

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

### **1. INTRODUCTION**

The Employer intends to procure the construction of a Solar PV plant, located at the Sere Wind Farm facility on the Namaqualand Coast in the Vredendal District, approximately 20 km west of Koekenaap in the north of the Western Cape Province. To procure the construction of the PV installations, the Employer will enter contracts with:

1. The Contractor, responsible for surveying, studies, permitting, design, engineering, manufacture, procurement and supply of all materials and labour, delivery to site, offloading, construction, erection, installation, off-site testing (construction Quality compliance to Regulations and Eskom requirements), on-site testing, commissioning, performance testing, provision of samples, preparation of all detail design drawings, as-built record drawings, operation and maintenance manuals and instructions for the works, in accordance with the general requirements and performance requirements as detailed in this document, and
2. Enter a two (2) year contract with the same Contractor for the Operations and Maintenance (O&M) of the PV installations and associated equipment.

This Appendix relates to item '2' above and it defines the functional minimum requirements for the Operations and Maintenance (O&M) to be supplied as part of the Works for the Sere Solar PV phase 1a Plant installations and associated PV plant Equipment that will collectively be referred to as the PV O&M Plant, (Referred to interchangeably as the "Plant" or the "Site").

### **2. CONTRACTOR'S SCOPE OF WORK**

1. The EPC Contractor performs the role of O&M Contractor for the first two (2) years of operation (referred to as the O&M period) and comes into effect upon Completion of the EPC Contract for the Sere PV Plant. The Contractor conducts Operation and Maintenance (O&M) of the PV installations and associated equipment for the O&M period.

### **3. CONTRACTOR'S EXPERIENCE**

1. The EPC Contractor shall have successfully performed the Operations and Maintenance (O&M) for at least two (2) years as the main O&M Contractor for at least two (2) ground mounted PV plants which were  $\geq 10$  MWac.
2. The Contractor provides project details for each project in 1 above, such as the name of the solar PV plant, location of the plant, name and contact details of developer, type of module technology, type of PV module mounting (fixed, tracking, etc.) mechanism, installed nameplate DC capacity (MWp), plant AC capacity (MWac), duration of operations and maintenance (months), commercial operation date, photographs (if possible), and proof verifying Solar PV plant O&M duties.

## **4. OPERATION AND MAINTENANCE REQUIREMENTS**

### **4.1 General Requirements**

1. The Contractor is responsible for the all-inclusive operations and maintenance (preventive, corrective, and spare parts replacement) and performance monitoring activities of the facility during the first two (2) years of operation.
2. The Contractor to perform operating and maintenance activities together with the Employer personnel, where the Employer personnel will be continuously trained during the O&M period.
3. The Contractor to form part of the Employers regular maintenance planning practices and this require, amongst others, that all operating and maintenance activity planning and decision making

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processes to be done in combination with the Employer's supervision and with the Employers approval.

4. The Contractor shall maintain and operate the PV Plant (including the complete solar PV Plant, the PV Plant MV stations/cabins enclosing the inverter, transformer and switchgear, Power evacuation cabling, and the Support Facilities), in good condition and performs the agreed O&M services in good faith, in accordance with the best industry practice.
5. The Contractor shall perform periodic inspection and testing of the PV plant and each component and report on the status of modules, cabling, structures, inverters, transformers, security system, monitoring system, power evacuation lines etc.
6. The Contractor shall repair any defect or replace any item, equipment, and component.
7. The Contractor shall perform maintenance activities as minimum as defined under preventive maintenance and corrective maintenance and as per guiding principles indicated in IEC 62446-2 for preventive and corrective maintenance.
8. The Contractor shall supply all required tools, equipment, and facilities (including water for PV module cleaning) which are necessary for carrying out the operation and maintenance of the PV plant.
9. The Contractor shall guarantee at all times the on-site availability of minimum spare parts.
10. The Contractor shall operate the plant to meet the guaranteed performance ratio and availability.
11. The Contractor shall maintain and ensure the compliance of the plant in respect to safety laws and regulations, also in respect of the safety of the workers and performing the services. This includes compliance to the Employer's work requirements detailed in 240-150642762 - Generation Plant Safety Regulations (PSR) and 240-114967625 - Eskom's Operating Regulations for High Voltage systems (ORHVS).
12. The Contractor shall follow the maintenance manuals for entire plant monitoring including the operational manual of specific components and safety instructions.
13. The Contractor shall protect any plant warranties and support the Employer on negotiation of any warranty or the claims available to Employer for material or equipment supply and for the performance work associated with the plant.
14. The Contractor shall respond in the shortest possible time to any alarm generated in PV plant and take the necessary actions (repair or replacement) and shall report to the Employer.
15. The Contractor shall operate and provide the maintenance of surveillance and control system, communications, security, and meteorological stations.
16. The Contractor shall provide O&M training to the Employer and Employer's representative along with all required material in hard copy and in electronic copy. Training requirements are further described in Section 5 of this document.
17. The Contractor shall co-operate and co-ordinate with the Project Manager in the best way to ensure the operation and maintenance activities are performed respecting all Employer's requirements.
18. The Contractor shall commence Operation and Maintenance activities respecting all legal, environmental, and administrative requirements.
19. The Contractor shall co-operate with third parties (upon request from the Employer) and with the Authorities for verification of their requirement during Project installation, commissioning, and operation.
20. The Contractor shall report periodically regarding the status of the plant, maintenance work and the performance evaluation of the pant according to the reporting schedule defined in this document.

