

Technical Specification for the Design, Supply, Installation and 1-year Maintenance of Solar PV Carports and Battery Energy Storage System at Eskom Academy of Learning

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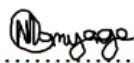
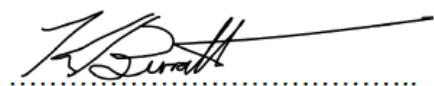
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1. INTRODUCTION

1.1 EXECUTIVE OVERVIEW

- a) This document sets the technical requirements for the *Contractor* to perform detailed Design, Procurement, Construction, Testing, Commissioning, Training, **12-months** Operating & Maintenance and Handover of Solar PV Carports (SPVC) and Battery Energy Storage System (BESS) at Eskom Academy of Learning (EAL), in Midrand, Gauteng Province. The site is owned by Eskom Holdings Limited Real Estate (henceforth referred to as the *Employer*). The scope is inclusive Civils & Infrastructure, Electrical and Control and Monitoring System (CMS) requirements.
- b) The sites selected for the installations are:
- 1) Kriel Carpark: Grid-tied Solar PV Carport with minimum capacity of **577kWp** (DC power) and **500kWac** (Inverter AC output power) connected to 500kVA Finesse Minisub through two new AC Distribution Boards.
 - 2) Admin Building Carpark: Solar PV Carport with minimum capacity of **1.334MWp** (DC power). The PV plant is split into Two (2) Solar PV-BESS Hybrid systems comprising of DC-coupled Solar PV and BESS with a control system for on-grid and off-grid operations, each connected to Admin Board A and Board B respectively with interface to two Diesel Generators and Grid power supplies.
The Admin PV-BESS Hybrid system is split from one Solar PV carport as follows:
 - a. DC-coupled Solar PV Carport with minimum capacity of **667kWp** and BESS with minimum capacity of **1200kWh/600kWac**.
 - b. DC-coupled Solar PV Carport) with minimum capacity of **667kWp** and BESS with minimum capacity of **1200kWh/600kWac**.
- c) This document also includes quality management, maintenance and training requirements. This document is read in conjunction with the Contract and relevant standards.

1.2 THE *EMPLOYER'S* OBJECTIVES

The *Employer's* main objectives for the installation is to create a Smart Village that:

- a) is a net-zero consumer.
- b) provide EV charging stations powered from renewable (i.e. PV) energy.
- c) showcase the *Employer's* involvement in renewable energy.

1.3 INTEPRETATION AND TERMINOLOGY

Abbreviation	Description
AC	Alternating current
ATS	Automatic Transfer Switch
CMS	Control and Monitoring system
DC	Direct current
DG	Diesel Generator

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Abbreviation	Description
DNI	Direct normal irradiance
EMI	Environmental Management Instrument (Weather Station)
EPC	Engineering, Procurement and Construction
EV	Electric Vehicle
FAT	Final Acceptance Testing
FDS	Fire Detection and Suppression
GHI	Global Horizontal Irradiation
HMI	Human Machine Interface
HVAC	Heating, Ventilation and Air-Conditioning
IT	Information technology
IM	Information management
IP	Ingress Protection
LAN	Local Area Network
LCOE	Levelised Cost of Energy
LV	Low Voltage ($0 < LV < 1000V$)
MCCB	Moulded Case Circuit Breaker
OEM	Original Equipment Manufacturer
OHS	Occupational Health and Safety
O&M	Operating and Maintenance
PAT	Provisional Acceptance Test
PCS	Power Conversion System
POA	Plane of array
PR	Performance Ratio
PV	Photovoltaic
QA	Quality Assurance
QC	Quality Control
QCP	Quality Control Procedure
TMY	Typical Meteorological Year
SPVC	Solar PV Carport
USB	Universal serial bus

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2. GENERAL REQUIREMENTS

2.1 THE CONTRACTOR'S SCOPE OF WORK

- a) The scope of work comprises of a grid-tied Solar PV Carport as well as all associated infrastructure and balance of plant to be installed at EAL Kriel Carpark, connected to Finesse Minisub through a new AC distribution board (PV AC-DB) and an extension DB at the Minisub.
- b) The scope of work comprises of two BESS with DC-coupled Solar PV Carport as well as all associated infrastructure and balance of plant to be installed at EAL Admin Building Carpark, each connected to Admin Board A and Board B respectively with interface to two Generators and Grid.
- c) The *Contractor* is responsible for surveying, design, supply of all materials and labour, manufacture, delivery to site, offloading, construction, erection, installation, off-site testing (factory acceptance testing), on-site testing (site acceptance testing), commissioning, performance testing, training, operating and maintenance, provision of samples, preparation of all detail design drawings, as-built record drawings, relevant authorisations, permits and compliance certificates, operating and maintenance manuals and instructions for the works, in accordance with the general requirements and performance requirements as detailed in this document. The *Contractor* provides the *works* as stated in this document and Works Information.

2.2 CONTRACTORS' EXPERIENCE

The *Contractor*:

- a) Demonstrates proven experience in engineering, procurement, execution, operating and maintenance of commercial scale Solar PV Carport and Battery Hybrid Systems.
- b) Has successfully executed a minimum of one PV-Battery Hybrid project as lead EPC *Contractor* with Solar PV DC capacity equal to or greater than **50kWp** and Battery Capacity equal to or greater **100kWh**.
- c) Provides the name, location, size, photos, contacts and date of commissioning of one (1) PV-Battery Hybrid project that meet the requirement in b).

2.3 GENERAL AND ADMINISTRATIVE

- a) The *Contractor* provides the *works* in a professional and highly skilled manner consistent with industry best practices and in accordance with established codes and standards and meet the requirements stated in the Contract.
- b) In the event of any Defect, the *Project Manager* notifies the *Contractor* in writing and *Contractor* corrects without delay, at *Contractor's* cost and expense, the Defect as to conform to the contractual requirements.
- c) If the *Contractor* fails to provide the *works* or correct any Defect after receipt of a written notice by the *Project Manager*, the *Employer* has a choice to correct Defects or procure that from *others*. The *Contractor* bears all costs incurred as a result thereof and the *Employer* is entitled to deduct the whole or any cost incurred.
- d) The *Contractor* promptly reviews all data, information, designs and drawings provided by the *Employer* and promptly bring to the attention of the *Project Manager* in writing all things which in *Contractor's* opinion appear to be deficiencies, inaccuracies, omission, contradictions or ambiguities in such data, information, designs and drawings.

