cable glands)

SANS 1339 (Electric cables - Cross-linked polyethylene (XLPE) insulated cables for rated voltages 3,8/6,6 kV to 19/33 kV)

SANS 1507 (Electric cables with extruded solid dielectric insulation for fixed installations (300/500 V to 1 900/3 300 V) (All parts)

SANS 1874 (Switchgear - Metal-enclosed ring main units for rated a.c. voltages above 1 kV and up to and including 36 kV)

SANS 1885 (AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 36 kV)

SANS 10142-1 (The wiring of premises Part 1: Low-voltage installations)

SANS 10142-2 (The wiring of premises Part 2: Medium-voltage installations above 1 kV a.c. not exceeding 22 kV a.c. and up to and including 3 MVA installed capacity)

SANS 10198 (The selection, handling and installation of electric power cables of rating not exceeding 33 kV) (all parts)

SANS 10199 (The design and installation of earth electrodes)

SANS 10200 (Neutral earthing in medium voltage industrial power systems)

SANS 10292 (Earthing of low-voltage distribution systems)

SANS 10160 (Load assumption and structural design)

SANS 10313 Protection against lightning - physical damage to structures and life hazard

SANS (IEC) 60076 (Power Transformers – All Parts)

SANS (IEC) 60529 (Degrees of protection provided by enclosures (IP codes)

SANS (IEC) 60947 (Low-voltage switchgear and controlgear)

SANS (IEC) 62271 (High-voltage switchgear and controlgear (All Parts))

NRS

NRS 013 (Medium Voltage Cables)

NRS 031 (Alternating current disconnectors and earthing switches (up to 145 kV))

NRS 029 (Current Transformers)

NRS030 (Inductive Voltage Transformers)

NRS 048 (Electricity Supply: Quality of Supply)

NRS 053 (Accessories for medium-voltage power cables (3,8/6,6 kV to 19/33 kV))

NRS 074-1 (Low-voltage (600/1 000 V) cable systems for underground electrical distribution Part 1: Cables)

NRS 074-2 (Low-voltage (600/1 000 V) cable systems for underground electrical distribution Part 2: Accessories)

NRS 088-1 (Duct and direct-buried underground fibre-optic cable Part 1: Product specification)

NRS 088-2 (Duct and direct-buried underground fibre-optic cable Part 2: Installation guidelines)

NRS 089-1 (Maintenance of electricity networks – Part 1: Underground Distribution Networks)

NRS 089-3-2 (Maintenance of electricity networks Part 3: Substations Section 2: Power transformers, circuit-breakers, isolators and instrument transformers)

NRS 089-3-3 (Maintenance of electricity networks Part 3: Substations Section 3: Miniature substations, distribution transformers and electrical enclosures)

NRS 097-2 (Grid Connection of embedded generation Part 2)

NRS 097-2-3

RPP Grid Code

IEC

IEC 60287: (Electric cables – Calculation of the current rating – All Parts)

IEC 62305 (Protection against lightning – All Parts)

IEC 60364 (Low-voltage electrical installations – All Parts)

IEC 60364-7-712 (Requirements for special installations or locations - Solar photovoltaic (PV) power supply systems)

IEC 61215 (Crystalline silicon terrestrial photovoltaic (PV) Modules - Design qualification and type approval)

IEC 61643-11 (Low-voltage surge protective devices - Part 11: Surge protective devices connected to low-voltage power systems - Requirements and test methods)

IEC 61643-11 (Low-voltage surge protective devices - Part 12: Surge protective devices connected to low-voltage power distribution systems - Selection and application principles)

IEC 61646 (Thin-film terrestrial photovoltaic (PV) modules - Design qualification and type approval)

IEC 61936 (Power installations exceeding 1kV AC – All Parts)

IEC 61724 (Photovoltaic system performance monitoring - Guidelines for measurement, data exchange and analysis)

IEC 61730 (part 1 and 2 safety)

IEC 62108 (Concentrator photovoltaic (CPV) modules and assemblies - Design qualification and type approval)

IEC 62109 (Safety of power converters for use in photovoltaic power systems)

IEC 62727 (Photovoltaic systems - Specification for solar trackers)

IEC 62817 (Photovoltaic (PV) module safety qualification)

IEC 60228 (Conductors of insulated cables)

IEC 62116 (Utility-interconnected photovoltaic inverters - Test procedure of islanding prevention measures)

IEC 60502-1 Power cables with extruded insulation and their accessories for rated voltages from 1 kV (Um = 1,2 kV) up to 30 kV (Um = 36 kV) - Part 1: Cables for rated voltages of 1 kV (Um = 1,2 kV) and 3 kV (Um = 3,6 kV)

IEC 60502-2 Power cables with extruded insulation and their accessories for rated voltages from 1 kV (Um = 1,2 kV) up to 30 kV (Um = 36 kV) - Part 2: Cables for rated voltages from 6 kV (Um = 7,2 kV) up to 30 kV (Um = 36 kV)

Others

TÜV2 Pfg 1169（Requirements for cables for use in photovoltaic-systems)

DST 34-1765 Distribution standard for the interconnection of embedded generation