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21. The Contractor warrants the absence of defects on any repair, replacement and generally on any activities of maintenance for two years in case of replacement or repair.
22. The Contractor will be allowed to utilise the Employer's storage space as agreed with the Employer. The Contractor to provide his spares storage requirements to the Employer 3 months prior to the commencement of the O&M Contract for review and agreement. The Contractor to make provision for temporary storage facilities should there be a shortfall between the Contractor's storage requirements and the Employer's available space.
23. Boundaries of Responsibility
  1. The Contractor shall be responsible for the Operation and Maintenance of the PV O&M Plant. The PV O&M Plant shall mean the following:
    - a. The Sere Solar PV phase 1a installation and all associated equipment and facilities. This includes all the power evacuation cable/s up to the cable termination point of the PV feeders on the 22kV Switchgear in the Skaapvlei Substation.
    - b. PV site security systems (CCTV, detection and alarm system, access control system, and security lighting).
    - c. The boundary includes operating and maintenance required on the new server room, the PV Plant related equipment installed to and in the existing Sere Wind Farm Control room and the PV supplied back-up power and related equipment.
    - d. The boundary excludes the work required in re-purposing the existing Sere Wind Farm buildings.
  2. The O&M of the Network Integration Equipment (132/22kV Switching Station and associated equipment) shall be the Employer's responsibility. The Boundary is shown in Figure 1 below. The Contractor is responsible for the operating and maintenance from the PV Plant up to and including the cable termination connecting on the switchgear located in Skaapvlei substation, where the boundary is the termination point on the switchgear (Contractor also responsible for the entire cable termination).

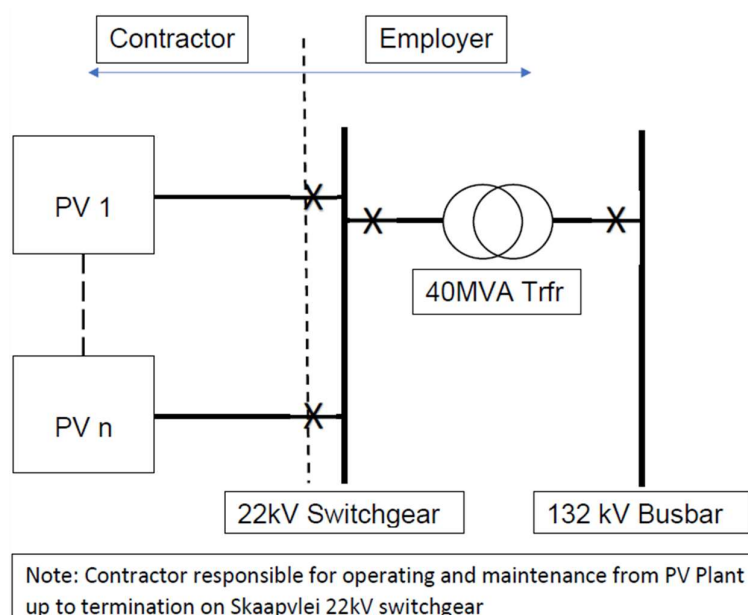


Figure 1: Boundaries of Responsibility

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## **4.2 Preventative Maintenance**

1. Preventive maintenance of the Plant includes all necessary measures to be performed by the Operator as indicated in the maintenance manuals provided by the Contractor under the EPC Contract, and in the preliminary maintenance plan guideline provided in Table 1, to avoid or anticipate possible or future malfunctions of the plant.
2. The Contractor defines the preventive maintenance plan for the PV Plant, including the frequency and scheduling of each maintenance activity. The frequency of preventive maintenance depends upon the component criticality. In this regard, the preventive maintenance of the inverter receives the greatest focus among all. The Contractor pays high level of attention to such components in its O&M plan.
3. The Contractor to submit the preventative maintenance plan to the Employer for acceptance 3 months prior to the O&M period starting.
4. Preventive inverter maintenance includes at least:
  - a. the inspection and tightening of connections,
  - b. ensuring water and dust tightness,
  - c. cleaning and replacing filters, lubricating moving parts which may include fans, handles and disconnects,
  - d. running electronic diagnostics,
  - e. routine maintenance according to manufacturer's recommendation
5. Preventive maintenance also involves module cleaning, inverter servicing, foundation and mounting structure maintenance, civil building work maintenance and balance of Plant inspection. The inspection on balance of Plant includes, but is not limited to, the inspection of junction boxes, conduit runs, combiner boxes, communication equipment, monitoring equipment, O&M building, PV Plant MV stations/cabins, security system, etc.
6. Preventive maintenance also includes erosion control, drainage system control, and vegetation management. Vegetation control must be performed to meet following criteria:
  - a. Modules are not shaded.
  - b. A fire hazard is not created.
  - c. Unrestricted access to the major equipment of the site is maintained.
7. Module Cleaning Requirement - It is expected that the Contractor provides suitable cleaning methods as well as cleaning frequency for the PV Plant design proposed. The following requirements are applicable, but not limited to:
  - a. The Contractor uses the methods, tools, and recommendations from equipment manufacturer for cleaning PV modules.
  - b. The Contractor provides all necessary tools for cleaning PV modules and transfers these to the Employer after the Operation and Maintenance period.
  - c. The Contractor cleans all PV modules on site upon the following situation (whichever occurs earlier):
    - When the solar irradiation measured by the two reference cells (one cleaned minimum on weekly basis and another not cleaned) differs by more than 5% for continuous five days period; or
    - On quarterly basis.