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- e) The *Contractor* conducts site visit to collect data and approvals that may be necessary to complete the *works*. When the *Employer* receives the Tendered documents, it is understood that the *Tenderer* has visited the site and is satisfied as to the nature and conditions of terrain; climatic and geological conditions; transportation and communication facilities; the requirements and availability of labour, water, electric power and roads; the location and condition of material sources for use in the *works*; and other factors that may affect the cost estimate and execution of the *works*.
- f) The *Contractor* is deemed to have studied the Works Information in detail together with general and special conditions of the contract including technical schedules and drawings and obtained any additional information necessary for the completion of the tender and for the execution of the *works* on his/her expense.
- g) The *Contractor* is responsible for obtaining the approval from the *Project Manager* prior to the execution of the *works* at site. Whenever the execution of the *works* on the *Employer's* site coincides with the activities or operations of *Others* at EAL, the *Contractor* obtains the *Project Manager's* approval of the sequence and scheduling of the *works* and does not interfere with operations or facilities except to the extent of such approval.
- h) The *Contractor* complies with the *Employer's* rules and regulations (including any subsequent changes or instructions as may be issued from time to time) concerning health, environment, safety, security and welfare.
- i) The *Contractor* is solely responsible for and, where applicable, provides at its sole cost and expenses all work permits, certificate of medical fitness, drivers' licences and all other permits and documentations as may be required for its employees to Provide the Works .
- j) The *Contractor* has no claim for extra payment nor be relieved or excused from any obligation under the *works* as a result of any lack of knowledge as to the nature of the site, means of access, local facilities, labour conditions and practices, or similar matters affecting performance of the *works*.
- k) The *Contractor* takes necessary actions to ensure that the Project is satisfactorily completed in time and within budget allocations.
- l) All the *works* required for the satisfactory completion of the Scope of Work are included in the specification and schedules, however any *works* not included in the specification and which the *Contractor* considers necessary to be done to complete the Scope of Work, costs of such work will be deemed to be within the tendered prices and no extra charges will be accepted. The *Contractor* shall clearly indicate these additional activities, with motivation, in the tender submission.
- m) The *Contractor* and *Subcontractors*, whilst in the Republic of South Africa respects the laws and customs of the Country.

2.4 PROCUREMENT, PERMITS AND SITE ESTABLISHMENT

- a) The *Contractor* is responsible for the procurement of all equipment and services which are required to complete the *works* in accordance with the performance specifications for the whole of *the works*.
- b) The *Contractor* acknowledges and agrees that he/she will not be entitled to any additional cost or expense or any adjustment to the Contract Price or to claim any extension to the Scheduled Substantial Completion and Final Completion or to make any claim under this Contract, any applicable Law, at law, in equity, in delict or otherwise based in whole or in part upon any discrepancy between the actual Site Conditions encountered by the *Contractor* during the progress of the *works* and those Site Conditions that the *Contractor* anticipated, or could have anticipated, at the Contract Signature Date.

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- c) The *Contractor* is responsible for obtaining any licenses, permits or approvals which are required during the construction of the plant for any construction activities as well as during operation for operation and maintenance activities related to the *works*.
- d) The *Contractor* obtains permission for site access after Contract Signature Date from the *Project Manager* before any site establishment. The *Contractor* ensures compliance with all applicable health and safety regulations at all times.
- e) The *Contractor* constructs the SPVC and BESS Plants with due consideration to the Site Rules, as those have or will be defined by the *Employer*.
- f) The *Contractor* is responsible for all site establishment work required enabling the completion of the *works*. This includes but not limited to; supply of construction power, any consumables and site offices.

2.5 QUALITY MANAGEMENT

- a) The *Contractor* engages in safety culture initiatives in line with the Eskom Life Saving Rules, Safety and Quality Requirements Standard.
- b) The *Contractor* and all *Subcontractors* comply with the requirements listed in the *Employers* Specification document, 'Supplier Quality Management: Specification', document identifier QM58/240-105658000, for all the *Employers* Quality requirements.

2.6 KEY MILESTONES

Key Milestones and their definitions are listed below:

- a) Contract Signature Date – The date which the *Contractor* and *Employer* sign the Contract documents after the finalisation of Contract negotiation.
- b) Detail Design Freeze Date – The date upon which the final design documentation is reviewed and accepted by the *Project Manager*. The detailed design of the SPVC and BESS Plants to be completed and frozen within 30 calendar days after Contract Signature Date.
- c) Mechanical Completion (Construction and Pre-commissioning) – When the *Contractor* completes the Mechanical Completion Test of the SPVC and BESS Plants successfully as described in Section 3.7 and then the *Project Manager* issues a Mechanical Completion Certificate.
- d) Electrical Completion (Cold and Hot Commissioning) – When the *Contractor* completes the Electrical Completion Test as described in Section 3.7. The *Contractor* provides a Certificate of Compliance (COC) and Grid Code test report of the SPVC and BESS Plants certified by the responsible person and then the *Project Manager* issues a Commissioning Certificate.
- e) Substantial Completion - The Provisional Acceptance Test (PAT) as described in Section 3.9 takes place once the Commissioning Certificate is issued. The *Project Manager* issues a Substantial Completion Certificate after successfully completion on the PAT. No Partial Substantial Completion is accepted. The *Contractor* guarantees the Substantial Completion Date and provides information along with Tender documents.
- f) Final Completion - The duration of the Final Acceptance Test (FAT) as described in Section 3.9 is 12-month period after the issuance of Substantial Completion Certificate. The FAT period commences from the date of Substantial Completion until the issuance of the Final Completion Certificate by the *Project Manager*.

As part of the tender returnable, the *Tenderer* submits a **milestone schedule** which details the proposed timelines to complete each milestone.

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2.7 OPERATING AND MAINTENANCE

- a) The *Contractor* is responsible for the operating and maintenance of the Kriel SPVC and Admin Building BESS and SPVC Plants for **12-months** in accordance with Section 3.10 and the performance requirements detailed in Section 3.8.
- b) The *Employer* is responsible for the operating and maintenance of the works after Handover and issuance of the Final Completion Certificate to the *Contractor*.

2.8 TRAINING

- a) The *Contractor* is responsible for the training of chosen Eskom staff during the construction, operation and maintenance of the PV and BESS Plants. Eskom requires a minimum of 6 staff to be trained on the design, construction, testing and commissioning, operations and maintenance of the Kriel SPVC and Admin Building BESS and SPVC Plants.
- b) The *Contractor* provides training in following manner:
 - 1) Training on Design, Construction, Testing and Commissioning: Introduction to Project design, construction, testing and commissioning on the project and equipment must be provided by the EPC *Contractor* before Substantial Completion Certificate is issued by the *Project Manager*, such that those *Employer* representatives who will be at the site during normal working hours are enabled to safely shut down and/or ramp-up the plant, should that be required. This training will be in the classroom (theory) and on site (practical). The classroom training sessions are intended to provide concentrated instruction in the system design, equipment selection, capability, operation, inspection, and control of the Equipment and systems within the project.
 - 2) Training on Operating and Maintenance: Formal classroom and on-site training of the operating, maintenance and operations of the plant are essential to ensure the Trainees have a sound understanding of the plant functionality and O&M requirements. The Training requirements are presented in Section 3.10 of this document and to be completed during the O&M period.
- c) The training instructor with a minimum 2 years' experience in solar PV construction, commissioning and operations is required.
- d) All classroom training sessions are videotaped by the *Employer* at its expense for future use as an orientation/teaching aid during the commercial operating period.

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3. TECHNICAL REQUIREMENTS

3.1 PROJECT DEFINITION

3.1.1 Project Site Location

- a) Eskom Academy of Learning (EAL) aerial view is shown in Figure 3-1 and is located at the following address and coordinates.
- Address: Dale Road, Midrand, Gauteng, South Africa.
 - GPS Coordinates: 25°59'12.4"S 28°09'36.7"E
 - Temperature range: 4°C - 28°C (max 1°C - 30°C)
 - Altitude: 1562m
- b) The sites aimed for Solar PV Carport installations are Kriel carpark (Red boundary) near EAL main entrance and Admin carpark (Yellow boundary) at the back of EAL.

