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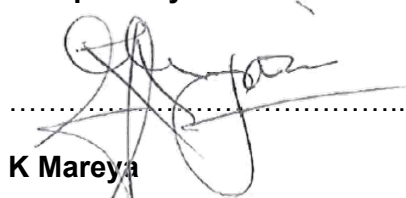
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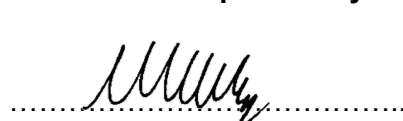


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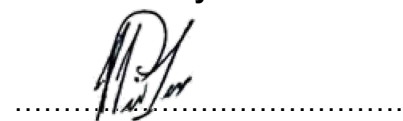


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1. PROJECT DEFINITION

This document provides technical requirements for Engineering, Procurement and Construction (EPC), including Commissioning of the Proposed Solar PV Agrivoltaics System at Komati Power Station, situated in Mpumalanga. It also sets out requirements relating to expected plant performance, quality, codes and standards.

This document must be read in conjunction with the Engineering & Construction Contract (NEC3) Part 3: Scope of Work – Employer and Contractor's Works Information.

1.1 OBJECTIVES

The main objective of the Project is to demonstrate feasibility of co-existence between the surrounding farming community and Solar PV Power Generation through adoption of Agrivoltaic solutions, showing Eskom's intention regarding renewable technology at Komati Power Station as part of the Repowering Initiative. The project also seeks to reduce the amount of electricity drawn from the Grid for self-consumption at Komati Power Station and carbon footprint, as well as establishing the impact of environmental conditions on performance of PV plant at the Komati site for influencing future expansion.

1.2 LOCATION

The Proposed Site at Komati Power Station (Site) is located with the following address/coordinates:

Address:	Steve Tshwete District Council, Komati, Mpumalanga, South Africa
GPS Coordinates:	26.098178°S; 29.450542°E, Elevation: 1,623m above sea level

1.3 SITE CONDITIONS, SCREENING AND SELECTION

1.3.0 General

The proposed Site at Komati Power Station is situated within the Station Services Building premises and the Parking & Drop-off Zone behind the Station Services Building (SSB).

1.3.1 Available Land

Suitable areas for the installation of PV and Agrivoltaics were identified and proposed during visual inspection of the proposed Sites, (*refer to Drawing #: 0.33/19495/ 0 Rev 0 - PV Pre-Feasibly Study Site Layout Diagram*). This preliminary site inspection and selection did not include any specialised environmental assessments and geotechnical investigations. The Contractor shall verify the suitability

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of the Sites for installation of PV and Agrivoltaics, and confirm compliance with regulations, and soil conditions prior to earthworks and excavations.

The following constraints and objectives have been identified in relation to the Project site:-

- The development of the PV and Agrivoltaics facility, and associated activities that may result in disturbing the Site, shall not trigger the need for Environmental Impact Assessment and Authorisations.
- The utilisation of the identified Site shall be maximised (within the identified constraints) in terms of energy generation, performance ratio, and availability of the PV and Agrivoltaics facility.

The Contractor shall comply with these constraints and objectives.

1.3.2 Site Access

Access to the proposed Sites is within a 1-kilometre radius from the Station's entrance.

1.3.3 Soil Conditions

Komati Power Station is underlain by sandstone, shale and coal beds of the Vryheid Formation, Karoo Super-group according to regional geology. Previous Geotechnical Investigations found marshy areas to be mainly clayey and potentially expansive soils may underlie it, however, the actual ground conditions at the selected Site may differ greatly. Hence it is expected that the Contract will perform the necessary geotechnical investigations at the Site prior to completing the detailed design, earthworks, and construction of the facility.

1.3.4 Weather Data

The Komati Weather Station is located approximately 2.7 km West South West of Komati Power Station (Location details: Latitude: 26.098178°S, Longitude: 29.450542°E, Elevation: 1,623m above sea level). A high level summary of the weather data recorded at the Weather Station from January 2014 to December 2018 are given in *Appendix: B – Table 3* (conclusions taken based on this data should be considered preliminary estimations. A larger dataset will minimise risk).

1.3.5 Meteorological Situation

The TMY generated for the Project Site is presented in Appendix B (for guidance purpose only) which the bidder can use to evaluate the plant performance and provide the estimated plant performance accordingly as defined *Appendix E - Table 10 & Table 11*. However, the bidder is free to choose his own TMY dataset to guarantee the performance ratio as defined in Appendix G.

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1.4 EXISTING INFRASTRUCTURES AND SERVICES

The Power Station has existing infrastructure and available services to support the construction, operating and maintenance of the PV plant. The Bidder shall maximize utilization of the existing infrastructure as part of his proposed design.

1.4.1 Buildings and Associated Infrastructure

The Power Station has available common buildings and infrastructure that could potentially be utilised for the operation, maintenance and services of PV systems. The Bidder shall in his design layout identify any such building and infrastructure identified for usage.

1.4.2 Potable and Process Water Supply

The existing Water Treatment Plants at the Power Station can supply water at the required quality as Potable or Process for the washing of PV panels (*refer to Table 36 Water Quality*)

1.4.3 Sewage Management

The existing Sewage facilities servicing the Power Station are adequate to meet any requirements placed by the Komati Pilot Solar PV Plant requirements.

1.4.4 Waste Management

Available Waste Management Systems and processes are adequate to meet any requirements placed by the Komati Pilot Solar PV Plant requirements.

1.4.5 Storm Water Management

All Storm Water Management within the Power Station Footprint is based on the already established SWMP. All storm water runoff from the PV modules and infrastructure with roofs is considered clean storm water runoff and can be released back into the environment.

1.4.6 Auxiliary Power Supply

A 6.6/0.4kV 630kVA mini-substation located near to the proposed PV plant site shall provide auxiliary power required for construction activities. Auxiliary power supply required for auxiliaries such as inverter control circuitry, meteorological system, servers, computers and night-time auxiliaries like perimeter lighting shall be supplied from PV Distribution Board (PV-DB).

1.4.7 Electrical Interconnection (Point of Interconnection)

A 630kVA, 6.6/0.4kV mini-substation supplying power to the Station Services building is located near the proposed PV plant Site. Refer to Figure 1 which shows the existing mini-substation. It is proposed

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that the PV plant interconnect to the station reticulation system through the existing mini-substation 400V system.

1.4.8 High Security Fence

A high security mesh fence borders the greater part of Area 1 and fully encloses Area 2 (refer to Drawing #: 0.33/19495/ 0 Rev 0 - PV Pre-Feasibly Study Site Layout Diagram). Access to Area 1 is not controlled whereas Area 2 is controlled.



Existing 6.6/0.4kV,
630kVA mini-substation

Figure 1 Existing mini substation to be used as a point of connection

2. TECHNICAL REQUIREMENTS

2.1 GENERAL REQUIREMENTS

2.1.1 PV Plant Capacity

As described in Sections 2.2 and summarised in *Appendix A - Table 1*, a number of land portions have been preliminarily identified as possible usable land for PV systems. The total suitable gross land area identified is approximately 12 000 m². The Bidder shall determine the Size & Capacity of PV System installations based on Net Usable or Effective Area which should be equal or less than 1 hectare to avoid the requirement for environmental authorisations. PV minimum specific technical requirements are listed in Appendix E – Table 10.

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2.2 HYBRID SOLAR PV SYSTEM REQUIREMENTS

A hybrid solar plant made up of Ground mounted and Agrivoltaics PV systems is required at Komati Power Station. The plant shall be located within Komati Power Station site boundary as indicated in the site layout in *Drawing #: 0.33/19495/ 0 Rev 0 - PV Pre-Feasibly Study Site Layout Diagram*. The capacity of the plant shall be determined from energy yield studies, which are to be performed by the Contractor based on the identified available land. Power generated from the plant shall be utilised for supplying auxiliary power to the plant with the rest fed into the station reticulation system through an identified point of connection for on-site consumption. The plant shall consists of but not limited to the following major components:- a combination of PV modules, PV ground mounting structures and foundations, inverters, AC distribution boards, AC and DC cabling, UPS, control and monitoring systems, interconnection cables and utilities such as roads, storm water infrastructure, buildings and meteorological measuring stations. Sizing of equipment and components used shall be based on the realised plant capacity, selected voltage, load flow and short circuit studies. Considering the hybrid nature of the proposed plant, a string network configuration is preferred. A single line diagram of the proposed hybrid plant is shown in *Drawing #: 0.33/19494/01/Rev 0 – Proposed Hybrid PV Single Line Diagram*.

2.2.1 Agrivoltaics Systems

Komati Power Station wants to gain initial experience with Agrivoltaic Systems and compare their performance with that of Conventional Ground-mounted north-facing PV systems over the course of the day and year and plans to use the data for a larger project under Repowering and Repurposing Project. The pilot project shall be scientifically monitored in order to find out how the combination affects the usability of agricultural machines, the agricultural productivity of the area and the microclimatic influence of the agro-photovoltaic system on the area.

2.2.1.1 General Considerations

Solar PV panels may affect crop yield due to shadowing effects. Crops can be classified as either being shadow-intolerant or shade-tolerant. Simulating and piloting of agrivoltaics with shade-tolerant crops shows that crop yield generally do not decrease. Experimental investigations of dynamic-agrivoltaics, which controls the tilt angle of panels using algorithms for optimum PV generation and crop production, have been undertaken by research institutions. Dynamic tracking involves the integration of two algorithms, the energy yield of the PV panels and the solar radiation requirement of the crops. The panels are moved or tilted in various configurations to optimise energy yield and crop yield.

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This pilot study however shall consider only fixed PV panels. Fixed systems do not incorporate any tracking systems. The panels are normally north-facing and the tilt angle is equal to the latitude of the site.

2.2.1.2 Design Configurations

Different configurations exist for Agrivoltaic Systems including: raised PV modules on stilts high enough to allow agricultural machines underneath. Vertically installed bifacial solar module systems whose mounting structure allows the vertically installed panels to exploit the incident solar radiation on their front and rear side and offer maximum performance during hours of high consumption, at dawn and at dusk. The Bidder shall take into consideration the following:

- Although commercial scale agrivoltaic installations utilise mounting structures with elevations based on the height of crops and the actual farming machinery to be used during the life cycle of the crop, this demonstration agrivoltaic installation shall utilise mounting structures with elevations at approximately 2.5-3m high for the purposes of testing and demonstrating the agrivoltaic principles.
- Wind loading, ground conditions and undermining should be considered in the design.
- Row spacing and spacing between panels considering the width of farming equipment to move between the panels as well as adequate solar radiation for the crops
- Density of panels to optimise the growth of crops
- Impact ground reflectivity has on the panels. Based on Proposed design the PV panel selection could consider panels capable of absorbing light at the back of the panel to increase the energy yield

2.2.2 Civil and Structural Requirements

2.2.2.1 Ground Mounting Structures and Foundations

The Contractor shall carry out a geotechnical assessment to determine the geotechnical parameters and to inform the foundation design of the mounting structures

Suitable mounting structures shall be designed, procured and constructed according to geotechnical assessment, and according to any environmental and licence requirements. The mounting structures shall be ground mounted, fixed type and facing perfect north. The structure shall withstand all possible static, dynamic and seasonal loads at site conditions. The mounting structures shall be designed for optimum PV module orientations. The tilt angle shall be between 20° – 30° and azimuth at perfect

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north. For ground mounted systems, the row-to-row distance shall be selected to minimize shading losses. For Agrivoltaics PV system, row-to-row distance shall be optimised to ensure that crops planted on the ground under the PV panel structure receives the minimum required sun hours for healthy development and permits access to agricultural equipment, mounting structures shall be selected to meet the minimum specific technical requirements set in technical schedules in *Appendix D - Table 9*

2.2.3 Electrical Requirements

2.2.3.1 PV Modules

Generally, two different concepts for generating energy by means of PV technology are commercially available on the market; crystalline silicon based and thin film-based PV technology. From the thin film technologies, amorphous Silicon (a-Si), Copper Indium Selenide (CIS) and CIGS are not preferred due to their large footprint, i.e., land usage that would be required. Furthermore, these modules are not easily available on the market and have a very limited track record.

Modules shall be designed to generate electricity for a minimum of 25 years under the environmental conditions of the site. The electricity generation capabilities of the modules shall meet or exceed the capabilities defined by the module electrical data sheet of the product. Module rated peak power (defined at standard test condition) shall be used to determine the peak power of the plant. The peak power of the plant shall be the sum of the manufacturer's nameplate data sheets for each individual module. Maximum annual degradation shall be specified. Modules shall be certified to IEC 61730 and shall carry appropriate IEC or European Norm (EN) certificates relevant to technology certified by the approved testing agency.