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- d. The Contractor is responsible for all necessary arrangements for PV module cleaning during the contract period.
8. The Contractor prepares the report according to minimum requirements indicated in the reporting template presented in Section 7 of this Appendix.
9. The Contractor to develop Work Instructions, Safe Work Procedures and Safe Operating Procedures for the maintenance activities defined in the maintenance plan. This to be submitted to the Employer for review and acceptance 2 months prior to the O&M period starting.
10. A preliminary maintenance plan guideline is indicated in Table 1, providing a general overview for preventive maintenance of the main components. The maintenance type and frequency of maintenance may depend upon the specific component type, manufacturer's recommendation, and local grid requirements. Furthermore, preventive maintenance that requires shutdown should be conducted where possible during non-peak production periods such as early mornings or evenings. Therefore, the Contractor provides the detailed preventive maintenance plan of each equipment, configuration, and systems considered in the plant.

**Table 1: Preventative Maintenance Plan Guideline – Minimum Requirement**

No.	Items	Frequency
1	PV Modules	
1.1	Cleaning of modules	Q (at least) or see below
1.2	Visual Inspection - glass breakage, yellowing & browning, corrosion, delamination, cracks on cell, hot spot, deformed connection box, module mounting and module frame condition etc.	M
1.3	Visual Inspection terminal connections and panel cabling - cable tightness, terminal box watertight, cleanliness, clamping etc.	M
1.4	I-V Curve measurement of strings	Once in two years
1.5	I-R Scanning of modules	A
2	Mounting structure and Foundation	
2.1	Visual Inspection of mounting structure	M
2.2	Check of integrity of mounting structures and clamping	M
2.3	Inspection of corrosion in fasteners, structure and check adequacy of fastener tightness	SA
2.4	Check on grounding connection (if any)	M
2.5	Visual inspection on foundation	M
3	String box/Junction Box/Combiner Box	
3.1	Visual Inspection - box screw tightness, incoming and outgoing cable tightness, cable labeling, water and dust tightness, etc.	M
3.2	Check of proper functioning of string fuses, DC disconnect switch and earthing cable etc.	M
3.3	Visual inspection of string monitoring equipment inside combiner box	M
3.4	Verify preventive maintenance activities described from 3.1 to 3.3 for secondary combiner box and fuse box (if any included in plant)	M
4	Inverter - General Preventive measures	
4.1	General visual inspection of the inverter and inverter enclosure	M
4.2	Inspection on cables and connection of the components	M

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No.	Items	Frequency
4.3	Check if inverter is running at adequate temperature range, as specified by the manufacturer	M
4.4	Check of inverter runs smoothly without producing strange noise	M
5	Inverter - Periodic and Specific measures	
5.1	periodic efficiency measurement (DC/AC conversion from inverter meter)	M
5.2	cleaning of air filter - as per manufacturer's recommendation	MS
5.3	checking and replacement of ventilation system - as per manufacturer's recommendation	MS
5.4	visual inspection of earth connections	M
5.5	Checking and verification of proper functioning of safety switches, fuses, cooling fan	M
5.6	Control and LCD display operation	M
5.7	Check of inverter according to manufacturer's operation and maintenance manual	MS
6	Inverter Station/Cabin	
6.1	Visual inspection of inverter station/cabin	M
6.3	Visual inspection of ventilation system, earthing and fire protection system	M
6.4	Check inverter temperature while running during the day and verify that ventilation is working properly, and inverter operating temperature is within manufacturer's recommended range	M
6.5	Visual inspection of transformer, switchgear board and protection device and verify that they all are running without any defects	M
7	Electrical Wiring	
7.1	Check on integrity and completeness of all electrical cables from PV module to connection point	M
7.2	Check for any damaged or discoloured cable	M
7.3	Check on status of fuses, circuit breakers and safety switches	M
7.4	Verification of proper earthing connections of the plant components	M
7.5	Verification of water tightening of electric cables and conduits	M
7.6	Electrical Insulation and grounding measurement of DC and AC cables	once in two years
7.7	Check and verify the labeling on electrical cables	M
7.7	IR scanning of electrical cable connection and verify that all cable connection are made properly and no heat generation in the connection	A
8	Security and Site Condition	
8.1	Check of integrity of security fences	SA
8.2	Verify that all security cameras and gates are working properly	M
8.3	Verify that communication of security systems with power station security system	M
8.4	Verify that internal roads are in good conditions	M
8.5	Keeping plant clean and free from waste and taking proper steps of the disposal of waste according to local regulation and procedures	SA
8.6	On Site presence – immediate answering to all alarms by an emergency service assuring on-site presence	
8.7	Check the vegetation level and ensure that they are controlled	M