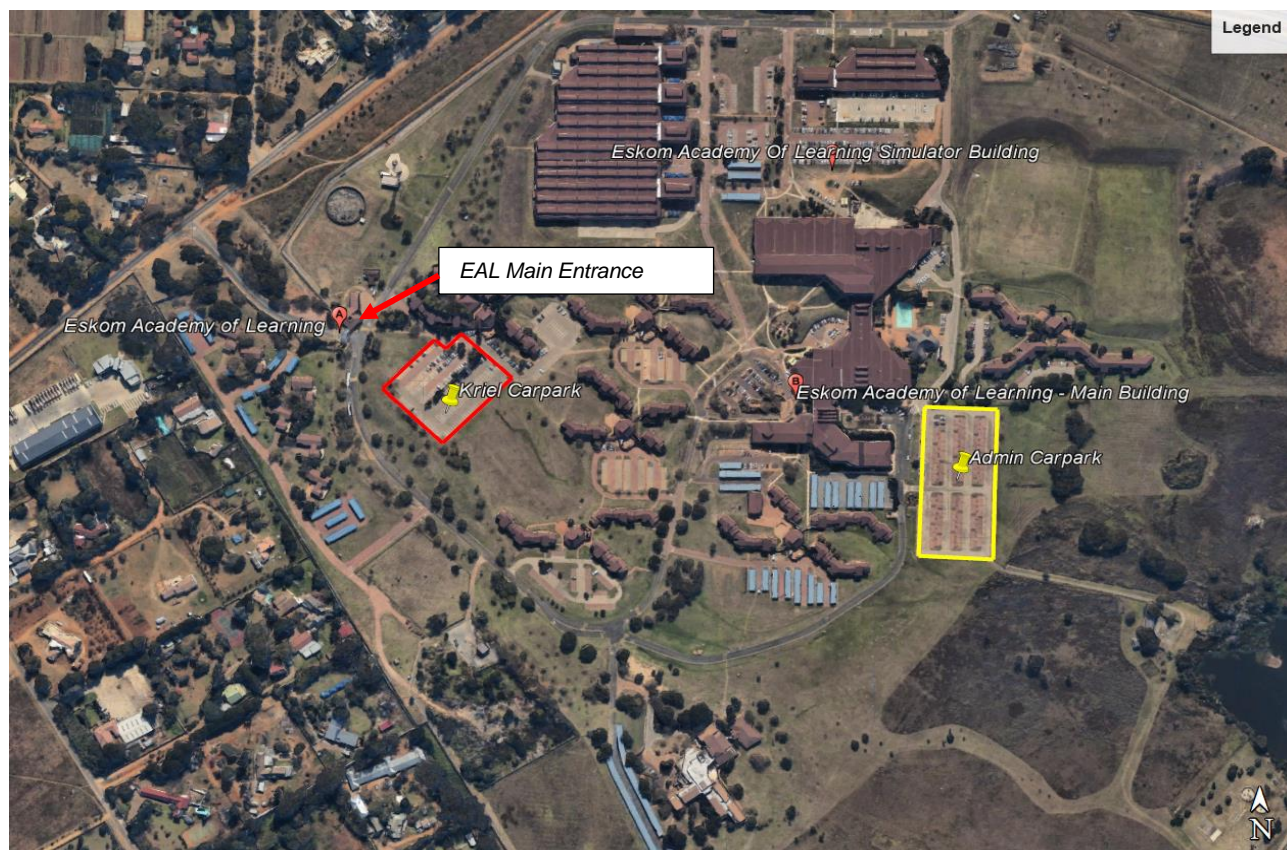


Figure 3-1: EAL Aerial View showing Kriel and Admin Carparks

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3.1.2 Plant Point of Connections (PoCs)

- The EAL single line diagram is shown in Figure 3-2. Kriel SPVC Plant is to be connected to the LV side of the 11kV/400V, 500kVA Finesse SUB No.8 Minisub as shown in Figure 3.2 and Appendix A.
- The power supply for the Admin Building is derived from two 11kV/400V, 800kVA, dry-type transformers fed from the 11kV Auditorium SUB. No. 15. oil-type Ring Main Units (RMUs). Each transformer is connected to the respective 400V Board A and Board B switchgear located inside a room on the northwest side of the building.
- EAL Admin Building BESS and SPVC Plants are to be connected to 400V Admin building Board A and Board B respectively with interface to two Generators and Grid supplies as shown in Figure 3.2 and Appendix B.