Modules shall be new and in order to maintain the homogeneity of the plant, all cells and modules connected to the same single inverter shall be supplied by the same manufacturer and shall be rated at the same nominal power. PV modules shall comply with the minimum specific technical requirement set in technical schedules in *Appendix E - Table 11*.

2.2.3.2 Inverters

Considering the hybrid nature of the proposed plant, a string inverter-module configuration is the preferred option. Grid-tied inverters shall be designed to provide all of the power conversion, maximum power point tracking (MPPT) and energy delivery functions including control, protection and monitoring necessary for a fully integrated hybrid solar PV plant. The inverter shall provide a three-phase sinusoidal waveform at 50Hz with a nominal power factor of 0.9 or higher and the DC-to-AC

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conversion efficiency shall be rated at least 98 percent. The inverter shall include the necessary DC circuit breakers/disconnect switches, AC circuit breakers/disconnect switches, local controls, remote monitoring and control interfaces and accessories necessary for the inverter to function properly as part of a power generating plant. The inverters shall be located to minimise losses.

The nominal power of the inverters shall be rated according to the nominal power of the associated PV module array with a design guide of maximizing the capacity of the inverter while observing the maximum ratings indicated by the manufacturer and safety guidelines of the applicable codes. The inverters shall be capable of complete automatic unattended operation, including start-up, synchronisation and disconnect and operating in parallel with other inverters and the utility. Auxiliary power requirements to power unit from other than station reticulation or PV (e.g. for night-time power if disconnected from the station reticulation) shall be defined. The inverters complete with the necessary DC and AC wiring and hardware accessories, including protection equipment, monitoring system, communication and control and other auxiliary equipment shall be suitable for outdoor installation with an IP rating of IP65. The inverter and accessories shall be installed under a suitable shade. Inverters shall comply with the minimum specific technical requirement set in technical schedules in Appendix E - Table 12.

2.2.3.3 Auxiliary Supply Distribution Board

The auxiliary supply distribution board supplies PV plant auxiliary loads and is fed from the inverter output. Sizing of the board to be based on the short-circuit study and PV plant auxiliaries load requirement. Auxiliary loads shall include lighting, socket outlets, control and monitoring system, security systems (perimeter lighting, cameras, etc.), fire detection, meteorological stations, etc. The DB shall be suitable for outdoor installation under a shade. The installation location must be easily accessible. The auxiliary board shall comply with the minimum specific technical requirement set in technical schedules in Appendix E - Table 13

2.2.3.4 PV Distribution Board

In between inverters and point of connection, the PV-distribution board serves mainly as combiner of several inverter output cables to connect the PV system via a single PV main cable to the point of connection. The PV-DB shall contain the following minimum equipment:

- String inverter incomer breakers (4P, lockable)
- Outgoing LV breaker
- Auxiliary distribution board supply breaker

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- Power and Energy Metering equipment to measure net power generated by the plant and the auxiliary power consumed by the plant and
- overvoltage protection

The PV-DB shall be rated for outdoor installation with an IP rating of IP65. It shall be positioned such that connections to the inverters are optimal. The enclosure shall be equipped with sun shields were exposed to direct sunlight. The installation location must be easily accessible.

The minimum technical requirements for the PV-Distribution Board are presented in technical schedules in Appendix E - Table 14.

2.2.3.5 Point of Connection (PoC) – Mini-substation LV Switchgear

The proposed point of connection shall be made through the 400V system of the existing Station Services Building mini-substation. Refer to Drawing #: 0.33-18022-2 Komati PS MV & LV Single Line Diagram for the proposed point of connection and Drawing 14-1379-A4 Rev 1 for schematic wiring of the mini-substation. The maximum power that can be evacuated at the point of connection is 600kVA.

It is proposed that a 400V, 1000A breaker be installed in an LV junction box mounted next to the LV compartment of the mini-substation. Installation of the LV junction box will require extending the 400V bus bars of existing mini-substation or installing cable jumpers. The Bidder shall propose the most feasible solution to connect to the existing mini-substation 400V bus bar. The additional 400V, 1000A breaker shall serve as the PV system termination and connection point. Refer to Figure 2 showing the existing mini-substation 400V compartment,



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Figure 2 Existing mini-substation 400V compartment

The bidder shall supply, install and connect (to the existing mini-sun 400V bus bars) the additional junction box complete with the breaker, accessories, connection and mounting arrangements. In addition, the bidder shall supply and install the PV-DB to junction box interconnection cable and termination kit. Minimum technical requirements for this LV breaker are specified in technical schedule in Appendix E - Table 15.

2.2.3.6 DC Reticulation System

DC reticulation comprises DC cabling, DC combiner boxes, DC connectors and other DC accessories which provide the electrical connection between individual PV modules of a solar generation facility to the string combiner boxes and as well as from PV sub-array and PV array combiner boxes to inverter.

DC cable insulation levels shall be rated according to the maximum system voltage. DC string cables shall be sized accordance with the solar photovoltaic code requirements. Cable insulation type shall be sunlight resistant, rated for wet locations and have a temperature rating of 90°C or better. DC cables shall be sized accordingly taking into account any ambient temperature or conduit de-rating factors and voltage drop considerations. DC string, array and main cabling shall be selected and installed in such a way to prevent risk of leakage currents. Minimum specific technical requirement for DC cabling is presented in technical schedules in Appendix E - Table 16 and Table 17.

PV module connectors and DC cable connectors shall be compatible and from the same manufacturer throughout the whole PV plant. The minimum technical requirements for module and cable connectors are presented in technical schedules in Appendix E - Table 18.

DC combiner boxes shall include an array of on-load disconnect switches which shall be accessible without opening the combiner box. This switch shall allow for isolating the array connected to the box for maintenance and emergency purposes and shall be lockable. The combiner box shall include a string fuse for each string. The fuse rating shall be rated according to the requirement from the module and inverter manufacturer. Primary combiner boxes shall include string-monitoring system with communicates to the DCS server. Combiner boxes shall comply with the minimum specific technical requirement set in technical schedule in Appendix E - Table 19.

2.2.3.7 AC Reticulation System

Three phase LV supply cables shall be used to connect inverters output to the PV-DB, auxiliary DB, auxiliary loads and to the point of connection. All AC cables shall comply with norm and standards,

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SANS 1507 and SANS 10142-1 and 2. The minimum specific technical requirement for AC cabling is presented in technical schedule in Appendix E - Table 20.

2.2.3.8 Earthing System

This encompasses all equipment installed and connected together that eliminates the risk to personnel or animals of electric shock under normal operating conditions as well as fault conditions. It shall include inter-alia earth mats, earth-connectors, earthing conductors. The earthing system shall be designed in accordance to Solar PV industry best practice and in compliance with SANS 10200:1985 and SANS 10292:2001. Earth calculations shall be performed in accordance with applicable standards to ensure that step and touch potentials are within acceptable limits. The plant-earthing grid shall be of adequate capacity to dissipate heat from earth current under the most severe conditions in areas of high earth fault current concentrations and in such a way that it is possible to maintain grid spacing to achieve safe voltage gradients. Major items of equipment such as switchgear, inverters, relay panels and control panels shall have integral earthing buses connected to the station-earthing grid.

2.2.3.9 Surge and Lightning Protection

The lightning protection system shall protect the whole PV plant including modules, structures, inverters, control and monitoring systems and other electrical and mechanical equipment against damage caused by lightning strikes. The lightning protection system shall be designed in accordance with the latest edition of SANS 62305. Overvoltage protection shall be installed at the DC side as well as the AC side of the inverter, DBs and within the PV arrays. Protection against direct strikes (direct strike lightning protection) shall be installed and coupling as a result of strikes elsewhere in the network (indirect strike lightning protection) shall be taken into consideration and designed out of the system. The minimum specific technical requirements for surge and lightning protection are presented in technical schedules in Appendix E - Table 21.

2.2.3.10 Metering and Measurements

The bidder shall design, supply and install energy metering inside the PV-DB. A complete metering solution shall include but not limited to energy meters, CTs, VTs and CT and VT test Blocks. The energy meter shall provide tariff metering, bi-directional energy measurements and power quality monitoring. The power quality monitoring and assessment shall be as described in Section 9 of Renewables Grid Code Ver. 2.6, NRS048-2 and SANS61000. For approved energy meters without power quality monitoring capability, a separate power quality monitoring meter shall be provided that

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meets the minimum power quality requirement in Section 9 of Renewables Grid Code Ver. 2.6, NRS048-2 and SANS61000 and shall be installed in the same panel with the energy meter. The Energy meter and Power Quality meter shall communicate with the respective control and instrumentation devices. The minimum communication protocol is RS485.

2.2.3.11 Abnormal Operations

In the event of a grid failure or supply parameters (voltage and frequency) drifting outside of the pre-set operating windows, a protection relay shall shut down the inverters and prevent the system from exporting electricity into the mini-substation 400V system. When the grid parameters return to normal levels the relay shall allow the inverters to turn on, synchronise and connect to the grid again. In the event of an emergency, the photovoltaic system has to be shut down quickly and completely. The Contractor shall install an emergency button for turning the installation off. Pressing the emergency button breaks the circuit and removes power from the relay. Once the installation has been turned off, the only way to activate the photovoltaic system again is by using a security key. The emergency button shall have a label "Emergency Stop".

2.2.4 Control and Monitoring System (CMS) Requirements

The Control and Monitoring System comprises of data acquisition servers and onsite user interfaces, power supplies to control and monitoring equipment, UPS, communication network cabling, instrumentation, fire detection system, weather and performance monitoring system. Control and monitoring equipment shall be housed in the Station Services Building. The CMS shall monitor the inverter parameters, Meteorological parameters, string currents and system status as minimum both local at site and remotely. The Bidder shall design, procure, install, test and commission the entire CMS scope as specified in the Works Information.

2.2.4.1 Meteorological System

Meteorological Station comprises of Pyranometer (horizontally mounted & unshaded) to measure the global horizontal irradiation. High-accuracy Reference Cells with the same technology and type as installed PV modules. Shielded ventilated thermal sensor to measure the ambient temperature and thermal sensor to measure module temperature.

Data from Reference Cell and Thermal Sensors is used to evaluate the plant performance. Pyranometer and ambient temperature measurements are kept as meteo records of Project Location and this data is used to cross check the reading from reference cell (especially from Pyranometer).

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2.2.4.2 Fire detection System

Fire Detection System comprises of fire panels with on-board display for local monitoring and have interface to the on-site CMS Network; and a dedicated LCD monitor at the control room for monitoring fire detection system. Fire Protection System includes fire alarm call point linked to existing fire alarm system, evacuation maps, and procedure in case of a fire, fire extinguishers and an emergency button.

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

3. INSPECTION TESTING AND COMMISSIONING

Contractor shall demonstrate performance through inspections, and tests during execution and operation of the project. These tests includes:

- Perform tests before installation (factory acceptance tests, site acceptance tests)
- Perform tests after installation (mechanical completion test and issue mechanical completion certificate, then electrical completion test and issue substantial completion certificate)
- Perform tests after completion (final acceptance test which is a 15 day performance ratio and availability test – issue operational acceptance certificate)

3.1 GENERAL REQUIREMENTS

The Contractor shall provide facilities necessary to enable the inspection, testing, commissioning and performance testing of the PV Facility to be satisfactorily completed including labour, equipment, materials, instruments, consumable materials, electrical power, fuel, lubricants, water, and such like.

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

The Contractor shall provide any instruments or other equipment for the Employer and Employer's representatives to review the accuracy, quality and performance of the PV Facility. Provide any assistance required by Employer and Employer's representatives in the use of instruments and measuring equipment.

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The Contractor shall ensure that instruments used for survey work, checking, inspection, testing, commissioning and performance monitoring are correctly calibrated and up to date, according to their relevant standards. The contractor shall submit the valid calibration certificates with method statements and test records.

The Contractor shall provide 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.

The Employer, Employer's representative and the Contractor shall agree on test protocol before the commencement of any tests. The Test protocol shall include but not limited to,

- Definition of each test type and test methods
- List of equipment to be used along with their specification, measurement uncertainties and relevant certificates
- Duration of each test
- Test evaluation method and Acceptance/Rejection criteria

The Contractor shall provide the report to the Employer and the Employer's representative upon the successful commencement of any tests during commissioning. The report shall include following but not limited to,

- Agreed final test protocol
- Test raw data (un-processed)
- Evaluation of raw data (processed data)
- Final result indicating the acceptance/rejection of each test types

3.2 TESTS BEFORE INSTALLATION

The Contractor shall submit for review and approval to Employer and Employer's Representatives the test program for Factory Acceptance Test comprising but not limited to:

- Detailed description of inspections/tests types.
- Component certificates, technical data sheets
- Manufactures' quality certificates
- Standards to be followed during testing/inspection

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- Test results of former inspections/tests, if available

Upon the successful completion of the Factory Acceptance Test, the Contractor shall submit the test report along with the relevant documents. All test reports shall be prepared by the Contractor and shall contain the following minimum information:

- Definition of each test type and test methods
- Technical data along with the component certificate of tested component
- Test evaluation and technical data of testing components including relevant certificates
- Compliance with the requirement for the project and/or Industry practice
- Summary and conclusion in regard to acceptance or rejection of equipment

The test reports shall be reviewed and approved by the Employer and the Employer's Representatives prior 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's Representative prior shipment of tested components.