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No.	Items	Frequency
8.8	Check the drainage channels and erosion control	M
9	O&M Building (Server room, Stores Building, Security Building and all other Buildings on the PV Environmental Approved Area)	
9.1	Visual inspection of O&M building and their walls, roofs, foundation and verify that there is no visual damage	M
9.2	Verify that control system, server and its back up system are working properly	M
9.3	Verify that the inventory of spare parts are maintained according to the contract requirement	M
9.4	Verify that all security measures inside the O&M and switchgear room are free of any defects and working properly	M
10	Power Evacuation	
10.1	Visual inspection of power evacuation route	M
11	Meteorological Stations and Monitoring System	
11.1	Cleaning of meteorological stations, routine inspection of sensors to be performed to check for soiling, misalignment, and other fault conditions (reference cell and pyranometer)	W
11.2	Calibration of meteorological equipment, if required	MS
11.3	Check of connection on meteorological components and communication with monitoring system	M
11.4	Check the weather station mounting structure and general physical condition	M
11.5	Check the slope and azimuth of reference cells pyranometers	M
11.6	Check on online record of energy output and irradiation through remote monitoring system	D
11.5	Check on alarm, event and status database - through remote monitoring system	D
11.6	Check on online record of availability of each inverter and availability of the plant - through remote monitoring system	D
12	Reporting	
12.1	Report on plant performance ratio and plant availability	M
12.2	Report on energy production recorded through inverters, meters at site and meters at point of connection	M
12.3	Report on meteorological measurement on site	M
12.4	Submission of raw and processed data on meteorological measurements and performance measurement to the Employer	M
12.5	Report on status of plant component and status of preventive maintenance	M
12.6	Report on alarms, events and status recorded	M
12.7	List of damage and faults verified	M
12.8	List of corrective maintenance service performed	M
12.9	List of spare parts available in inventory	M

Frequency: D→ Daily, W → Weekly, M → Monthly, Q→ Quarterly, SA→ Semi-Annually, A→ Annually, MS → Manufacturer specification and operation manual

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#### **4.3 Corrective Maintenance (Unscheduled Maintenance)**

1. Corrective maintenance includes at all times during the contract period and in all cases attending to and repairing breakdowns and failures of the components of the plant caused by wear and tear and/or breakages under normal operating conditions to ensure that the plant operates normally (in the desired condition) throughout the duration of the O&M Period.
2. Corrective maintenance is carried out during the preventive maintenance visits (if the faults/failures do not affect energy production) or when the remote monitoring system registers an operational problem. In case of corrective maintenance, the Contractor performs:-
  - a. A problem diagnosis, performance notification, and identification of which parts need to be replaced,
  - b. Supplying the replacement component parts in the event of failure or anomaly,
  - c. Repairing or replacing, when necessary, the affected component/equipment from inventory and bringing the plant back in working condition,
  - d. Purchasing and transporting the replaced component and keeping the inventory at the level defined by the Contractor.
3. Where market conditions prevent the supply of parts identical to those already installed. The Contractor proposes replacement parts for the Employer acceptance. Proposed replacement parts do not result in a reduction below the rated output or efficiency of the plant. The Contractor is responsible to update any plant drawings, catalogues, manuals for such a replacement once approval has been obtained from the Employer. The Contractor repairs or replaces (with the spare parts) the affected item immediately or, under all circumstances, within the time frame agreed with the Employer. In the absence of an agreement with the employer the repair time shall not exceed forty-eight (48) hours following the identification of the failure / initiation of alarms.
4. The Contractor is responsible for maintaining the plant in accordance with the laws in force at any given time.
5. In case where an immediate repair or replacement is not possible due to the lack of sufficient availability of components in inventory, the Contractor to propose a temporary solution to the Employer for approval to mitigate the risk of production losses, prior to implementation of the solution.
6. All work related to the corrective maintenance of each component or part must be performed in accordance with the relevant manufacturer's manual and recommendations. All materials, components and parts used by the Contractor must be new.
7. In case the incident or breakdown or malfunction is caused by Force Majeure or by the Employer's actions, not authorized by the Contractor, the Contractor performs all necessary activities (procurement, transportation, installation/repair/removal etc.) of corrective maintenance. Prior to such corrective maintenance activities, the Contractor notifies the Employer of the necessary cost and plan. The Contractor's offer must be according to the market and competitive. Only upon the approval from the Employer, the Contractor will execute the process. To avoid doubt, if such malfunction or breakdown requires the replacement of the components and the necessary components are available in the inventory of spare parts, the Contractor immediately corrects the breakdown or malfunction with the available spare parts.
8. The Contractor, in any case warrants the absence of defects on any repair, replacement and generally on any activities of corrective maintenance for two years in case of replacement or repair.