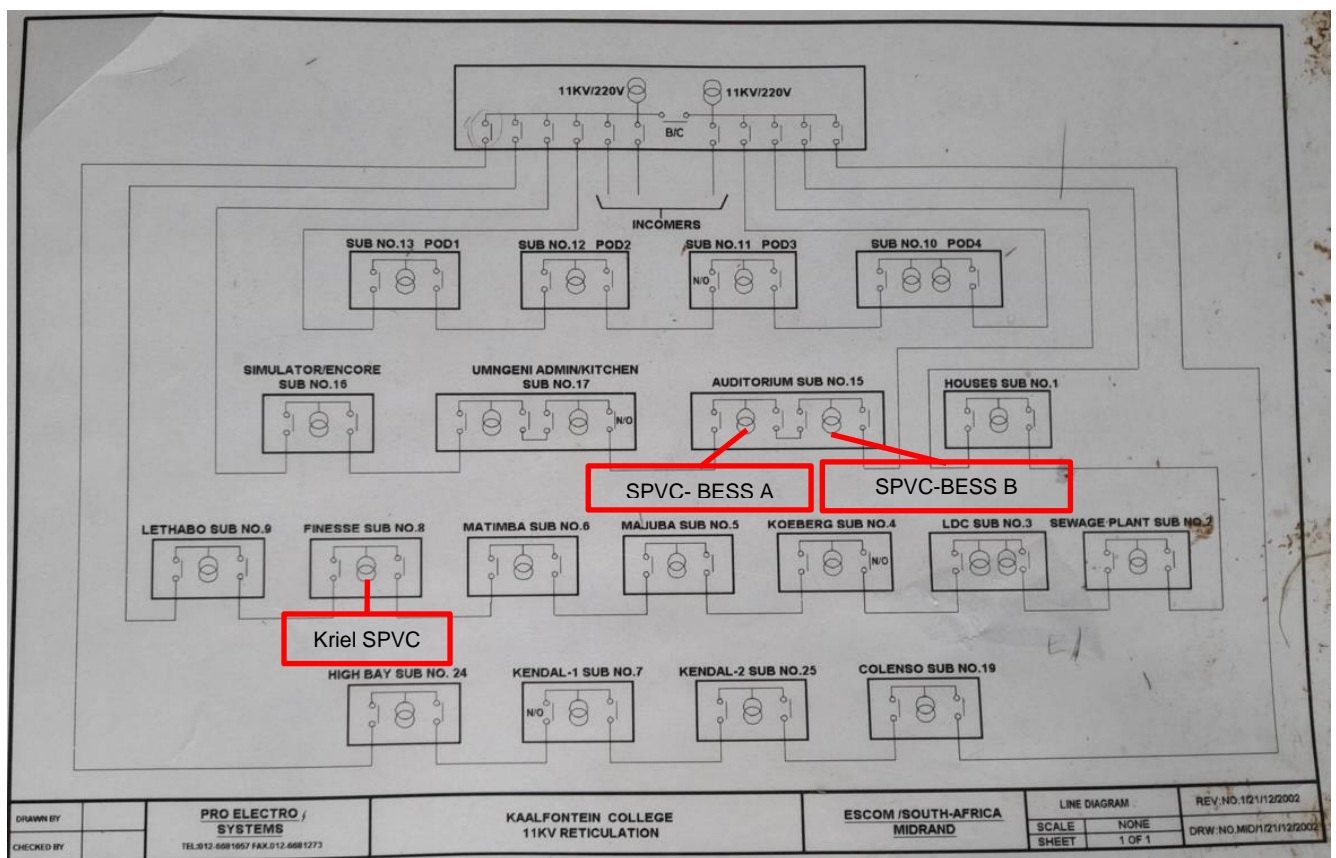


Figure 3-2: EAL Single Line Diagram

3.1.3 Meteorological Situation (Solar Resource and Temperature)

- The long term annual average solar irradiation on horizontal plane (GHI) is expected to be around 2,232 kWh/m².
- The annual average temperature at the site is estimated to be around 20°C.
- The *Contractor* designs the PV Plants operation for minimum and maximum ambient temperature of -0°C and +40°C respectively, unless specified otherwise.
- The *Contractor* choses its own TMY dataset for evaluating the PV plant performance and to guarantee the performance ratio as defined in Section 3.8.

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3.1.4 Design Definition

- a) The *Contractor* submits basic design proposals as part of the tender submission requirements.
- b) The *Contractor* develops the detailed design of the Plants in full compliance with the general requirements and performance specifications as set out in this document and takes *liability* for the design.
- c) The *Contractor* ensures that all designs are signed off by an ECSA (Engineering Council of South Africa) registered Professional Engineer with minimum working experience of 3 years.
- d) The *Contractor* designs the Solar PV Carports performance and provide the performance ratio calculation along with detail calculation and losses assumption using own TMY data. The *Contractor* uses industry standard methods and software for carrying out yield and performance ratio calculations and demonstrate the basis of the calculations.
- e) The *Contractor* submits the detailed designs to the *Project Manager* for review, comments and acceptance prior to procurement and construction of the SPVC and BESS Plant equipment. Each document review turnaround time is 5 working days. The detailed design of the SPVC and BESS Plants to be completed and frozen not more than 30 calendar days after Contract Signature date.
- f) The *Contractor*, as part of the design, considers all relevant requirements stipulated in the South African Grid Code for renewables for the size of the PV plant. The *Contractor* ensures that design and construction of the SPVC and BESS Plants complies with current standards and statutory obligations arising from current legislation and regulations, including statutory legislation and codes of practice, and relevant South African and international standards.
- g) The *Contractor* ensures that *the works* are carried out according to the Eskom Supplier Quality Requirements Specification and requirements in Section 2.5.
- h) The *Contractor* designs the SPVCs and BESS Plants with due consideration to the prevailing environmental conditions and ensures that all equipment is protected from conditions outside their normal operating conditions, as stipulated within the respective manufacturers' operating manuals and other associated literature such as IEC 60721 - Classification of Environmental Conditions.
- i) The *Contractor* ensures compliance with all applicable health and safety regulations at all times during design, construction and operation of the SPVCs and BESS in accordance with OHSAS 18000 and in accordance with the Eskom Health and Safety Specification provided in the Contract.
- j) If there is a conflict of method, or level of provision, the *Contractor* adopts the specification, recommendation or regulation with the most stringent conditions. The *Contractor* submits details of any such conflicts and the provisions adopted.
- k) The *Contractor* designs the SPVCs and BESS Plants with due consideration to the minimisation of lifecycle costs (achieving an optimal balance between delivered kW, kWh, reliability, life cycle cost, maintainability, and overall cost effectiveness).
- l) The Systems are designed for ease of future deconstruction and recycling and designed for disassembly with an associated end of life waste management plan.
- m) With respect to any surveys or analysis of existing infrastructure relevant to the facility installation, the *Employer* does not assume responsibility for the completeness or accuracy of such surveys and analysis.
- n) The *Contractor* reviews, validates and subsequently takes responsibility for the scope and accuracy of any such data relevant to completion of the *works* provided by the *Employer* and to be relied upon by the *Contractor* and be responsible for planning, specifying and executing any additional site investigations required in order to satisfy themselves that the required level of scope and accuracy

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of data and analysis has been obtained, so as to not in any way affect the execution of its obligations.

3.1.5 Material Quality Specification

The *Contractor*:

- a) Ensures that all components and materials supplied are designed, manufactured and tested in accordance with the latest applicable IEC and SANS standards.
- b) Ensures that Equipment Products, Components and/or Accessories conform to all applicable Product Safety Standards appropriate for the intended markets.
- c) Ensures that the quality and performance of materials and products are appropriately certified under a suitably approved scheme.
- d) Ensures appropriate certification and independent testing has been carried out on any materials and products proposed. Submits all relevant test reports and certificates with the tender.
- e) Ensures materials and products used are suitable for the service conditions.
- f) Ensures that all *works*, materials, parts, components etc. supplied are new, both in the construction of the SPVCs and BESS Plants, and maintenance of the systems throughout the Operating and Maintenance Period.
- g) Does not use any materials or substances that are generally known at the time of use to be deleterious, a health risk, or a fire hazard, either in use or in their manufacture.
- h) Does not use substances known to deplete the ozone layer, whether or not specifically excluded from use by current EC legislation, as refrigerants or foaming or filling agents for insulation.
- i) Does not use any materials or substances that support mould, bacterial growth or vermin or cause objectionable odours under service conditions. Ensures that, where possible, all materials used are recyclable.
- j) Ensures materials and products delivered to site bear the manufacturer's name, brand name and any other data required to verify that their performance and specification complies with the requirements of this document and the *Employer's* Project Specific Requirements.
- k) Ensures materials and products are appropriately CE/UL marked or SABS approved.
- l) Follows manufacturers' instructions on the use of materials and products. Ensures that materials and components are transported and stored in accordance with manufacturer's guidelines.
- m) Selects materials & products with regard to standardisation and availability of spare parts and for ease of maintenance.
- n) Ensures the same manufacturer is used for materials or products of a similar type and that identical parts of similar products are interchangeable.
- o) Provides suitable packaging for the protection of all materials and equipment during delivery, storage, and where exposed to damage on site. The *Contractor* disposes the packaging in an environmentally friendly manner. The *Contractor* takes particular care to protect and maintain plant and equipment delivered early.
- p) Examines materials and products supplied when delivered to site and immediately prior to installation. The *Contractor* notifies the *Project Manager* replaces any damaged or faulty materials or products.
- q) Stores all materials on raised boarded platforms under weatherproof covers and/or according to manufacturers' specifications.

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- r) Protects all materials and equipment which may be exposed to damage, inclement weather, or ultraviolet light.
- s) Ensures that sensitive plant and equipment items are stored and handled in accordance with the manufacturer's recommendations to maintain the warranties and long-term reliability.
- t) Repairs any damage to finished materials and equipment prior to handover of the works.
- u) Where codification of the plant equipment (inclusive of spares and tools) is required, the Contractor provides the required information in the required Eskom format.