The Contractor shall be responsible for all arrangements for the Factory Acceptance Tests and will be responsible for management and any additional expenses that is caused due to requirement on repetition of Factory Acceptance Tests.

The Contractor shall verify 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. The Site Acceptance Test shall be witnessed and approved by the Employer and the Employer's representative.

3.3 TESTS AFTER INSTALLATION

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. They must demonstrate:

- Completeness of the mechanical and electrical construction works
- Correctness of the assembly and installation
- Safety and reliability of the works under all operating conditions
- Inspection and functional tests

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- Proper functioning of the components and system under all operating conditions

Tests after Installation are considered successful if the Plant complies with the requirements defined for each type of inspections described in this specification.

Copies of all tests and data are provided to the Project Manager for review and acceptance.

3.3.1 Test Pre-Requisite – Minimum System Documentation Requirement

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.

The completeness of the documentation is reviewed and accepted by the Project Manager before commencement of the tests.

The following non-exclusive list of Plant sections are documented and checked during the Tests after Installation:

- Basic system information:
 - Project location and installation date
 - Rated system capacity (DC and AC)
 - PV modules and inverter – manufacturer, model and quantity
 - Installation date
 - Commissioning date (to be updated later if time schedule of tests not met).
- System designer's information (name, affiliate, contact details)
- System installer/Contractor information (name, affiliate, contact details)
- 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 cabinets.
- General specifications of array:
 - Module type
 - Module number
 - Number of modules per string
 - Number of strings

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

3.3.2 Mechanical Completion Test

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

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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.

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.

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

3.3.2.1 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.

3.3.2.2 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 modules is documented according to installation location on site; and
- Verify that the installation was done according to manufacturer's recommendation and/or requirements.

3.3.2.3 PV String Combiners

- Verify that PV String cables have been permanently marked and numbered;
- Check cable Pulling Test records;

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- 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 CMS system

3.3.2.4 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.

3.3.2.5 Foundation and Civil works

- Verify all civil works are completed according to design and according to permits for the Project;
- Verify that security system (fences, video surveillance) are installed according to Employer's requirement;

3.3.2.6 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; and
- Verify all inverter parameters are set up within Manufacturer's recommendations, grid requirements and local regulations;

3.3.2.7 Control and Monitoring System

- Verify all system components and respective electrical and data connections are according to design;
- Verify all Calibration Certificates are available;

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- Verify broadband equipment and connections

3.3.2.8 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

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

3.3.3 Electrical Completion Test

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

3.3.3.1 Tests on AC circuits

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;

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- 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 and
- Verification of voltage drop

3.3.3.2 Tests on DC Circuits

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;
- 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;

3.3.3.3 Functional Tests

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.

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- 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

3.3.3.4 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.

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.

3.3.3.5 Certificate of Compliance

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.

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.

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

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

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

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

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3.3.3.6 Functional Test of Meteorological System and C&I system

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

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

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

Test communications with string combiner boxes and inverters.

Verify format and handling of acquired data set.

Check threshold alarm controls.

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

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

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

Control of remote system access and data downloading.

Handover of access rights and passwords.

3.3.3.7 Infrared Thermography

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/m².

3.3.3.8 Grid Code connection test

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.

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

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.

3.3.3.9 Test Reporting

Once the Electrical Completion tests are successfully performed, the Contractor provide the report to the Project Manager, 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.

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

3.4 TESTS AFTER COMPLETION

Tests after Completion refer to the “Final Acceptance Test (FAT)” which verifies both performance ratio and availability of the plant against the Contractor’s guarantee.

The following is to be completed before the start of FAT:

- Mechanical Completion Certificate, Certificate of Compliance (COC) for electrical installations, safety clearance certificates for plant installations, Substantial Completion Certificate have been issued;
- Training on Construction and Commissioning to the Employer’s representative and Employer’s staff have been completed;

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- The Contractor has provided O&M Manual to the Employer and the Employer's representative, which include, but not limited to:
 - 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.);
 - Safety Guidelines including emergency shutdown/isolation procedures;
 - Preventive and corrective maintenance procedures including site inspection checklist for each component including power evacuation line and security systems;
 - Scheduling of routine maintenance;
 - A checklist of what to do in case of system failure;
 - Documentation on stock of spare parts and spare parts management including contact information and procedures for replacement of defective components;
 - Inverter O&M Manual (troubleshooting for error codes, repair, software for inverter, Fault finding on the DC Plant);
 - Data Acquisition System and CMS O&M Manual (troubleshooting, equipment descriptions, repair, metering equipment downloading, weather station);
 - Method of PV module cleaning;
 - Operation and maintenance manual for inverter, transformer and module from respective manufacturers;
 - Performance monitoring and reporting procedures

3.4.1 The Final Acceptance Test (FAT)

The Contractor executes the FAT, and is witnessed by the Employer and the Employer's representative.

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

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

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.

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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.

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/m², measured by 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.

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

3.4.1.1 The FAT Procedure

Parameters and Instrumentation:

- 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/m²]
 - Global solar irradiation on horizontal surface: [kWh/m²]
 - Module temperature: [°C]
 - AC Energy output from each inverter: [kWh]
 - Ambient air temperature: [°C]
- 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.

3.4.1.2 FAT Stopping and Restarting Procedure

The FAT is stopped and restarted:

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- If the Plant, wholly or in part, ceases to operate at any time during FAT due to causes beyond the control of the Contractor, then the FAT is suspended during that time and resumes following restoration of operation, until the total FAT 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 substantial dates.
- The Contractor maintains a log of any such event, including the cause, the duration and the times at which FAT was suspended and resumed. The Contractor provides written notice to the Employer within eight (8) hours following each such FAT suspension and resumption. All pre-requisites specified must remain satisfied on any such FAT resumption.
- If at any point during FAT the Contractor deems that it is unlikely to pass the FAT, then the Contractor notifies the Project Manager and may discontinue the FAT. The Contractor may subsequently commence a new FAT, subject to compliance with all provisions and procedures within this Section.

3.4.1.3 Performance Ratio (PR) Evaluation Procedure

The plant Performance Ratio (PR) is evaluated according to equations below:

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

Where:

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

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

$[E_{PV}]_{PAT}$ = Theoretical energy that could have been produced by PV modules during the Final 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 name plate power of modules installed in the plant, expressed in kWp

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$[Irr_{POA-measured}]_{PAT}$ = Average solar irradiation measured on Plane of Array during the complete Final Acceptance Test period when the plant was available, expressed in kWh/m²

$[Irr_{STC}]$ = Solar irradiation at Standard Test Conditions (STC) condition, 1 kW/m² (constant)

3.4.1.4 Plant Availability Evaluation Procedure

The plant Availability is measured for a consecutive 15 day period, for the FAT.

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.

The evaluation of plant Availability is done only for the periods during which the global solar irradiation on module plane is higher than threshold level of solar irradiation. The threshold value of solar irradiation on module plane for plant availability is 100 W/m². This level of irradiation is considered as the minimum level of irradiation required to overcome the inverter's threshold power.

The stoppage of the plant due to events caused by following is not considered while evaluating the plant availability:

- events caused by faults, except than 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

The Plant Availability $[A_V]$ is defined as average of individual inverter availability, as shown in the equations below:

$$[A_V] = \frac{\sum_{i=1}^n [A_{Vi}]}{n}$$

Where, "i" is the number of each individual inverter and "n" is the total number of inverters in the Plant. The individual technical availability of the inverter "i" is calculated by using the equation shown below:

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$$[AV] = \frac{T_{op}}{T_{tot} - T_{grid} - T_p - T_{fm}} \times 100 \%$$

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/m², 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 a 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/m²).

3.4.1.5 Criteria for FAT Acceptance

The Final Acceptance Test is considered successful if:

- Measured Performance Ratio (PR) is greater than or equal to Guaranteed Performance Ratio during FAT, and
- Measured Plant Availability is greater than or equal to Guaranteed Plant Availability during FAT

3.4.1.6 Criteria for Issuance of Operational Acceptance Certificate

The Operational Acceptance Certificate is issued by the Project Manager, if:

- FAT requirements are successfully completed

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- The complete O&M manual is provided by the Contractor and accepted by the Project Manager
- Punch List is reviewed and accepted by the Project Manager
- 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
- The site is free from any wastes, residues from site establishment and construction
- If applicable, any delay liquidated damage payable to the Employer by the Contractor is completed

4. CONTRACTOR'S GUARANTEE ON PERFORMANCE AND AVAILABILITY

The Contractor provides the following guaranteed values for Final Acceptance Test:

- Performance Ratio (PR)
- Plant Availability

These Performance Guaranteed Values for the PV Facility are verified during the Final Acceptance Tests.

The guaranteed Performance Ratio shall be evaluated at 100% plant availability. The actual Plant Availability is guaranteed and evaluated separately.

The Contractor is required to provide Performance Guaranteed Values as indicated in Appendix G – Table 22

With regards to the “Guaranteed annual average Performance Ratio for first year of operation - for Final Acceptance Test” provided in Appendix G – Table 23, the Contractor is required to provide a monthly breakdown of this Performance Ratio guarantee, along with estimation of solar irradiation on module plane, in a tabular format as shown in Appendix G – Table 23.

The PR guaranteed for the Final Acceptance Test will be the corresponding monthly average PR (shown in Appendix G – Table 23), during which the FAT is performed. If the FAT duration covers period of two consecutive months, then the guaranteed PR during FAT is calculated based on weighted average PR of the two respective months.

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4.1 EQUIPMENT WARRANTY

4.1.1 PV Plant

The Contractor provides equipment warranty according to minimum requirement set in Appendix G – Table 24.

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.

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

4.2 O&M TRAINING

O&M Training is provided to the Employer and Employers' representatives' within six (6) months after the issuance of Substantial Completion Certificate. The Training is based on Classroom and Onsite Training.

- The Contractor provides formal classroom training of the operations, maintenance to ensure Employer's representatives' has a sound understanding of the plant layout, characteristics and functionality.
- Training material for classroom training is based on O&M manual content (O&M Manual requirement is presented in in this document) and contains evaluation criteria on each section of the plant covered in order to establish the level of Employer's representatives' understanding.

The Contractor provides formal on-site training of the operations, maintenance of the plant is essential to ensure Employer's representatives' have a sound understanding of the plant functionality and O&M requirements.

Training material for on-site training is based on O&M manual (requirement of O&M Manual is presented in this document) in addition to detailed operating and maintenance plans and procedures.

Training focuses on following area,

- Operation and Maintenance of the Facility

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- Inverter Technician Training: specification, functioning and safe operation following Manufacturers O&M Manual (troubleshooting for error codes, repair, software for inverter, Fault finding on the DC Plant) and
- Data Acquisition System and PLC Training

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

The Contractor ensures that experienced personnel (minimum 5 years of experience in operation and maintenance of utility scale PV projects) conduct all trainings in professional manner.

4.3 SPARE PARTS AND TOOLS

The Contractor must provide a list of spare parts and tools recommended by equipment manufacturers for operation and maintenance for 25-year lifetime period. The Contractor considers such list as minimum required spare parts and tools for the Project.

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.