#### **4.4 Permit to Work system**

1. All work to be performed under this contract to be performed as per the following Employers regulations;

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- 240-150642762 - Generation Plant Safety Regulations (PSR)
  - 240-114967625 - Eskom's Operating Regulations for High Voltage systems (ORHVS)
2. These regulations details the permit to work system (PTW) to be applied when performing work. This requires the Contractor to have the required Responsible Persons appointed as per the requirements of the PSR and ORHVS.
  3. The Contractor plans and trains his own personnel as per the requirements of the Employers Plant Safety and ORHVS requirements.
  4. The Employer provides the details of suitable vendors for the training of personnel. The practical assessment and appointment of personnel is done by the Employer's Assessment panel as per the *Employer's* requirements.

## **5. TRAINING**

1. O&M Training shall be provided to the Employer and Employers' representatives during the O&M period. The focus of this training to be on practical operating and maintenance related activities during plant operation covering at least the following: Plant monitoring, identifying plant normal and abnormal operations and resolving plant abnormalities during actual plant operation.
2. O&M Training to illustrate the different modes of plant isolations that may be required as per the Plant Safety Regulations and Operating Regulations for High Voltage Systems.
3. Where required the Contractor shall provide formal classroom training of the operations and maintenance to ensure Employer's representatives have a sound understanding of the plant layout, characteristics, and functionality.
4. Training material to be provided where applicable.
5. The Contractor shall ensure that all training are conducted by experienced personnel in a professional manner.
6. Additional general training requirements are indicated in 474-12578 – Sere Solar PV Functional Specification – Section 3.4.

## **6. DOCUMENTATION REQUIREMENTS**

The Contractor provides, but not limited to, documents as indicated in Table 2 before, during, and after the Operation and Maintenance period.

**Table 2: Documents related to Operation and Maintenance**

No.	Document / Drawing	Review Type
Within 12 weeks prior to the issue of EPC Completion Certificate		
1	Preventative maintenance plan in compliance to specification	A
Within 8 weeks after the issue of EPC Completion Certificate		
1	Training Material for "Training of Operation and Maintenance of the Project" in compliance to specification	A
2	Training schedule for both classroom and on-site operation and maintenance training	A
3	Project Quality Plan during operation and maintenance	A
Within 12 Weeks after the issue of EPC Completion Certificate		
4	Final Training Material for "Training of Operation and Maintenance of the Project" in compliance to specification	A
5	Final Training schedule for both classroom and on-site operation and maintenance training	A

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No.	Document / Drawing	Review Type
Operation and Maintenance Report		
6	O&M activities and O&M report according to Section 7.1 of this Appendix.	A
7	Daily reporting shall be provided within immediate next calendar day	A
8	Monthly reporting shall be provided within 1 weeks after the reporting month period	A
9	Annual reporting shall be provided within 4 weeks after the reporting annual period	A
10	Maintenance Engineering Standard	A
11	Maintenance Implementation Standard	A
12	Task Manuals including inspection sheets	A
13	Job Plans	A
14	PMs in Maximo	A
15	Location of assets (Maximo / Smallworld)	A
16	Assets in Small World / CMMS	A
17	Maintenance assurance processes	A
Within 24 weeks (6 months) after the issue of Substantial Completion Certificate		
18	Proof of completion of "Training on Project Operation and Maintenance", accepted by the Employer's Project Manager	A

## **7. O&M REPORTING**

### **7.1 General**

1. The Contractor shall report on plant status and operation and maintenance activities to the Employer.
2. The Contractor shall prepare following reports during the Operation and Maintenance period:
  - a. Daily Report
  - b. Monthly Report
  - c. Annual Report

### **7.2 Daily Reporting**

1. The web-based monitoring system shall have ad hoc reporting capabilities that allow the Employer at any time to produce reports for any period.
2. The Contractor shall prepare the report of the preceding day and submit to the Employer with the following information, as a minimum:
  - a. Plant Performance and meteorological records (according to Table 3 below)
  - b. Alarms, faults (if any) and cause
  - c. Force Majeure event (if any)

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**Table 3: Plant Performance and Meteorological Records – Daily Reporting Format**