3.1.6 Kriel Carpark Project Definition

3.1.6.1 Site Location

- a) The Kriel Carpark aerial view is shown in Figure 3-3 and located at the following address and coordinates. Site access path is indicated by the red line from the main entrance.
 - Address: Dale Road, Midrand, Gauteng, South Africa.
 - GPS Coordinates: 25°59'12.4"S 28°09'36.7"E



Figure 3-3: EAL Kriel Carpark Aerial View

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- g) The equipment (Inverters, DBs, switches, etc.) are located under covering that will allow easy and safe access for operating and maintenance, taking emergency escape requirements into consideration.
- h) The PV string and the DC to AC ratio sizing is done as per inverter manufacturer's recommendation to maintain inverter warranty. The total inverter clipping losses are limited to 1% for Kriel PV Plant.
- i) The *Contractor* designs the string size in such a way that inverter always operates within its Maximum Power Point range throughout anytime in a year and throughout the project lifetime.
- j) String inverters are considered due to different panel orientations, lower cost, flexibility and for internal string voltage and current monitoring required for performance assessment and maintenance.
- k) DC string boxes are required per inverter for maintenance, protection and isolation purposes.
- l) An outdoor AC distribution board (DB) is required to combine string inverters and to supply Sub-DB, lighting, CMS, future EV charging points and to connect the SPVC AC output to the Minisub.
- m) An outdoor AC Sub-distribution board (Sub-DB) is required to supply future EV charging points.
- n) The Point of Connection (PoC) for the SPVC Plant is at Finesse Minisub (500kVA, 11kV/400V) low voltage side as shown in **Appendix A**. The location of the Minisub is shown in Figure 3-4.
- o) The *Contractor* provides the minimum CMS requirements stated in Section 3.4.
- p) The *Contractor* provides a **PV plant site layout** showing module layout and location for inverters, distribution boards and PoC.
- q) The *Contractor* provides a **single line diagram** showing electrical connection of modules, inverters, distribution boxes/boards, isolators, protection devices, metering and PoC.
- r) The *Contractor* provides all relevant technical drawings, operating and maintenance user manuals that are required for safe and effective operating and maintenance of the works.
- s) The *Contractor* designs and installs suitable outdoor lighting that is surface mounted under the carport. The lighting design considers the required lux levels, distances and glare considerations. The *Contractor* submits the lighting design documentation including supporting relux files and product IES/LTD files are submitted to the *Project Manager* for review and acceptance.
- t) The luminaire selection is based on latest energy efficient LED technology. Prior to installation, the *Contractor* demonstrates the lighting equipment meets the project requirements and properties used within the lighting design. All lighting equipment samples, designs and product information are submitted to the Eskom Lighting lab for acceptance prior to implementation.
- u) The *Contractor* demonstrates the installed lighting system is as per the accepted design and within the required parameters, which includes and not limited to onsite measurement with a calibrated Lux meter, witnessed by the *Project Manager*.
- v) The lighting design, type and fixture is in accordance with:
 - 1) 240-55714363 Generation PS Lighting and Small Power Installation Standard
 - 2) 240-139282493 Security Lighting for Eskom Applications
 - 3) SANS 10389-2

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3.1.6.3 Main Equipment of the Grid-tied PV Plant

Component	Description
PV Modules	Crystalline Silicon PV modules of same type, size and from the same manufacturer with minimum module size of 545Wp and efficiency >21%.
Mounting Structures , Foundations and Waterproofing	Fixed-mount cantilever waterproof structure with approved structural analysis report or Design report. Foundation designed as per relevant codes.
PV DC String Box (PV DC-DB)	PV String box with circuit breakers for protection and isolation of module strings.
String Inverters	Strings inverter concept for different panel orientation with string voltage/current monitoring, and power limit and energy export control.
AC and DC Cabling	DC cables that are UV rated, halogen free, double insulated and installed within trays and conduits. AC cables provided and terminated as per Eskom standard.
AC Combiner/ Distribution Board (AC-DB) and Sub-DB	The AC Distribution Board to supply lighting, CMS, Sub-DB and main output connected to the Finesse Minisub. The Sub-DB to supply future EV Chargers.
Extension Distribution Board (PoC DB) and Point of Connection (PoC)	PoC is at the Finesse Minisub (500kVA, 11kV/400V). An LV extension DB with PoC MCCB, Energy meter and reroute new EV charger cable and 250A MCCB.
Plant Protection	Plant and equipment protection including Earthing, Lightning, Surge protection devices, inverter isolation, fire protection, anti-islanding among others defined in this document. Lighting protection provided as per assessment report.
Energy meters at AC-DB and PoC Ext-DB	A bi-directional Energy meter to be installed at the AC-DB for PV energy production and Another Energy meter at PoC Ext-DB for energy export/import with communication to the CMS.
Control and Monitoring System and Weather Station	A CMS comprising of a datalogger with display capability which interfaces with inverters, metrological station and energy meter with capability of connection to Eskom and other 3 rd party network. Weather station consists of Reference cells, Pyranometer and Temperature sensors.
Lighting System	Lights underneath the modules along the carpark as defined in this document

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3.1.7 Admin Building Carpark Project Definition

3.1.7.1 Site Location

a) The Admin Building Carpark aerial view is shown in Figure 3-5 and located at the following address and coordinates.

- Address: Dale Road, Midrand, Gauteng, South Africa
- GPS Coordinates: 25°59'12.62 S, 18.631937 E