The Employer, at its option, may decide to purchase such additional spare parts and tools subject to schedule of delivery to be agreed upon

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5. AUTHORISATION

This document has been seen and accepted by:

Name & Surname	Designation
Viren Heera	Chief Engineer Prof Engineering
Marubini Manyage	Chief Engineer Prof Engineering
Paul Du Plesis	Chief Technologist Electrical
Kuvhanganani Magidimisa	Senior Engineer Prof Civil
Kellie Kwinika	Engineer Prof Civil
Adhir Debising	Engineer Prof Engineering
Imraan Dindar	Senior Engineer Prof Mechanical
Bongani Mashimbye	Middle Manager Engineering

6. REVISIONS

Date	Rev.	Compiler	Remarks
July 2021	0	K. Mareya	Draft Issue (Review & Signatures)
July 2021	1	K. Mareya	First Issue

7. DEVELOPMENT TEAM

The following people were involved in the development of this document:

- Kuda Mareya – Senior Engineer Prof Mechanical
- Freeman Chiranga - Senior Engineer Prof Electrical

8. ACKNOWLEDGEMENTS

N/A

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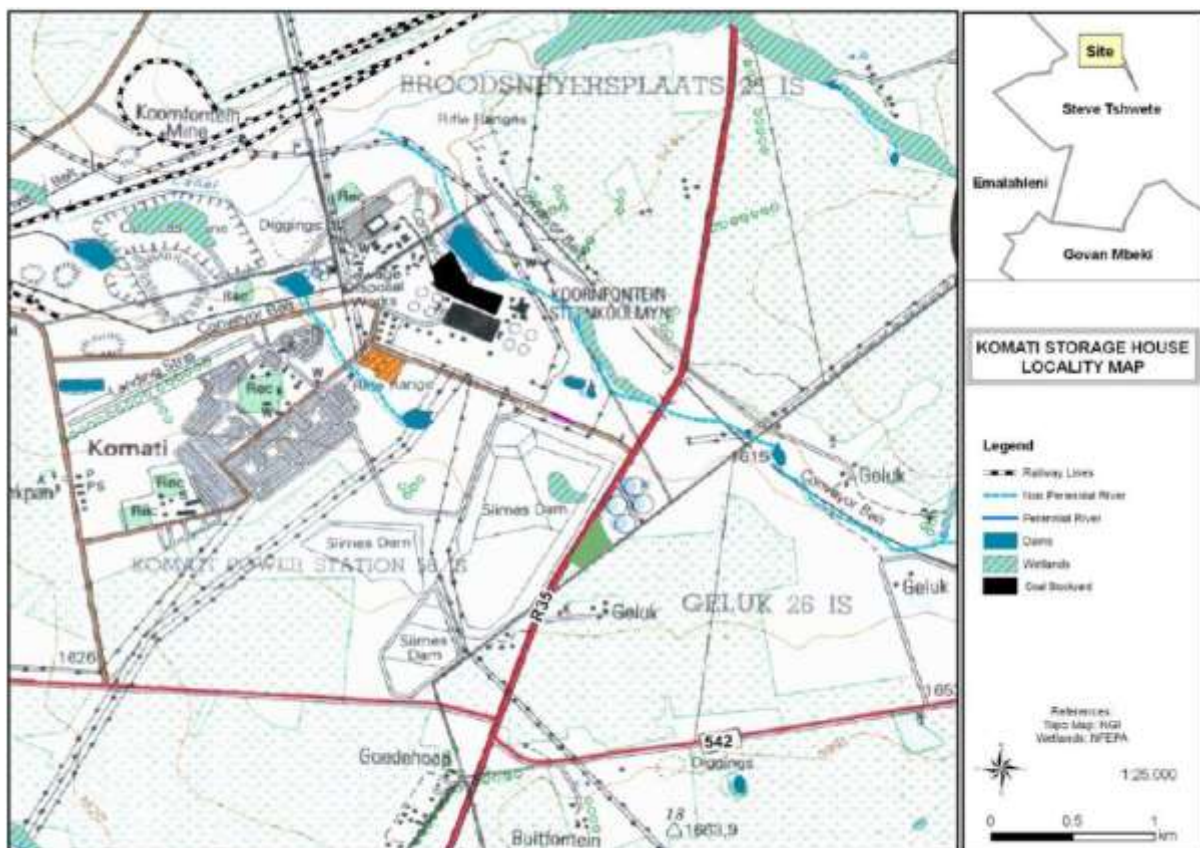
APPENDIX A: LOCATION DATA & SITE CONDITIONS

Table 1: Area Estimates for the Proposed Site – Area 1-4 within Station Services Building Premises

Site	Size Estimates		Notes
	Gross Area (m ²)	Perimeter (m)	
Area 1	8 100	387	a) No wetlands or overhead lines
Area 2	3 000	267	b) No wetlands or overhead lines
Area 3	3 745	270	c) No wetlands or overhead lines
Area 4	2 390	270	d) No wetlands or overhead lines
Area 5	4 850	-	e) Covered Parking Roof Area (Induction Center Parking Lot).

Net/Effective Area (m²) to be determined by the Bidder

Figure 3 Location of the Proposed Installation Site.

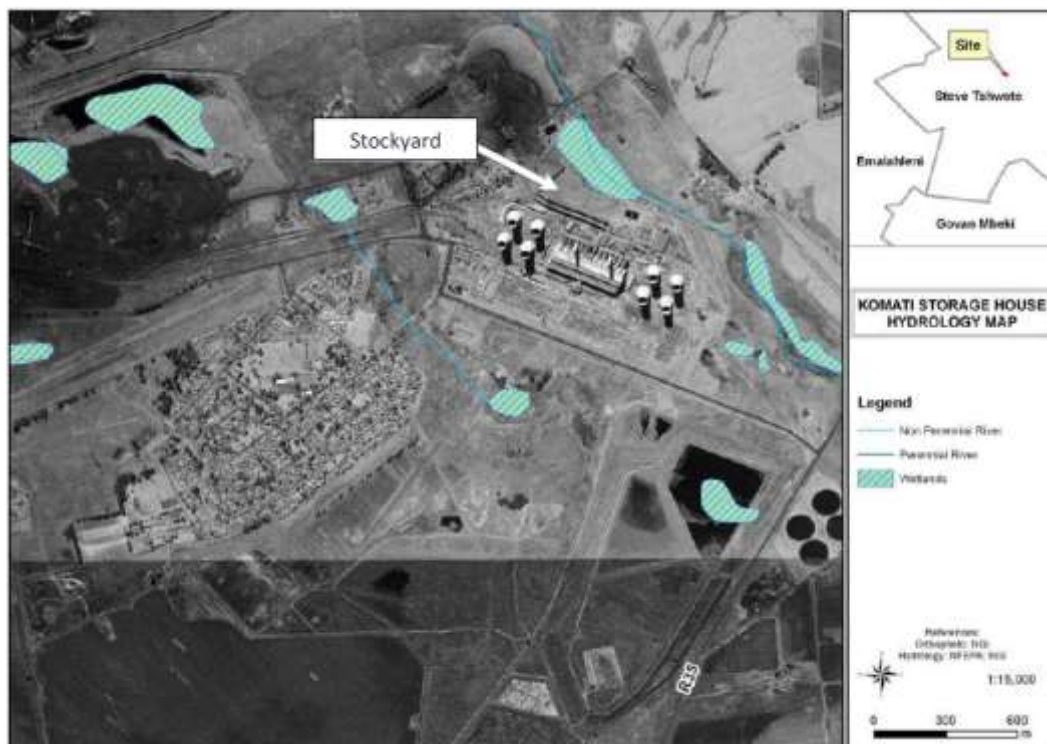


Source: Wet Land Opinion Report – May 2013, Komati Coal Stockyard Extension

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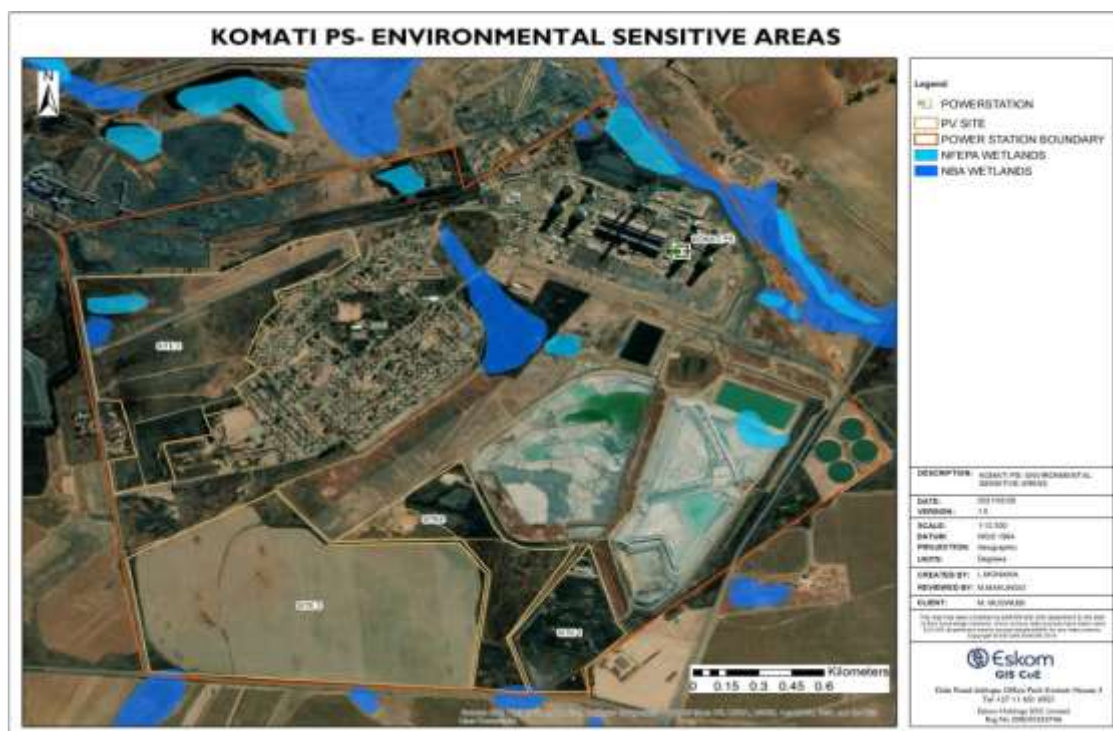
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Figure 4 Hydrology of the Proposed Site as per Existing Spatial Layers



Source: Wet Land Opinion Report – May 2013, Komati Coal Stockyard Extension

Figure 5 Komati PS Environmental Sensitive Areas – Source: GIS Desktop Study – May 2021



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No presence of threatened Terrestrial Ecosystem and Protected Area

Figure 6 Komati PS Servitude Infrastructure – Source: GIS Desktop Study – May 2021

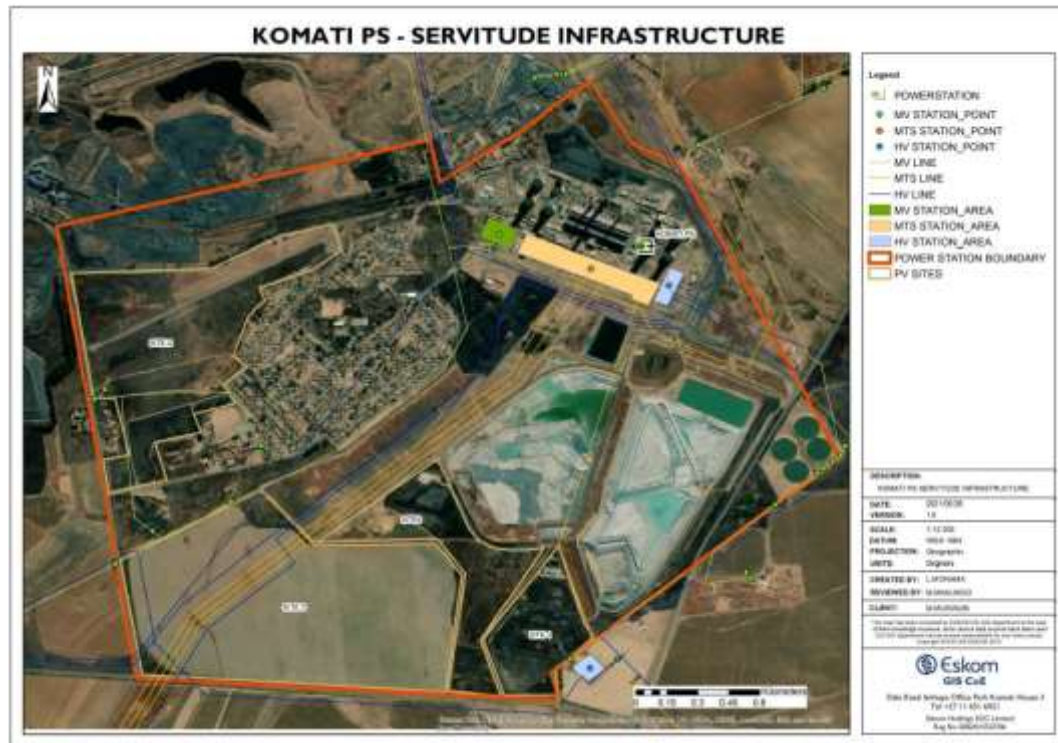
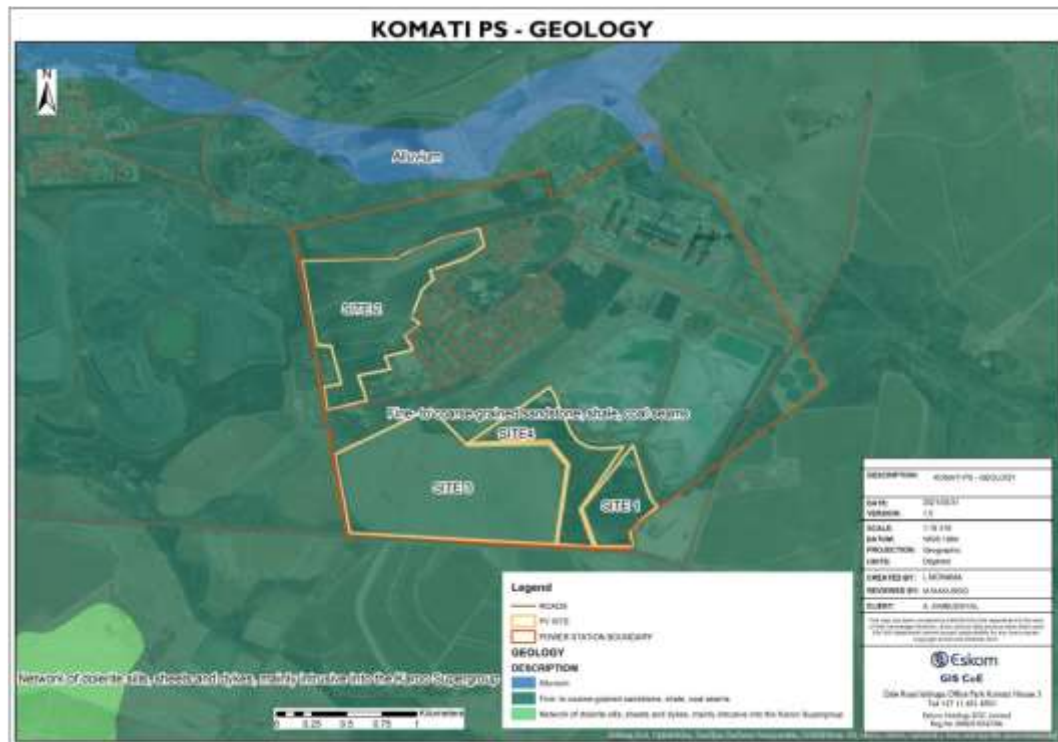