Parameter	Unit	Value	Comment
Date	dd:mm:yy		
Global Solar Irradiation on Horizontal plane	[kWh/m <sup>2</sup> ]		
Global Solar Irradiation on front side of module plane	[kWh/m <sup>2</sup> ]		
Global Solar Irradiation on rear side of module plane (in case of bifacial systems)	[kWh/m <sup>2</sup> ]		
Net energy production recorded in inverter level	[kWh]		
Net energy production recorded in meter at site	[kWh]		
Net energy production recorded in meter at POC	[kWh]		
Daily Average Performance Ratio	[%]		
Daily Average Plant Availability	[%]		
Avoided CO2 emission	[tons]		
Maximum Inverter Station/Cabin Temperature	[°C]		

3. The Contractor shall check the completeness of the monitoring data on a daily basis and store them as raw data (on hourly basis, as minimum) for the evaluation of plant performance.
4. Every recorded technical parameter (plant performance, meteorological, inverter parameters, grid measurement) shall be included in raw data.
5. The Contractor shall provide such raw data upon the request from Employer at any time or provide them at the end of every month on an electronic storage device (CD, DVD, or an external storage unit).

### **7.3 Monthly Reporting**

1. Within the first week of every month, the Contractor shall prepare and provide the report on operation and maintenance activities performed during previous month.
2. The report shall be reviewed and approved by the Employer.
3. The monthly report shall include as minimum following information:
  - a. List of preventive maintenance activities performed during the respective month and the Contractor's comments on findings, if any – as presented in Table 4.
  - b. List of corrective maintenance performed if any, as presented in Table 5.
  - c. Update of spare parts in stock, changes, and re-order status.
  - d. Alarms, faults (if any) and cause, as presented in Table 6.
  - e. Force Majeure event (if any).
  - f. Tabular presentation and comparison of daily average energy recorded in each inverter and energy fed into the grid – as presented in Table 7.
  - g. Tabular representation of recorded average solar irradiation on front side of module plane – as presented in Table 8.
  - h. Tabular representation of recorded average solar irradiation on rear side of module plane (in case of bifacial systems) – as presented in Table 9.

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- i. Tabular representation of recorded meteorological parameters (i.e., global solar irradiation on horizontal plane, ambient temperature, and wind speed) on daily basis – as presented in Table 10.
- j. Tabular representation of recorded global solar irradiation on module plane by reference cells and recorded module temperature on daily basis – as presented in Table 10.
- k. Summary of monthly Plant Performance and meteorological records – as presented in Table 11.
- l. Evaluation of daily average plant performance and plant availability – as presented in Table 12 and Table 13.
- m. Tabular representation of minimum and maximum operating temperature of each inverter installed in the plant and comparison with the corresponding manufacturer specification – as presented in Table 14.
- n. Raw data (from monitoring system on 15 minutes basis), intermediate calculations in Excel or PDF format.
- o. Preventive maintenance schedule for the following six months.

**Table 4: Preventive Maintenance – Monthly and Annual Reporting Format**

No.	Items	Frequency	Date Performed	Findings, If any
1	PV Modules			
1.1	Cleaning of modules	Q (at least) or see below		
1.2	Visual Inspection - glass breakage, yellowing & browning, corrosion, delamination, cracks on cell, hot spot, deformed connection box, module mounting and module frame condition etc.	M		
1.3	Visual Inspection terminal connections and panel cabling - cable tightness, terminal box watertight, cleanliness, clamping etc.	M		
1.4	I-V Curve measurement of strings	Once in two years		
1.5	I-R Scanning of modules	A		
2	Mounting structure and Foundation			
2.1	Visual Inspection of mounting structure	M		
2.2	Check of integrity of mounting structures and clamping	M		
2.3	Inspection of corrosions in screws, structure and check adequacy of screw tightness	SA		
2.4	Check on grounding connection (if any)	M		
2.5	Visual inspection on foundation	A		
3	String box/Junction Box/Combiner Box			
3.1	Visual Inspection - box screw tightness, incoming and outgoing cable tightness, cable labeling, water and dust tightness, etc.	M		
3.2	Check of proper functioning of string fuses, DC disconnect switch and earthing cable etc.	M		

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No.	Items	Frequency	Date Performed	Findings, If any
3.3	Visual inspection of string monitoring equipment inside combiner box	M		
3.4	Verify preventive maintenance activities described from 3.1 to 3.3 for secondary combiner box and fuse box (if any included in plant)	M		
4	Inverter - General Preventive measures			
4.1	General visual inspection of the inverter and inverter enclosure	M		
4.2	Inspection on cables and connection of the components	M		
4.3	Check if inverter is running at adequate temperature range, as specified by the manufacturer	M		
4.4	Check of inverter runs smoothly without producing strange noise	M		
5	Inverter - Periodic and Specific measures			
5.1	periodic efficiency measurement (DC/AC conversion from inverter meter)	M		
5.2	cleaning of air filter - as per manufacturer's recommendation	MS		
5.3	checking and replacement of ventilation system (if required) - as per manufacturer's recommendation	MS		
5.4	visual inspection of earth connections	M		
5.5	Checking and verification of proper functioning of safety switches, fuses, cooling fan	M		
5.6	Control and LCD display operation	M		
5.7	Check of inverter according to manufacturer's operation and maintenance manual	MS		
6	Inverter Station/Cabin			
6.1	Visual inspection of inverter cabin	M		
6.3	Visual inspection of ventilation system, earthing and fire protection system	M		
6.4	Check inverter temperature while running during the day and verify that ventilation is working properly and inverter operating temperature is within manufacturer's recommended range	M		
6.5	Visual inspection of transformer, switchgear board and protection device and verify that they all are running without any defects	M		
7	Electrical Wiring			
7.1	Check on integrity and completeness of all electrical cables from PV module to connection point	M		
7.2	Check for any damaged or discolored cable	M		