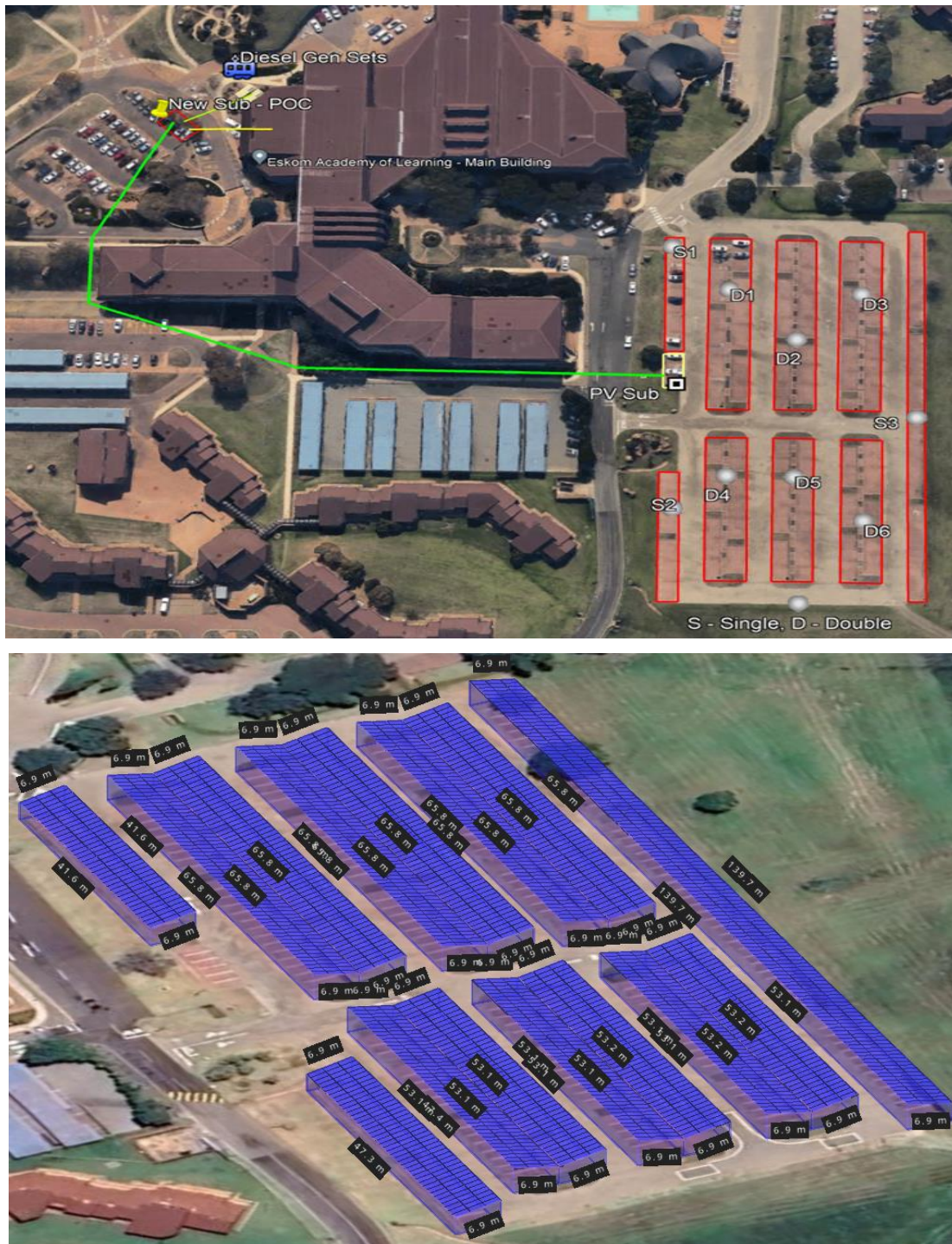


Figure 3-5: EAL Admin Carpark Aerial View and Solar PV Plant Indicative Layout

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3.1.7.2 Admin Building Power Supply

- a) The power supply for the Admin Building is derived from two 11kV/400V, 800kVA dry-type transformers fed from the 11kV Auditorium SUB. No. 15. oil-type RMUs as shown in Figure 3-2. Each transformer is connected to the 400V switchgear Board A and Board B respectively through a 1000A MCCB and an Automatic Changeover Switch (ATS) with Diesel Generator supply as shown in Appendix B.
- b) There are two 400V Marelli Diesel Generators (DGs), each rated at 510kVA and 680kVA, with ATS installed in two separate DG containers located near the Admin switchgear room as shown in Figure 3-5. The nameplate information for the DGs together with ATS and MCCB locations is shown in Figure 3-6. The DGs are used on a loss of normal power supply to power Board A and Board B separately.



Figure 3-6: EAL Admin Building Diesel Generator Specification

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3.1.7.3 Plant Configuration Design

- a) The *Contractor* designs a Solar PV Carport with minimum capacity of **1.334MWp** (DC power) covering the areas shown in Figure 3-5 with East-West PV module orientation.
- b) The *Contractor* splits the PV Plant into Two (2) Solar PV-BESS Hybrid systems, each comprising of a DC-coupled Solar PV, BESS (Lithium-Ion batteries, Hybrid inverter Bi-directional PCS) and the Control and Monitoring System for on-grid and off-grid operations, each connected to Admin Board A and Board B respectively with interface to two Generators and Grid.
- c) The SPVC-BESS Hybrid system is split as follows:
 - 1. DC-coupled Solar PV with minimum capacity of **667kWp** and BESS with minimum capacity of **1200kWh/600kWac**.
 - 2. DC-coupled Solar PV with minimum capacity of **667kWp** and BESS with minimum capacity of **1200kWh/600kWac**.
- d) The *Contractor* designs the SPVC-BESS Plants for automatic on-grid and off-grid operations with and without Generators. The system monitors and control the operation plant mode of the Admin facility in the following order of priority.
 - 1. PV, BESS and Grid (On-grid operation): PV supplies power to the Admin building load, charge the battery and excess PV power is exported to the grid.
 - 2. PV and BESS alone (Off-grid operation during grid failure): PV and BESS supply power to the Admin building load with PV power as priority and a battery power as support.
 - 3. BESS alone (Off-grid operation during grid and PV failure): BESS supplies power to the Admin building load and initiate Diesel Generator startup on set Battery State of Charge (SOC).
 - 4. Generator alone (Off-grid operation during Grid, PV and BESS failure).
 - 5. Reinstating the normal operation(on-grid operation) when Grid supply is restored.
- e) The *Contractor* provides equipment that control and communicate with each other to meet the on-grid and off-grid requirements in d).
- f) The power supplies from PV/BESS, Grid and DG and load switching to be at the new Switch Station specified in Section 3.3.3.7 and as shown in Figure 3-5. This is to optimise cabling from all the supplies.
- g) The *Contractor* provides a PV Plant with a design life of 25 years with annual guaranteed performance and availability as presented in Section 3.8.
- h) The Contractors selects the Solar Charge Controller (SCC) with minimum PV DC capacity stated in this document.
- i) The PV string and the DC to AC ratio sizing is done as per SCC and PCS manufacturer's recommendation to maintain SCC and PCS warranties. The total inverter clipping losses are limited to **3%**.
- j) The *Contractor* designs the string size in such a way that SCC always operates within its Maximum Power Point Tracking (MPPT) range throughout anytime in a year and throughout the project lifetime.
- k) The SCC MPPT and Battery operating voltages are selected to fully charge the batteries. The SCC has at least Two (2) MPPTs for the different panel orientations shown in Figure 3-5.
- l) PV DC combiner boxes with string voltage and current monitoring are required for performance assessment, protection and maintenance.
- m) The *Contractor* provides the minimum CMS requirements stated in Section 3.4.4.