Figure 7 Komati PS Geology – Source: GIS Desktop Study – May 2021



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Consist of fine-to-coarse-grained sandstone, shale and coal seams

Figure 8 Komati PS Topography – Source: GIS Desktop Study – May 2021

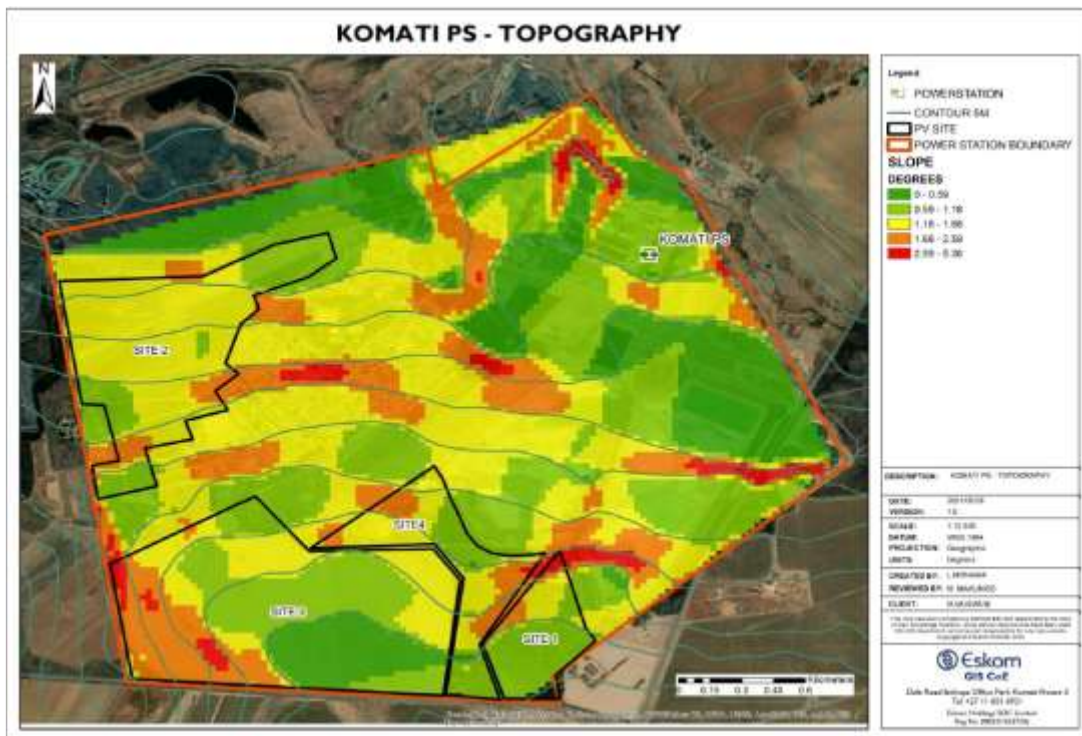
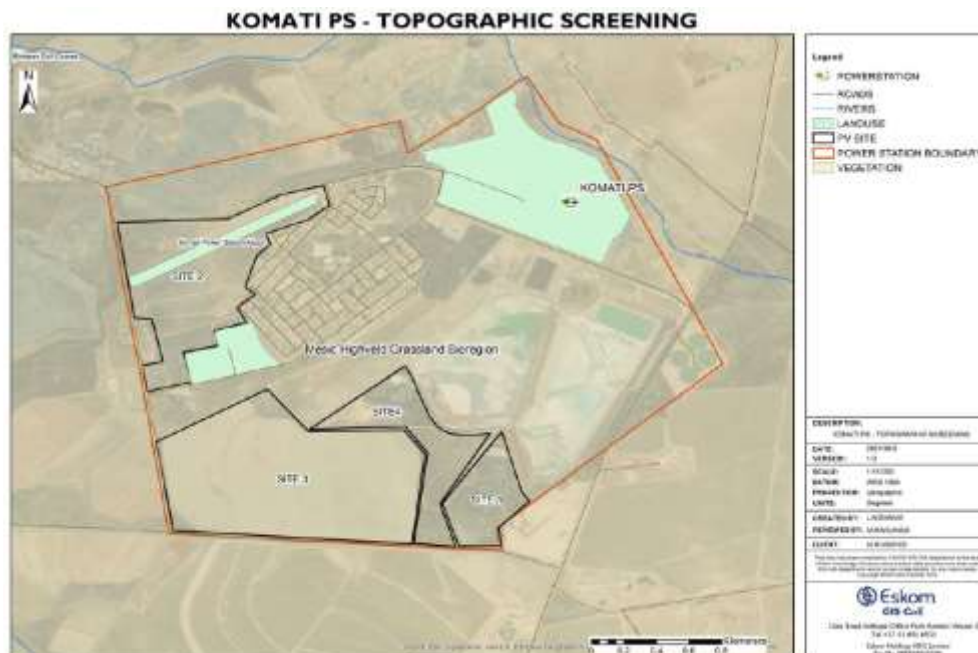


Figure 9 Komati PS Topography Screening – Source: GIS Desktop Study – May 2021



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APPENDIX B WEATHER (TMY) DATA

Ambient Temperature

Table 2: Ambient Temperatures – January 2014 to December 2018

Year	Mean	Std. Dev.	Max	Min
2014	15.8	6.9	31.5	-4.3
2015	17.1	7.3	34.1	-4.8
2016	16.4	7.1	36.2	-2.6
2017	15.8	6.5	32.0	-0.8
2018	16.2	6.9	33.7	-4.2

The lowest measured temperature: -6.8 °C; and Maximum: 35.3 °C.

Wind Speed

Table 3: Wind Speed – January 2014 to December 2018

Year	Mean	Std. Dev.	Max
2014	2.7	1.8	12.4
2015	3.2	2.0	16.8
2016	3.0	2.0	15.1
2017	2.8	1.9	12.5
2018	2.8	1.9	12.7

The maximum measured wind speed: 16.8 m/s.

Wind Direction

Table 4: Wind direction. North North Easterly (NNE) wind most predominant in 2015, 2017 and 2018.

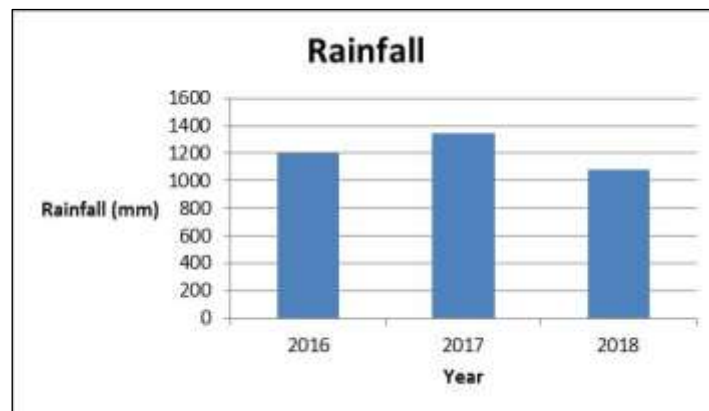
Year	Wind Direction
2014	ENE
2015	NNE
2016	NNW
2017	NNE
2018	NNE

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Rainfall

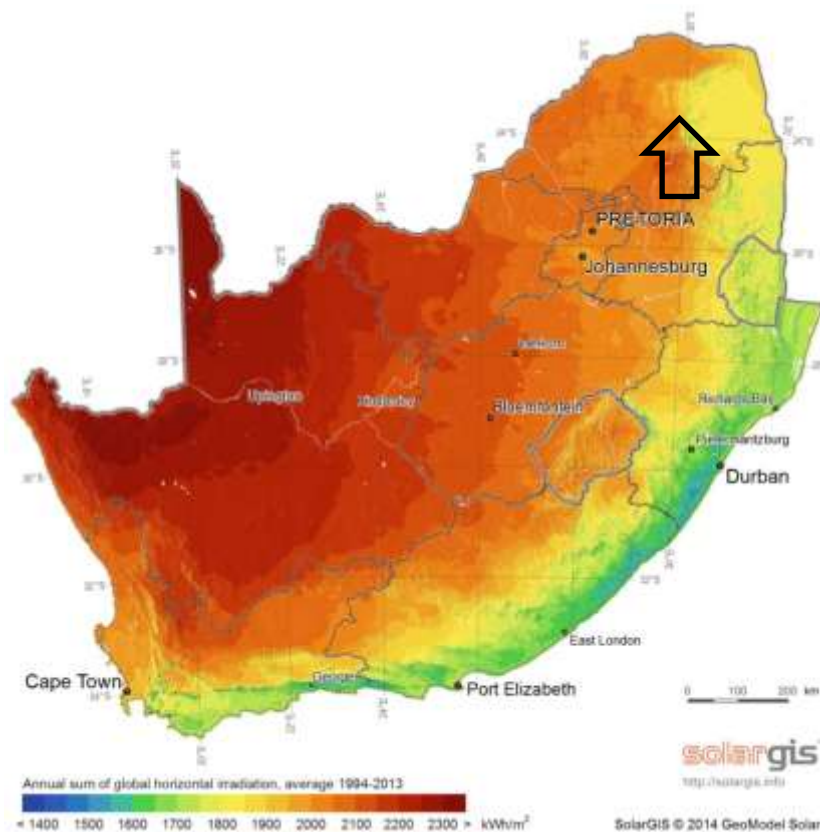
Figure 10 Annual Rainfall 2016 - 2018



The highest measured amount of rainfall: 1349 mm in 2017 and Lowest: 1080 mm.in 2018

Solar Resource

Figure 11 Annual GHI Map – South Africa (Source CRSES) [Site indicated by an arrow]



Expected Annual Average GHI at the Project Location is between 1972 kWh/m² and 2045 kWh/m²

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Table 5: Long-term annual GHI different data sources at Project Location – (Max deviation: 6%)

Data Base	Data Source	Data Spatial Resolution	Period	GHI [kWh/m ²]
HelioClim	Satellite	3 km × 3 km	2004-2006	1912
PVGIS	Satellite	1 km × 1 km	2007-2016	2035
SolarGIS	Satellite	Up to 90 m × 90 m	1994 - recent	2032

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APPENDIX C: CODES AND STANDARDS

Table 6 Codes & Standards – Civil Engineering Design Work

All Civil Engineering Design Work Shall Comply With The Following:

Standard/Code	Description
SANS 10400	Code of Practice – The Application of the National Building Regulations
SANS 10100	The structural use of concrete
SANS 10160	Basis of structural design and actions for buildings and industrial standards
SANS 10162-1	The structural use of steel Part 1: Limit states design of hot-rolled steelwork
SANS 10162-2	The structural use of steel Part 2: Limit states design of cold-formed steelwork
SANS 10162-4	The structural use of steel Part 4: The design of cold-formed stainless steel structural members
SANS 10021 Ed4.0	The water-proofing of buildings (including damp-proofing and vapour barrier installation)
SANS121:2011 Ed2	Hot dip galvanized coatings on fabricated iron and steel articles - Specifications and test methods
SANS 2001 – CS1:2012 Ed.1.01	Construction works Part CS1 – Structural steel works
SANS 1921-3:2004 Ed.1	Construction and Management requirements for works contracts – Part 3 Structural steel works
SANS 1200H: 1990 Ed3	Standard specification for Civil Engineering construction - Structural steel work installation
SANS 1200HC: 1988	Standardized specification for civil engineering construction Section HC: Corrosion protection of structural steelwork
SANS 2001	Construction

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Table 7 Codes & Standards – Equipment & Services

All Equipment And Services Supplied Shall Comply With The Standards Listed Below:

Standard/Code	Description
General	
	Grid Connection Code for Renewable Power Plants (RPPs) Connected to the Electricity Transmission system (TS) or the Distribution System (DS) in South Africa Version 2.8, July 2014
SANS 10142	The wiring of Premises – Part 1: Low voltage installation
PV Modules	
IEC 61215 Ed.2	Crystalline silicon terrestrial photovoltaic (PV) module - Design qualification and type approval
IEC 61730-1 Ed.1.2	Photovoltaic (PV) module safety qualification - Part 1: Requirements for construction
IEC 61730 -2 Ed.1.0	Photovoltaic (PV) module safety qualification - Part 2: Requirements for testing
IEC 61701 Ed. 2	Salt mist corrosion testing of photovoltaic (PV) modules
IEC 62716 Ed. 1	Photovoltaic (PV) modules - Ammonia corrosion testing.
IEC 60891:1987	Procedures for temperature and irradiance corrections to measured I-V characteristics of crystalline silicon photovoltaic devices, Amendment 1 (1992) .
IEC 60904-1:1987	Photovoltaic devices – Part 1: Measurements of photovoltaic current voltage characteristics.
IEC 60904-2:1989	Photovoltaic devices – Part 2: Requirements for reference solar cells.
IEC 60904-6:1994	Photovoltaic devices – Part 6: Requirements for reference solar modules.
IEC 60904-7:1998	Photovoltaic devices – Part 7: Computation of spectral mismatch error introduced in the testing of a photovoltaic device.
IEC 60904-9:1995	Photovoltaic devices – Part 9: Solar simulator performance requirements.
IEC 60904-10:1998	Photovoltaic devices – Part 10: Methods of linearity measurements.
IEC 61853	Performance testing and energy rating of terrestrial photovoltaic (PV) modules
IEC 60068-2-78:2001	Environmental testing – Part 2-78: Tests – Test Cab: Damp heat steady state.

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IEC 60068-2-21:1999	Environmental testing – Part 2-21: Tests – Test U: Robustness of terminations and integral mounting devices
Inverters	
IEC 62093 Ed. 1.0	Balance-of-system components for photovoltaic systems - Design qualification natural environments
IEC 62109-1 Ed 1.0	Safety of power converters for use in photovoltaic power systems - Part 1: General requirements
IEC 62109-2 Ed 2.0	Safety of power converters for use in photovoltaic power systems - Part 2: Particular requirements for inverters
IEC 62116 Ed 2.0	Utility-interconnected photovoltaic inverters - Test procedure of islanding prevention measures.
IEC 60730-1 Ed.5	Automatic electrical controls - Part 1: General requirements.
NRS 097-2-1 Ed.1	Grid Interconnection of Embedded Generation Part 2: Small-scale embedded generation.
IEC 61683	Photovoltaic systems - Power conditioners - Procedure for measuring efficiency
IEC 61000 - 6 / 3	Electromagnetic compatibility (EMC)
IEC 61000-6-3/4	EMC Emission
IEC 61000-6-1/2	EMC Immunity
IEC 61727 Ed.2	Photovoltaic (PV) systems - Characteristics of the utility interface
IEC 62103	Electronic equipment for use in power installations
Electrical Cabling	
	Requirements for cables for use in photovoltaic systems 2Pfg1169” by TÜV
SANS 1507 Part 1	General - Electric cables with extruded solid dielectric insulation for fixed installations (300/500 V to 1900/3300 V)
SANS 1507 Part 2	Wiring Cables - Electric cables with extruded solid dielectric insulation for fixed installations (300/500 V to 1900/3300 V)
SANS 1507 Part 3	PVC Distribution cables - Electric cables with extruded solid dielectric insulation for fixed installations (300/500 V to 1900/3300 V)
SANS 1507 Part 4	XLPE Distribution cables – Electric cables with extruded solid dielectric insulation for fixed installations (300/500 V to 1 900/3300 V)

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SANS 1507 Part 5	Halogen-free Distribution Cables - Electric cables with extruded solid dielectric insulation for fixed installations (300/500 V to 1900/3300 V)
SANS 1507 Part 6	Service cables - Electric cables with extruded solid dielectric insulation for fixed installations (300/500 V to 1900/3300 V)
SANS 10198:2004 Parts 1-14	The selection, handling and installation of electric power cables of rating not exceeding 33 kV Part 1 to 14
SANS 1213	Mechanical Cable Glands
NRS 074-1/2	Low Voltage cables systems
Earthing, Lightning & Surge Protection	
IEC 60364-4-41	Low-voltage plants installation. Part 4-41 - Protection for safety – protection against shock
SANS 10313	Protection against lightning
SANS 62305	Earthing and Lightning Protection
SANS 10292:2001	Earthing of low-voltage (LV) distribution systems
SANS 1063:1998	Earth rods and coupling
SANS 10199	The design and installation of earth electrodes
IEEE 80	Earthing
IEEE 665:1995	Guide for Generating Station Grounding
SANS 61312-3:2006/IEC TS 61312-3:2000	Protection against lightning electromagnetic impulse Part 3: Requirements of surge protective devices (SPDs)
SANS 62305-1 to 4 /IEC 62305-1 to 4	Protection against lightning - Parts 1 to 4
SANS 10313:2008	Protection against lightning - Physical damage to structures and life hazard
SANS 10200:1985	
NRS 039	Surge arresters for use in distribution systems
IEC 61009	Residual current operated circuit-breakers with integral overcurrent protection for household and similar uses (RCBO's)
SANS 61024	Protection of structures against lightning
Metering and Measurements	

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IEC 62053	Electricity metering equipment (A.C.) – particular requirements
IEC 60051-1	Direct acting indicating analogue electrical measuring instruments and their accessories - definitions and general requirements common to all parts
IEC 61036	Alternating current static watt-hour meters for active energy
NRS 057/ SANS 474	Code of practice for electricity metering
NRS 049	Advanced metering infrastructure () for residential and commercial customers
Switchgear	
IEC 60898	Electrical accessories - circuit breakers for overcurrent protection for household and similar installations
IEC 61009	Residual current operated circuit-breakers with integral overcurrent protection for household and similar uses (RCBO's)
IEC 60269	Low-Voltage fuses
SANS 62271- 100 /IEC 62271 - 100	High-voltage switchgear and control gear – Alternating Current Breakers
SANS 60694:2003/ IEC 60694:2002	Common specifications for high-voltage switchgear and control gear standards
SANS 1973-1 to 4	Low-voltage switchgear and control gear Assemblies Parts 1 to 4
SANS 1765:2003	Low-voltage switchgear and control gear assemblies (distribution boards) with a rated short-circuit withstand strength up to and including 10 kA
SANS 60439-1 to 5 /IEC 60439-1 to 5	Low-voltage switchgear and control gear assemblies parts 1 to 5
SANS 60947 / IEC60947	Low-voltage switchgear and control gear
IEC 60529	Specification for degrees of protection provided by enclosures (IP code)
Control and Monitoring System (CMS) Field Equipment, Cabling and Installation	
IEC 61850-7	Communication networks and systems for power utility automation - Part 7-420: Basic communication structure – Distributed energy resources logical nodes
IEC 60870	Tele control equipment and systems. Remote control of photovoltaic power plants.
EIA/TIA 568	Standard for structured cabling
EIA/TIA 569	Standard for communication pathways and spaces

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EIA/TIA 607	Standard for grounding and bonding of communication cabling
TIA/EIA 485	Electrical Characteristics of Generators and Receivers for Use in Balanced Digital Multipoint Systems
SANS 10142-1-2012	The Wiring of Premises Part 1: Low-voltage installations
SANS 10340-1	Installation of telecommunication cables part 1: Fibre optic cables in buildings
SANS 10340-2	Installation of telecommunication cables part 2: Outdoor fibre optic cables
SANS 60794-1-1	Optical fibre cables - Part 1-1: Generic specification – General
SANS 60794-1-2	Optical fibre cables - Part 1-2: Generic specification - Basic optical cable test procedures
SANS 61312	Protection against lightning electromagnetic impulse
SABS 1411: Parts 2-6	Materials of Insulated Electric Cables and Flexible Cords
SANS 60947-7-1 and 60947-7-2	The terminal blocks for the junction box terminations
SANS 60429	Degree of protections provided by enclosures (IP)
Inspection, Testing and Commissioning	
IEC 62446	Grid connected photovoltaic systems – Minimum requirements for System documentation, commissioning tests & Inspections
IEC 60364 – 6 Ed. 1	Low Voltage Electrical installations,
IEC 62337	Commissioning of Electrical, Instrumentation and Control systems
IEC 62381	Factory acceptance test (FAT), site acceptance test (SAT), and site integration test (SIT)
IEC 62382	Electrical and Instrumentation loop check activities
IEC 62337	Commissioning of electrical, instrumentation & control systems
IEC 61724	Photovoltaic system performance monitoring - Guidelines for measurement, data exchange and analysis
Plant Coding and Labelling	
ISO 10007:2003	Guidelines for configuration management
VGB-R 171e VGB	Guideline - Provision of Technical Documentation (Technical Plant Data, Documents) for Power Plants, 2nd Edition 2010

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Fire Safety Standards	
SANS 10400-T:2011	South African National Standard Part T: Fire Protection
SANS 10139	Fire detection and alarm systems for buildings - System design, installation and servicing
	International Fire Code 2012

Table 8 Codes & Standards – Regulatory Approvals, Requirements & Normative References

List of Regulatory Approvals, Requirements and Normative References - Grid Code Compliance:

Standard/Code	Description
Act 4 of 2006	Electricity Regulation Act,
Act, of 2006	Electricity Regulation Amendment Act, 2006
Act, No. 73 of 1989	Department of Environmental Affairs & Tourism in terms of Environment Conservation Act
Act, No. 107 of 1998	National Environmental Management Act, (as amended)
No. 26 of 1956	Explosives Act, as amended
Act, No. 85 of 1993	Occupational Health & Safety Act, as amended
Act 5 of 2008	Compulsory Specifications Act
	South African Distribution Code (all parts)
	South African Grid Code (all parts)
IEC 60068-2-1	Environmental Testing – Part 1 Cold
IEC 60068-2-2	Environmental Testing – Part 2 Dry Heat
IEC 60068-2-30	Environmental Testing – Part 30 Damp heat, cyclic (12h + 12h cycle)
IEC 60255-3	Electrical relays Part 3 : Single input energizing quantity measuring relays with dependent and independent time
IEC 60255-6	Electrical relays Part 6 : Measuring relays and protection equipment
IEC 60255-21	Electrical relays Part 21 : Vibration, shock, bump and seismic tests on measuring relays and protection equipment (all sections)
IEC 60255-22	Electrical relays Part 22 : Electrical disturbance tests for measuring relays and protection equipment (all sections)