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No.	Items	Frequency	Date Performed	Findings, If any
7.3	Check on status of fuses, circuit breakers and safety switches	M		
7.4	verification of proper earthing connections of the plant components	M		
7.5	Verification of water tightening of electric cables and conduits	M		
7.6	Electrical Insulation and grounding measurement of DC and AC cables	once in two years		
7.7	Check and verify the labeling on electrical cables	M		
7.7	IR scanning of electrical cable connection and verify that all cable connection are made properly and no heat generation in the connection	A		
8	Security and Site Condition			
8.1	Check of integrity of security fences	SA		
8.2	Verify that all security cameras and gates are working properly	M		
8.3	Verify that communication of security systems with power station security system	M		
8.4	Verify that internal roads are in good conditions	M		
8.5	Keeping plant clean and free from waste and taking proper steps of the disposal of waste according to local regulation and procedures	SA		
8.6	On Site presence – immediate answering to all alarms by an emergency service assuring on-site presence			
8.7	Check the vegetation level and ensure that they are controlled	M		
8.8	Check the drainage channels and erosion control	M		
9	O&M Building (Server room, Stores Building, Security Building and all other Buildings on the PV Environmental Approved Area)			
9.1	Visual inspection of O&M building, walls, roofs, foundation and verify that there is no visual damage	M		
9.2	Verify that control system, server and its back up system are working properly	M		
9.3	Verify that the inventory of spare parts is maintained according to the contract requirement	M		
9.4	Verify that all security measures inside the O&M building is free of any defects and working properly	M		
10	Power Evacuation			
10.1	Visual inspection of power evacuation route and verify that all poles and lines are in good condition	M		
11	Meteorological Stations and Monitoring System			
11.1	Cleaning of meteorological stations (reference cell and pyranometer)	W		

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No.	Items	Frequency	Date Performed	Findings, If any
11.2	Calibration of meteorological equipment, if required	MS		
11.3	Check of connection on meteorological components and communication with monitoring system	M		
11.4	Check the weather station mounting structure and general physical condition	M		
11.5	Check the slope and azimuth of reference cells. pyranometers	M		
11.6	Check on online record of energy output and irradiation through remote monitoring system	D		
11.5	Check on alarm, event and status database - through remote monitoring system	D		
11.6	Check on online record of availability of each inverter and availability of the plant - through remote monitoring system	D		
12	Reporting			
12.1	Report on plant performance ratio and plant availability	M		
12.2	Report on energy production recorded through inverters, meters at site and meters at the Eskom 33kV switching station.	M		
12.3	Report on meteorological measurement on site	M		
12.4	Submission of raw and processed data on meteorological measurements and performance measurement to the <i>Employer</i>	M		
12.5	Report on status of plant component and status of preventive maintenance	M		
12.6	Report on alarms, events and status recorded	M		
12.7	List of damage and faults verified	M		
12.8	List of corrective maintenance service performed	M		
12.9	List of spare parts available in inventory	M		

Frequency: D→ Daily, W → Weekly, M → Monthly, Q→ Quarterly, SA→ Semi-Annually, A→ Annually, MS → Manufacturer specification and operation manual

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**Table 5: List of Corrective Maintenance – Monthly Reporting**

Date	Corrective maintenance type		Reasons for replacement/Repair
	Repair	Replacement	
dd:mm:yy			

**Table 6: List of Alarms/Faults – Monthly Reporting**

Date	Time on which alarm or faults are received	Cause	Date and time on response to alarm	Comments
dd:mm:yy				

**Table 7: Comparison of Daily Energy Production Recorded in Inverter and Meters – Monthly Reporting**

Date	Energy Production [kWh] recorded in inverter					Energy Recorded at meters on site [kWh] (per PV Block)		Energy Recorded at 22kV Eskom Switching Station [kWh]	
	Inv 1	Inv 2	.....	Inv (n-1)	Inv n	Meter 1	Meter n	Meter at 22kV Eskom Switching Station busbar 1a PV Feeder 1	Meter at 22kV Eskom Switching Station busbar 1a PV Feeder 2
dd:mm:yy									

**Table 8: Average Solar Irradiation on front side of Module Plane – Monthly Reporting**

Date	Average Global Solar Irradiation [kWh/m <sup>2</sup> ] recorded on front side of				
	Module plane, 1	Module plane, 2	Module plane, 3	Module plane 4	Average on Module plane
dd:mm:yy					