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- n) The Solar PV Carport modules are mounted in such a manner that will provide effective shading and protection against rainwater. The cantilever PV structure is provided with waterproof material between PV modules.
- o) Portrait-mounted modules with maximum tilt angle of 10° are required. The tilt angle to be higher than 7° to avoid water entering into module cell and dust accumulation at the bottom edge of the module. Single parking Solar Carports are installed with 1.2m extra space at the edge of the carpark to provide shade for future EV Chargers installation.
- p) The equipment (Inverters, BESS, DBs, switches, etc.) is located under covering that will allow easy and safe access for operating and maintenance, taking emergency escape requirements into consideration.
- q) An AC distribution board (DB) is required to supply the EV Sub-DB, lighting, auxiliaries and connect the SPVC-BESS output to each PoC through a new Switching Station.
- r) An outdoor AC Sub-distribution board (Sub-DB) is required to supply EV charging points.
- s) The Point of Connection (PoC) for each BESS Plant is at the 400V switchgear inside a room on the northwest side of the building.
- t) The *Contractors* provides a SPVC-BESS plant **site layout** showing module layout, BESS, AC distribution boxes/boards and PoC locations.
- u) The *Contractors* provides a **single line diagram** showing electrical connection for modules, SCC, Batteries, PCS, Distribution boxes/boards, isolation, protection devices and PoC.
- v) The *Contractor* provides all relevant technical drawings, operating and maintenance user manuals that are required for safe and effective operating and maintenance of the works. The *Contractor* designs and installs suitable outdoor lighting that is surface mounted under the carport. The lighting design considers the required lux levels, distances and glare considerations. The Contractor submits the lighting design documentation including supporting relux files and product IES/LTD files are submitted to the *Project Manager* for review and acceptance.
- w) The luminaire selection is based on latest energy efficient LED technology. Prior to installation, the Contractor demonstrates the lighting equipment meets the project requirements and properties used within the lighting design. All lighting equipment samples, designs and product information are submitted to the Eskom Lighting lab for acceptance prior to implementation.
- x) The Contractor demonstrates the installed lighting system is as per the accepted design and within the required parameters, which includes and not limited to onsite measurement with a calibrated Lux meter, witnessed by the Project Manager.
- y) The lighting design, type and fixture is in accordance with:
 - 1) 240-55714363 Generation PS Lighting and Small Power Installation Standard
 - 2) 240-139282493 Security Lighting for Eskom Applications
 - 3) SANS 10389-2

3.1.7.4 Main Equipment of the BESS and PV Plant

Component	Description
PV Modules	Crystalline Silicon PV modules of same type, size and from the same manufacturer with minimum module size of 545Wp and efficiency >21%.
Mounting Structures, Foundations and Waterproofing	Fixed-mount cantilever waterproof structure with approved structural analysis report or Design report. Foundation designed as per relevant codes.
DC String combiner box	String protection and isolation box with current monitoring system and communicates with CMS.
PV/BESS System	Solar Charge Controller (SCC), Lithium-ion Batteries, DC cabinet and Inverter (PCS) to convert PV power and Battery power to AC power. The Equipment are house in a Container with HVAC and Fire Detection and Suppression system. UPS required for essential loads and/or CMS.
DC and AC Cabling	DC cables that are UV rated, halogen free, double insulated and installed within conduits. AC cables provided and terminated as per Eskom standard.
AC Distribution Board and Sub-DB	The AC Distribution Board to supply EV Sub-DB, Lighting, etc. Sub-DB to supply power to EV charging points.
Point of Connection (PoC) and Common Switching Station.	400V Low voltage Admin Board A and Board B connected through a Switching Station Container with 2x BESS, Grid and Diesel Generators Power supplies, each with ATS and Bypass system controlled by CMS/PCS. UPS required for essential loads and/or CMS.
Plant Protection	Plant and equipment protection including Earthing, Lightning, Surge protection device, circuit breakers, fire protection, among others defined in this document. Lighting protection provided as per assessment report.
Energy meters	Bi-directional Energy meters for BESS/PV energy production and Grid Export/Import per connection point (Board A and Board B).
Control and Monitoring System and Weather Station	A CMS comprising of a datalogger with display capability which interfaces with BESS, Metrological Station and Energy meters with capability of connection to Eskom and other 3 rd party network. Weather station consists of Reference cells, Pyranometer and Temperature sensors.
Lighting System	Lights underneath the modules along the carpark

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3.2 CIVIL AND STRUCTURAL REQUIREMENTS

The following is applicable to the design and construction of all civil and structural works for the Solar PV plants at the Main Admin Carpark, Kriel Carpark and the Battery Energy Storage System (BESS) infrastructure.

3.2.1 General

- a) The *Contractor* ensures that all structures, foundations, cable trenches/routings, road/carpark marking, paving which are incorporated in the *works* are functionally and efficiently located and that each component is sized for optimum space usage.
- b) The *Contractor* submits the design calculations, drawings of the civil items which are within this scope of work for review, acceptance, and comments by the *Project Manager*.
- c) Calculations clearly identify the subject of the calculations and include the following information: Project name, *Contractor's* name, Date of calculation, Revision No., Assumptions used for design purposes, Codes and standards used, Computer programmes used, and Safety factors used. Calculations are arranged in a logical sequence and include sketches and annotations as may be required to make them self-explanatory.
- d) The *Contractor* engages a Professional Engineer experienced in the design of similar work to be fully responsible for the design.
- e) Details and drawings of any civil works which are not expressly included in this Contract but which, in the opinion of the *Contractor*, are necessary for the completion and proper execution of the project are to be included by the *Contractor* and submitted to the *Project Manager* for acceptance.
- f) Acceptance of the *Contractor's* drawings or calculations by the *Project Manager* does not relieve the *Contractor* of any of his obligations to meet all the requirements of the Contract or relieve the *Contractor* of his responsibility for the adequacy of design, calculations and drawings.
- g) No construction starts prior to acceptance by the *Project Manager*.
- h) Method statements for the installation of the mounting structures and other civil works are submitted to the *Project Manager* for acceptance.
- i) The *Contractor's* design considers the existing drainage design and philosophy of the carparks and seamlessly ties into this reticulation accordingly.

3.2.2 PV Mounting Structures and Foundations Design

- a) The *Contractor* designs a Fixed-mount PV Mounting structure that support the PV DC capacity specified in this document. The whole structure is a solar PV carport optimised to provide shade and effective protection against water for cars, chargers, electrical equipment and produce power.
- b) The *Contractor* designs a PV Carport structure that is of a modern design, fit for purpose and aesthetically pleasing.
- c) The mounting structure is designed for optimum PV module orientations, tilt angle and row-to-row distance (space between adjacent parking) with minimal shading losses of less than 2% throughout the year.
- d) The *Contractor* conducts the necessary geotechnical investigations to inform the foundation design of the PV mounting structures and BESS foundation.
- e) The *Contractor* provides an approved structural analysis report for acceptance by the *Project Manager* before construction. The structure analysis shows the dominant combination of dead

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loads, construction live loads, impact and dynamic effects due to operation of plant, maintenance loads, wind loads and temperature effects. This analysis should be done in accordance with the applicable codes and SANS standards. The report is approved by the *Contractor's* appointed Professional Engineer.

- f) The *Contractor* submits the PV carport specification showing materials used and drawings showing the following:
 - 1) General arrangement layout,
 - 2) Layouts and sections of the different components,
 - 3) Details of embedded parts,
 - 4) Details of the PV carport mounting structure and fixing,
 - 5) Structural steel detailing and corrosion protection,
 - 6) Details of all plinths, openings, box-outs, holding down arrangements, grouting, connections etc. required for plant and equipment.
- g) The minimum warranty for the carport structures is 10 years.
- h) The PV structure is provided with waterproof material between PV modules to divert water to the bottom edge. Water is carried away to tie into the drainage system of the parking areas.