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IEC 61727	Photovoltaic (PV) systems - Characteristics of the utility interface
IEC 62271-100	High voltage alternating current circuit breakers
IEC 62116	Test procedure of islanding prevention measures for utility- interconnected photovoltaic inverters
IEEE 1547	IEEE Standard for interconnecting distributed resources with electrical power systems
IEEE 1547.1	IEEE Standard conformance test procedures for equipment interconnecting distributed resources with electric power systems
NRS 029	Current transformers for rated a.c. voltages from 3,6kV up to and including 420kV
NRS 030	Electricity distribution – Inductive voltage transformers for rated a.c. voltages from 3.6kV up to and including 145kV for indoor and outdoor applications
NRS 031	Alternating current disconnectors and earthing switches (above 1000V)
NRS 037-1	Telecontrol Protocol for stand-alone remote terminal units NRS 048-2 : Electricity Supply – Quality of Supply Part 2 : Voltage characteristics, compatibility levels, limits and assessment methods NRS 048-4 : Electricity Supply – Quality of Supply Part 4 : Application guidelines for utilities
NRS 048-7	Electricity Supply – Quality of Supply Part 7 : Application practices for end-users
NRS 054	Rationalized User Specification – Power Transformers
NRS 057 (SANS 474)	Code of Practice for Electricity Metering
NRS 097-1	Code of Practice for the interconnection of embedded generation to electricity distribution networks : Part 1 MV and HV
NRS 097-2	Grid interconnection of embedded generation : Part 2 Small scale embedded generation
SANS 1019	Standard voltages, currents and insulation levels for electricity supply
SANS IEC 60529	Degrees of protection provided by enclosures (IP Code)
SANS IEC 61000-4	Electromagnetic compatibility (EMC) : Test and measurement techniques (all sections)

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APPENDIX D: CIVIL & STRUCTURES REQUIREMENTS**Table 9 Mounting Structure Requirement**

Item No.	Description	Unit	Required	Tendered
1	Product information			
1.1	Manufacturer			
1.2	Model			
2	Track Record			
2.1	Proven technology (included tested, commissioned and operated) commercially PV plants above 5 MW and with similar ambient conditions	Yes/No	Yes	
3	Mounting Characteristics			
2.1	Mounting Type	Fixed/ Tracking	Fixed	
3.2	Mounting Orientation		20 - 30° tilt and Perfect North (0° North)	
3.3	Row to row shading loss on annual energy generation	%	To be provided by the bidder	
3.4	Type of foundations – Grass Land Section	N/A	To be provided by the bidder and according to approved permits	
3.5	Corrosion protection	Yes/No	Yes	
3.6	Module positions	Landscape/ Portrait	To be provided by Tenderer. Must respect row-to-row shadowing and cell (and bypass diode) connections of the PV module	
4	Minimum required standards (to be proven by respective Certificate or Conformity Declaration)			
4.1	EN ISO 146	Yes/No	Yes	
5	Product Warranty/ Guarantee			
5.1	Duration of warranty (materials)	Year	≥ 10	
5.2	Lifetime design warranty	Year	≥ 25	
6	Documentation			
6.1	Detailed technical specification	N/A	Required	
6.2	Product information catalogue	N/A	Required	

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Item No.	Description	Unit	Required	Tendered
6.3	Installation Manual	N/A	Required after contract award	
6.4	Operation and Maintenance Manual	N/A	Required after contract award	
6.5	Project References	N/A	Required	

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APPENDIX E: ELECTRICAL REQUIREMENTS**Table 10 PV Minimum Specific Technical Requirement - Capacity General Requirement**

Item No.	Description	Unit	Required	Tendered
1	PV Facility Capacity			
1.1	Nominal AC capacity	kW	To be determined from Energy Yield Study	
1.2	Ratio of DC to AC Capacity	-	1.05 to 1.2	
1.3	DC capacity	MWp	To be defined by the bidder	
2	PV Modules and Inverters Number			
2.1	Total number of PV modules offered for the project	N/A	To be defined by the bidder	
2.2	Total number of inverters offered for the project	N/A	To be defined by the bidder	

Table 11 PV Minimum Specific Technical Requirement - PV Module General Requirement

Item No.	Description	Unit	Required	Tendered
1	Product information			
1.1	Manufacturer			
1.2	Product Type			
2	Track Record			
2.1	Production track record	year	Last 5	
2.2	Minimum annual production capacity	MW	50	
2.3	Module provider in five different financed non-recourse (by five different banks) in past 2 years or Tier 1 panels	Yes/No	Yes	
2.4	Module type or series commercially financed PV plants of operation in ambient temperature up to 45°C or better	months	≥ 12	
3	Technical Characteristics			
3.1	PV Module/Cell technology	N/A	crystalline	
3.1	Module rated power at STC	Wp	At least 450W	
2.3	Module Efficiency at STC	%	≥ 18 for c-Si	
2.4	Temperature coefficient on power at STC (negative on sign)	- %/°C	Not more than 0.4	

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Item No.	Description	Unit	Required	Tendered
2.5	Nominal Power Tolerances from Manufacturer (used for acceptance to the module)	± %	0% ≤ P _{nom} ≤ +5% (positive tolerance only)	
2.6	Module Maximum System Voltage	V	1,000	
2.7	Module operating temperature (ambient) range	°C	-10°C to +55°C or better	
3	Product Warranty and Performance Guarantee			
3.1	Power output guaranteed during the first year of operation	%	Minimum : 97%	
3.2	Linear degradation coefficient from year 2 to year 25	%/year	Maximum degradation of -0.6%/year	
3.3	Guaranteed output of the nominal power after 10 years	%	Minimum 90%	
3.4	Guaranteed output of the nominal power after 25 years	%	Minimum 80%	
3.5	Product Warranty against Manufacturing defects	Years	Minimum 10	
4	Minimum Certificates and Standards			
4.1	IEC 61215 – Crystalline silicon terrestrial photovoltaic (PV) modules – Design qualification and type approval	Yes/No	Yes for crystalline technology	
4.3	IEC 61730 Photovoltaic (PV) module safety class II qualification	Yes/No	Yes	
4.4	IEC 62716 – PV modules Ammonia corrosion testing	Yes/No	Yes	
4.5	PID free certified performed by reputable third party laboratories	Yes/No	Yes	
4.6	IEC 60904-1 – Flash test data of all modules	Yes/No	Yes	
4.7	Certified Junction box (DIN EN 50548 (VDE 0126-5))	Yes/No	Yes	
4.8	Other Standards considered relevant by the Bidder	Yes/No	To be detailed by the Bidder	
5	Documentation for acceptance of PV modules			
5.1	Detailed Technical Specifications	Yes/No	Yes	
5.2	Limited Product and Peak Power Warranty	Yes/No	Yes	
5.3	Flash test data	Yes/No	Yes after contract award	

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Item No.	Description	Unit	Required	Tendered
5.3	Installation manual	Yes/No	Yes after contract award	
5.4	Brief description of the cleaning strategy Instruction	Yes/No	Yes	
5.5	Recycling strategy	Yes/No	Yes	
5.6	Other documents considered relevant by the Bidder	Yes/No	To be detailed by the Bidder	

Table 12 Solar Inverter Specific Requirements

Item No.	Description	Unit	Required	Tendered
1	Product information			
1.1	Manufacturer			
1.2	Product Type (indicate quantity and types)			
2	Track Record			
2.1	Production track record	year	Last 5	
2.3	Inverter type or series project experience with more than 50 MW (minimum 3 projects) utility scale solar plant	Yes/No	Yes	
2.4	Inverter type or series commercially at nonrecourse financed PV plants of operation in similar ambient conditions	months	≥ 12	
2	Inverter Characteristics			
2.1	Inverter type/concept	-	String Inverter	
2.2	Minimum AC capacity per unit	kW	≥ 25	
2.2	Minimum conversion efficiency	%	≥ 98	
2.4	Operating ambient temperature range (without derating within this range)	°C	-10 ... +45	
2.5	Cooling concept	Yes/No	Yes: The inverter cooling concept shall be designed for outdoor installation and operation in	

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Item No.	Description	Unit	Required	Tendered
			site condition (hot condition)	
2.6	Maximum DC voltage	V	1,500	
2.7	Connection phases		Three-Phase	
2.8	Frequency	Hz	50	
2.9	Total harmonic distortion	%	≤ 3	
2.10	Power Factor	N/A	1 / 0.9 leading to 0.9 lagging	
2.11	Anti-islanding protection	Yes/No	Yes	
2.12	Protection type IP (EN 60529)		≥IP65	
2.13	Controllability of inverter output per remote control / energy management system, if possible.	Yes/No	Yes Dynamic adjustable	
2.14	Earthing concept	Yes/No	Yes Earthing according to installation requirements of PV module and inverter manufacturer	
2.16	Input Failure detection	Yes/No	Yes	
2.17	Frequency protection	Yes/No	Yes	
2.17	DC overvoltage protection	Yes/No	Yes	
2.18	Surge protection	Yes/No	Yes	
3	Minimum required standards (to be proven by respective Certificate or Conformity Declaration)			
3.1	IEC 62109 Part 1 and Part 2: Safety of Static Inverters	Yes/No	Yes	
3.2	IEC 61727 Characteristics of the Utility Interface	Yes/No	Yes	
3.3	IEC 62116 Testing procedure of Islanding Prevention Methods for Utility-Interactive Photovoltaic Inverters	Yes/No	Yes	
3.4	IEC 62103 Electronic equipment for use in power installations	Yes/No	Yes	
3.5	IEC 61683: Photovoltaic systems - Power conditioners - Procedure for measuring efficiency	Yes/No	Yes	
3.6	IEC 61000-3-2/12 - EMC Compatibility	Yes/No	Yes	

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Item No.	Description	Unit	Required	Tendered
3.7	IEC 61000-6-1/2/3 - EMC Immunity	Yes/No	Yes	
3.8	IEC 61643-11/12 : Surge Protection Device connected to Low Voltage power distribution	Yes/No	Yes	
3.9	South African Grid code compliance: Grid connection code for Renewable Power Plants (RPPs) connected to the electricity Transmission system (TS) or the Distribution system (DS) in South Africa	Yes/No	Yes	
3.10	Other Standards (CE conformity and others)	N/A	To be detailed by the Contractor	
4	Monitoring system requirements			
4.1	Continuous data logging to the CMS system for the defined technical plant performance parameters including events and status	Yes/No	Yes	
4.2	Connection interface to CMS	Yes/No	Yes	
5	Product Warranty			
5.1	Product warranty	Year	≥ 10	
5.2	The Bidder shall indicate if the inverter manufacturer proposes a extension of Contract Service. If yes, maximum duration of the Contract shall be indicated	N/A	Information to be provided	
6	Documentation			
6.1	Detailed technical specification	N/A	Required	
6.2	Product information catalogue	N/A	Required	
6.3	Installation Manual	N/A	Required	
6.4	Operation and Maintenance Manual	N/A	Required	
6.5	Project References	N/A	Required	
6.6	Calculations for ensuring electrical compatibility between the inverters and the modules	N/A	Required	

Table 13 Auxiliary Supply Distribution Board Requirements

Item No.	Description	Unit	Required	Tendered
1	General requirements			
1.1	Rated for outdoor condition and suitable for working environment	Yes/No	Yes	

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Item No.	Description	Unit	Required		Tendered
1.2	Expected period of use	years	25		
2	Technical requirements				
2.1	IP Protection (IEC 60529) indoor installation		≥ IP 65		
2.2	Safety Class II	Yes/No	Yes		
2.3	Maximum AC Voltage	V	1000		
2.4	Maximum ambient temperature	°C	≥ +50		
2.5	Equipped with AC MCBs (all phases)	Yes/No	Yes		
2.6	Equipped with Lightning/Overvoltage protection	Yes/No	Yes		
2.7	Incomer supply cable isolation Switch	Yes/No	Yes		
3	Certification of compliance				
3.1	CE label or equivalent	Yes/No	Yes		
4	Documents				
4.1	General Physical information	Yes/No	Yes		
4.2	Technical data sheet	Yes/No	Yes		

Table 14 PV-Distribution Board Specific Requirements

Item No.	Description	Unit	Required	Tendered
1	General requirements			
1.1	Rated for outdoor and suitable for working environment		Required	
1.2	Expected period of use	years	25	
2	Technical requirements			
2.1	IP Protection (IEC 60529) outdoor installation		IP 65 or better	
2.2	Safety Class II		Required	
2.3	Maximum AC Voltage	V AC	1000	
2.4	Maximum ambient temperature	°C	≥ +50°C	
2.5	Main switch circuit breaker (4P, lockable)	Yes/No	Yes	

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Item No.	Description	Unit	Required	Tendered
2.6	Equipped with Lightning/Overvoltage protection	Yes/No	Yes	
2.7	Circuit breaker for each inverter (4P, lockable)	Yes/No	Yes	
2.8	Metering equipment	Yes/No	Yes	
3	Certification of compliance			
3.1	CE/SABS label or equivalent		Required with Tender documents	
4	Documents			
4.1	General Physical information		Required with Tender documents	
4.2	Technical data sheet		Required with Tender documents	