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**Table 9: Average Solar Irradiation on rear side of Module Plane – Monthly Reporting**

Date	Average Global Solar Irradiation [kWh/m <sup>2</sup> ] recorded on rear side of				
	Module plane, 1	Module plane, 2	Module plane, 3	Module plane 4	Average on Module plane
dd:mm:yy					

**Table 10: Record of Meteorological Parameters – Monthly Reporting**

Date	Average Global Solar Irradiation [kWh/m <sup>2</sup> ] recorded on				Temperature [°C]		Wind Speed [m/s]
	Horizontal plane	Reference Cell 1 – cleaned frequently	Reference Cell 2 – not cleaned	Difference between Reference cells	Ambient Temp.	Average Module Temp.	
dd:mm:yy							

**Table 11: Summary of Plant Performance and Meteorological Records – Monthly Reporting**

Parameter	unit	Value	Comment
Month	-		
Average Global Solar Irradiation on Horizontal plane	[kWh/m <sup>2</sup> ]		
Average Global Solar Irradiation on front side of module plane	[kWh/m <sup>2</sup> ]		
Average Global Solar Irradiation on rear side of module plane (in case of bifacial systems)	[kWh/m <sup>2</sup> ]		
Net energy production recorded in inverter level	[kWh]		
Net energy production recorded in meters at Site	[kWh]		
Net energy production recorded in meters at PoC	[kWh]		
Monthly Average Performance Ratio	[%]		
Monthly Average Plant Availability	[%]		
Avoided CO2 emission	[tons]		

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**Table 12: Summary of Plant Availability – Monthly Reporting**

Parameter	unit	Value	Comment
Month	-		
Total hours during which the irradiation on module plane is higher than 50 W/m <sup>2</sup>	[h]		
Total hours during which the inverters were producing energy and the irradiation on module plane were higher than 50 W/m <sup>2</sup>	[kWh]		
Total time period during which the plant could not feed energy into the grid because of the fault from utility	[h]		
Total hours during which the plant could not feed energy into the grid due to force majeure events	[h]		
Monthly average plant availability	[%]		

**Table 13: Plant Performance Evaluation – Monthly Reporting**

Date	Average Global Solar Irradiation on Module plane [kWh/m <sup>2</sup> ]	Energy supplied to Eskom 22 kV Switching Station [kWh]	Performance Ratio [%]	Plant availability [%]
dd:mm:yy				

**Table 14: Record of Inverter Operating Temperature – Monthly Reporting**

Date	Minimum [°C]	Maximum [°C]	Manufacturer's recommended operating range [°C]	Comment
dd:mm:yy				

## 7.4 Annual Reporting

- The Contractor shall provide the Employer with an annual report for each year by the end of the first month of the following year under review including but not limited to the followings:-
  - All monthly reports during the reporting year.
  - Summary on preventive maintenance activities performed during the year, comparison with planned frequency and Contractor's comments on findings, if any – as presented in Table 4.
  - Summary on general status of the plant, Contractor's recommendation or comments on requirement of improvement (if any).
  - Update of spare parts in inventory, changes and re-order status.
  - Annual Summary of Energy Production, Plant Performance Ratio and annual availability as presented in Table 15.
  - Monthly breakdown of plant performance ratio and plant availability as presented in Table 16.

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- g. Comparison of measured annual plant performance ratio and annual plant availability with guaranteed plant performance ratio and annual average plant availability as presented in Table 17.
- h. Calculation of Performance Liquidated Damage, if any.
- i. Raw data (from monitoring system on 15 minutes basis), intermediate calculation in Excel or Pdf format.
- j. Preventive maintenance schedule for the following year.

**Table 15: Summary of Plant Performance and Meteorological Records – Annual Reporting**

Parameter	unit	Value	Comment
Year	-		
Average Global Solar Irradiation on Horizontal plane	[kWh/m <sup>2</sup> ]		
Average Global Solar Irradiation on module plane	[kWh/m <sup>2</sup> ]		
Net energy production recorded in inverter level	[kWh]		
Net energy production recorded in meters at Site	[kWh]		
Net energy production recorded in meters at PoC	[kWh]		
Monthly Average Performance Ratio	[%]		
Monthly Average Plant Availability	[%]		
Avoided CO2 emission	[tons]		

**Table 16: Plant Performance Evaluation – Annual Reporting**

Month	Average Global Solar Irradiation on Module plane [kWh/m <sup>2</sup> ]	Energy supplied to station boards [kWh]	Performance Ratio [%]	Plant availability [%]
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
Annual				

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**Table 17: Measured and Guaranteed Performance Comparison**

Parameter	Unit	Value	Comment
Year	-		
Annual average measured Performance Ratio	[%]		
Annual average guaranteed Performance Ratio	[%]		
If applicable, Performance Liquidated Damage	[Rand]		
Annual average measured plant availability	[%]		
Annual average guaranteed plant availability	[%]		
If applicable, Performance Liquidated Damage	[Rand]		

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