Table 15 Point of Connection LV Circuit Breaker Specification

Item No.	Description	Unit	Required	Tendered
1	Product information			
1.1	Manufacturer			
1.2	Circuit Breaker Type (indicate insulation medium)			
2	Circuit Breaker Characteristics			
2.1	Model			
2.2	Rated Operational Voltage	V	690	
2.3	Rated Insulation Voltage	V	800	
2.4	Impulse Voltage	kV	8	
2.5	Rated Frequency	Hz	50	
2.6	Rated current	A	1000	
2.7	Rated symmetrical short-circuit breaking current at 380/415 V AC according to IEC 60947-2. (Ics)	kA	50	
2.8	Short-time withstand current (1 sec.)	kA	21	
2.9	Protection Type	N/A	Overload protection (long time) Instantaneous short circuit protection	

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Item No.	Description	Unit	Required	Tendered
2.10	Long-time pick-up adjustment	N/A	9 steps Adjustable with 0.4....1 x In	
2.11	Long-time protection delay adjustment range	N/A	9 steps Adjustable with 0.5...24s at 6 x Ir	
2.12	Instantaneous pick-up adjustment	N/A	Adjustable with 1.5....10 x In	
2.13	Auxiliary Contact	N/A	1 NO/NC	
2.14	Local Signalling	N/A	LEDs for protection operated trip	
2.15	Mounting Support	N/A	Backplate	
2.16	Upside Connection	N/A	Front	
2.17	Downside Connection	N/A	Front	
4	Minimum required standards (to be proven by respective Certificate or Conformity Declaration)			
4.1	IEC 60947-2	N/A	Required	
4.2	Other Standards	N/A	To be detailed by the Contractor	
5	Monitoring system requirements			
5.1	Continuous data logging to the CSM system for the defined technical plant performance parameters including events and status	N/A	Required	
5.2	Connection interface to CMS system using protocols,	N/A	RS 485	
5.3	Voltage Presence Indicating System (VPIS)	N/A	Required	
6	Product Warranty			
6.1	Standard Product warranty	Year	≥ 5	

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Item No.	Description	Unit	Required	Tendered
6.2	The Bidder shall indicate if the circuit breaker manufacturer proposes a Contract Service. If yes, maximum duration of the Contract shall be indicated	N/A	Information to be provided	
7	Documentation			
7.1	Detailed technical specification	N/A	Required	
7.2	Product information catalogue	N/A	Required	
7.3	Installation Manual	N/A	Required	
7.4	Operation and Maintenance Manual	N/A	Required	

Table 16 DC Cables Specific Requirement

Item No.	Description	Unit	Required	Tendered
1	General requirements			
1.1	Rated for exterior condition and suitable for working environment	Yes/No	Yes	
1.2	Weather-proof and UV resistant	Yes/No	Yes	
1.3	Plus and Minus (+ and -) side shall be separated	Yes/No	Yes	
1.4	Expected period of use	years	≥25	
2	Technical requirements			
2.1	Cross section	mm ²	To be determined by Contractor	
2.2	Conductor material	N/A	Copper/Aluminium	
2.3	Operating temperature range	°C	Max.+90 or better	
2.4	Temperature index	°C	120 or better	
2.5	Maximum DC Voltage	kV	1.8	
2.6	Type Code	N/A	PV 1-F	
2.7	Insulation	N/A	Halogen free, double insulated	
2.8	Trademark and Code designation on cable	Yes/No	Yes	
2.9	Fire Resistant	Yes/No	Yes	
2.10	Installation method		Outdoor exposed DC cabling to be installed within	

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Item No.	Description	Unit	Required	Tendered
			conduits and shall be UV protected.	
3	Certification of compliance			
3.1	VDE-AR-E 2283-4 Requirements for DC cables for PV plants	Yes/No	Yes	
3.2	CE label or equivalent	Yes/No	Yes	
3.3	"2Pfg1169" by TÜV	Yes/No	Yes	
4	Documents			
4.1	General Physical information		Required with detailed design	
4.2	Electrical Properties data sheet		Required with Tender documents	
4.3	Installation method		Required with detailed design	
4.4	Ground condition		Required with detailed design	

Table 17 DC Cable Installation Requirements

Item No.	Description	Unit	Required	Tendered
1	DC Cables			
1.1	Cables from PV array Shall be laid into cable trays/corrugated tubes according to manufacturer recommendations and local conditions	N/A	To be determined by the Bidder	
1.2	Cable shall be continuous without making any junction. If a junction is necessary, the Contractor shall use adequate sleeves according to voltage level of the cable system to muffle the junction according to generally recognized codes of practice	N/A	To be confirmed by the Bidder	
1.3	If relevant, the plus and minus DC cables with sections above 50 mm ² (if any) shall be located in different conduits	N/A	To be confirmed by the Bidder	

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Table 18 Connector Specific Requirement

Item No.	Description	Unit	Required	Tendered
1	General requirements			
1.1	Rated for exterior condition and suitable for working environment	Yes/No	Yes	
1.2	Weatherproof and UV resistant	Yes/No	Yes	
1.3	Compatible with module connectors (type and manufacturer)	Yes/No	Yes	
1.4	Touch proof safety design	Yes/No	Yes	
1.5	Snap-lock mating	Yes/No	Yes	
1.6	Internal locking mechanism to prevent accidental/unauthorized decoupling	Yes/No	Yes	
1.7	Connector type		MC4 or equivalent recommended by module manufacturer	
2	Certifications of compliance			
2.1	CE label or equivalent	Yes/No	Yes	
3	Documents			
3.1	General Physical information		Required with detailed design	
3.2	Electrical Properties data sheet	Yes/No	Yes	

Table 19 DC Combiner Box Specific Requirement (if applicable)

Item No.	Description	Unit	Required	Tendered
1	General Requirements			
1.1	Rated for exterior condition and suitable for working environment	Yes/No	Yes	
1.2	Weather-proof and UV resistant	Yes/No	Yes	
1.3	Plus and Minus (+ and -) side shall be separated within the box	Yes/No	Yes	
1.4	DC fuses for each string	Yes/No	Yes	
1.5	Over voltage protection	Yes/No	Yes	
1.6	Array Isolation Switch	Yes/No	Yes	

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Item No.	Description	Unit	Required	Tendered
1.7	Individual String Monitoring (only for primary combiner box)	Yes/No	Yes	
1.8	Protection from direct contact of live parts	Yes/No	Yes	
1.8	Expected period of use	years	≥ 25	
2	Technical Requirements			
2.1	IP Protection (IEC 60529)		≥ 65 or higher	
2.2	Safety Class II		Required	
2.3	Maximum DC Voltage	V	1000	
2.4	Maximum operation temperature	°C	+45 or better	
3	Certificate of compliance			
3.1	CE label or equivalent	Yes/No	Yes	
4	Documentation			
4.1	Detailed technical specification	Yes/No	Yes	
4.2	Installation Manual	Yes/No	Yes	
4.3	Operation and Maintenance Manual	Yes/No	Yes	

Table 20 AC Cables (Inverter to PV-DB and PV-DB to Point of Connection) Specific Requirements

Item No.	Description	Unit	Required	Tendered
1	General requirements			
1.1	Rated for interior and outdoor condition, and suitable for working environment		Required	
1.2	Expected period of use	years	≥ 25	
2	Technical requirements			
2.1	Cross section	mm ²	To be determined by the Bidder	
2.2	Conductor material	N/A	Copper	
2.3	Maximum conductor temperature	°C	90	
2.4	Rated AC Voltage	V	1000	
2.5	Insulation		Halogen free	
2.6	Trademark and Code designation on cable	Yes/No	Yes	
2.7	Fire resistant	Yes/No	Yes	

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Item No.	Description	Unit	Required	Tendered
2.8	Installation method		All exposed outdoor cables shall be installed within conduits or enclosed cable trays. All installations according SANS 10142-1:2012 requirements.	
2.9	Ground – Cable Laying	Yes/No	Yes, To be determined by the Bidder	
2.10	Number of conductors per cable	Yes/No	Yes To be determined by the Bidder	
3	Certifications of compliance			
3.1	CE label or equivalent	Yes/No	Yes/No	
4	Documents			
4.1	General Physical information	Yes/No	Yes/No	
4.2	Electrical Properties data sheet	Yes/No	Yes/No	

Table 21 Overvoltage/Surge Protection Devices Specific Requirements

Item No.	Description	Unit	Required	Tendered
1	Combiner Box, AC Box			
1.1	Minimum Over Voltage Arrestors (SPD Type II) better lightning Current arrestors (SPD Type I or combination of Type I and Type II): peak current: 150 kA (10/350 □s), limited peak voltage 94 kV at 10 kA (8/20 □s)	Yes/No	Yes	
3	O&M building, Control and Monitoring System (CMS)			
3.1	Overvoltage arrestors (SPD Type II) limited surge voltage: 2.5 resp. 1.5 kV	Yes/No	Yes	
4	DC Boards, PV Array			
4.1	Overvoltage arrestors (SPD Type II) better Lightning Current arrestors (SPD Type I or combination of Type I and Type II), peak current: 50 kA (10/350 □s), limited surge voltage: 4 kV at 25 kA (8/20 □s).	Yes/No	Yes	

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APPENDIX F: CONTRACTORS GUARANTEE ON PERFORMANCE AND AVAILABILITY**Table 22 Plant Performance Guarantee – From the Contractor**

Parameter	Minimum required for Bidders Proposal with crystalline modules		Guaranteed by Contractor
First year guaranteed annual average Performance Ratio	78%		
Guaranteed plant availability during FAT	99.5 %		

Table 23 Monthly Breakdown of First Year Guaranteed Performance Ratio

Month	Breakdown of first year annual guaranteed PR (%)	Estimated Solar Irradiation on Module Plane (kWh/m ²)
January		
February		
March		
April		
May		
June		
July		
August		
September		
October		
November		
December		
Annual Average		

Table 24 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
Fire Protection Equipment	2

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Equipment	Minimum Warranty Period in Years

Table 25 Water Qualities

Parameter	Unit	Raw Water		Potable Water		IX Plant		RO Plant	
		Average	*95 th percentile	Average	*95 th percentile	Average	*95 th percentile	Average	*95 th percentile
Ca Hardness (as CaCO ₃)	mg/kg	34.06	37.4	34.9	43.7	-	-	-	-
Cl	mg/kg	9.68	10	17.07	19.4	0.47 µg/kg	0.36 µg/kg	-	-
Free Cl ₂	mg/kg	-	-	1.6	1.32	-	-	-	-
Al	mg/kg	0.20	0.2	-	-	-	-	-	-
K	mg/kg	10.48	3.6	3.70	3.46	-	-	-	-
F	mg/kg	0.16	0.2	0.16	0.12	-	-	-	-
Fe	mg/kg	0.27	0.2	0.11	0.2	-	-	-	-
NO ₃ as N	mg/kg	0.94	0.72	0.82	0.121	-	-	-	-
NH ₃ as N	mg/kg	-	-	0.11	0.02	-	-	-	-
PO ₄	mg/kg	0.07	0.2	-	-	-	-	-	-
Conductivity	µS/cm	173.06	206	204.76	240	0.22	0.36	0.47	0.086
M Alkalinity	mg/kg	50.56	56.9	55.91	42.4	-	-	-	-
Mg Hardness (as CaCO ₃)	mg/kg	35.48	39.7	35.49	39.7	-	-	-	-
Na	mg/kg	8.24	9.83	14.23	13.4	1 µg/kg	0.63 µg/kg	1.10 µg/kg	1.1 µg/kg
P-Alkalinity	mg/kg	0.25	0		1.4	-	-	-	-
pH @25°C		7.61	8.18	8.18	8.31	-	-	-	-
SiO ₂	mg/kg	4.20	2	2.62	3	4.65 µg/kg	3 µg/kg	2.52 µg/kg	1.5 µg/kg
SO ₄	mg/kg	27.05	30.4	27.55	35.4	0.83 µg/kg	0.2 µg/kg	-	-
Total Hardness (as CaCO ₃)	mg/kg	69.23	77	72.09	71.5	-	-	-	-
TOC as C	ppm	5.01	5	3.01	2.6	77.66 µg/kg	49 µg/kg	-	-
Turbidity	NTU	4.24	2.72	0.51	0.524	-	-	-	-

*Based on 95th percentile of Conductivity

*The above water qualities were extracted from LIMS over a 4 year period (2016-2020)

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APPENDIX G: SITE LAYOUT AND SINGLE LINE DRAWINGS LIST**Table 26 Lists Drawings Issued by the Employer**

The table below lists drawings issued by the *Employer*

Drawing number	Revision	Title
033/19495/01/Rev 0	0	PV Pre-feasibility Study Site Lay-out Diagram
033/18022/02/Rev 1	1	Komati Power Station MV & LV Single Line Diagram
033/19494/01/Rev 0	0	Proposed Hybrid PV Singe Line Diagram
033/10/002/001/Rev 3B	3B	Komati Power Station Station-Services-Building Site Plan
N/A	-	Schematic Wiring for 630kVA, 6.6/0.4kV Mini-sub

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