3.2.3 Fabrication and Construction for Civil works – PV Plant

- a) The *works* to be provided by the *Contractor* include:
 - 1) Provision of all scaffolding, site craneage, lifting equipment, etc. which are required by the *Contractor*.
 - 2) Construction of the PV modules mounting structures.
 - 3) Testing of the welding work to be done in accordance with SANS 1200H Section 7.3 and allowance also has to be made for Magnetic Particle Inspection testing.
 - 4) Corrosion protection of the steel supporting structures, roofing material, bolts, nuts, and embedded parts in accordance with SANS 121 and SANS 1200HC. Structural elements are designed such that all material from which the equipment is manufactured from is compatible with the intended duty and service conditions. All equipment is suitably treated and protected from corrosion.
 - 5) Power supply and fire protection where applicable.
- b) Concrete works are of suitable strength for the purpose, with durability for the minimum 50 years life. Finishing to be off-shutter or wood float. All corners to be chamfered 20x20mm. Jointing design and material are suitable for the generally high/low temperature conditions on site, to minimize shrinkage and joint failure.

3.2.4 Codes and Standards

- a) All civil engineering construction work complies with the requirements of SANS 1200.
- b) All steel materials supplied, and erection of the steelwork shall comply with the requirements of SANS 2001
- c) For surface treatment of steelwork provided SANS 121
- d) 240-56364545 Structural Design and Engineering Standard (Rev 4)
- e) SANS 10100 – The structural use of concrete.

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- f) SANS 10160 – Basis of structural design and actions for buildings and industrial standards.
- g) SANS 10162-1 – The structural use of steel Part 1: Limit states design of hot-rolled steelwork
- h) SANS 10162-2 – The structural use of steel Part 2: Limit states design of cold-formed steelwork
- i) SANS 10162-4 – The structural use of steel Part 4: The design of cold-formed stainless steel structural members
- j) SANS121:– Hot dip galvanized coatings on fabricated iron and steel articles - Specifications and test methods
- k) SANS 1921-3– Construction and Management requirements for works contracts – Part 3 Structural steel works.

3.3 ELECTRICAL REQUIREMENTS

3.3.1 General

3.3.1.1 PV Modules

- a) The *Contractor* selects PV Modules technology of crystalline silicon (c-Si) type with minimum rating of 545Wp (STC) and positive power tolerance. All PV modules supplied for the Plants are of the same type, size and from a single manufacturer with module efficiency greater than 21%.
- b) The PV modules minimum guarantees from the manufacturer are;
 - 1) Power Output Warranty: maximum power output degradation of 10% and 20% of rated peak power for 10 years and 25 years operational period, respectively. First year power output degradation of not more than 2.5% with maximum degradation of 0.6%/year.
 - 2) Workmanship guarantee: Product guarantee against manufacturing defects for a minimum of 12 years.
- c) The *Contractor* ensures that PV modules are sourced from a Tier 1 manufacturer. (Tier 1 in this context refers to the Tier 1 list of Bloomberg New Energy Finance published at most 6 months or two quarters before publishing of the tender documents). Locally assembled modules are considered Tier 1 if there is a clear connection to one of the manufacturers of the BNEF Tier 1 lists.
- d) All modules have valid certifications of IEC61215 and IEC/UL61730 issued by reputable testing institutions according to IEC and other standards.
- e) The modules comply with IEC 61215, IEC 61730-1, IEC 61730-2, IEC 61701, IEC 62716, IEC 60891, IEC 60904-1-3, 6,7,9,10, IEC 61853, IEC 60068-2-78 and IEC 60068-2-21.
- f) The *Contractor* provides the flash test data from manufacturer (measurement according to IEC 60904 part I) for each module to be installed in the project. The sum of power in flash test data is equal to or higher than peak power of the plant.
- g) The *Contractor* arranges the modules to minimize the losses due to mismatching. The *Contractor* uses proper sorting method and only modules from the same set is used in the same string.
- h) All transportation, storage, handling and installation of the modules are in accordance with the specifications from the manufacturer, as to not to void the module manufacturer's warranty.
- i) The *Contractor* verifies the quality of PV modules according to the requirements set out in inspection, test and commissioning section of this document.
- j) A **datasheet, certificates, warranty, installation and O&M manuals** from the OEM is provided to support PV Module technical requirements.

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3.3.1.2 PV DC Cabling

- a) PV DC cabling provides electrical connection between individual modules and strings to combiner boxes.
- b) Cables are designed and installed in accordance with the latest edition of all applicable standards.
- c) Cables in the Plant are fastened adequately to avoid swinging and tension and durable mounted in such a way as to protect them from rodent attack, abrasion, weathering and UV radiation.
- d) All cables are uniquely numbered to facilitate easy traceability & fault location. Circuits and cables are planned and installed to ensure accessibility and ease of maintenance.
- e) The *Contractor* designs for cable losses of under 1% on DC cable circuits except where other agreed with the *Employer*. Evidence of a detailed wiring loss analysis is submitted as part of the detail design submission.
- f) DC string cabling is selected and installed in such a way to prevent the risk of leakage currents. Single-core conductors are used for the enforcement of cable protection against outer impact.
- g) The area inside DC cable loops is kept as small as possible to reduce the induction of unwanted voltages and currents, for example due to lightning strikes.
- h) The earthing of one pole of the module string is carried out according to the PV module and inverter manufacturers' installation manual only.
- i) Cables are rated for exterior condition and suitable for working environment, weather-proof and UV resistant with design life of 25 years.
- j) DC cables are halogen free, fire resistant, double insulated and installed within trays or conduits.
- k) The red and black cables are selected for positive and negative terminal identification respectively with maximum voltage rating of 1.8kV. PV DC string cables are not less than 6mm² i.e. the minimum cable size to ensure plant reliability for 25 years.
- l) A **datasheet** from the OEM is provided to support the PV DC cable technical requirements.

3.3.1.3 DC Connectors

- a) DC Connector provide the electrical connection between string cables and cables going into the DC combiner boxes and inverters.
- b) Modules connectors and DC cables connectors are compatible and from the same manufacturer throughout the whole PV plant. MC4 type or equivalent, recommended by module manufacturer.
- c) The *Contractor* uses cables with connectors which are contact/touch-proof, weatherproof and UV resistant and designed to avoid corrosion.
- d) Connectors have an internal locking mechanism to prevent accidental/unauthorized decoupling.
- e) A **datasheet** from the OEM is provided to support the DC connectors technical requirements.

3.3.1.4 AC Cabling

- a) AC Cables provide the electrical connection between inverters, AC switchgear, auxiliaries and the PoC.
- b) The *Contractor* performs detailed design for the cable size considering route length, loads, permissible voltage drop, installation method, fault levels and environmental conditions. Evidence of a detailed wiring loss analysis is submitted as part of the detail design submission.

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- c) The selected LV cable route is the most practical and economical route available. The cable route is evaluated and selected in-conjunction with the Project Manager including safety representative, Civil Engineer and Project Engineer.
- d) The *Contractor* takes into account all existing services above and below ground along the cable route. The *Contractor* performs the necessary underground scanning for existing services that may be along the selected route for the cable which is approximately 330 meters from carpark area to the PoC.
- e) The *Contractor* provides load schedule to indicate and list the types, length sizes, current carrying capacity of cables used for the works.
- f) LV power cables comply to the Eskom's Standard 240-56227443 Generation Requirements for Control and Power Cables for Power Stations Standard. All AC cables comply with SANS 1507, SANS 1213 and SANS 10142-1. These covers the cable ratings, environmental conditions and terminations.
- g) The *Contractor* uses any existing cable racks in the cable tunnels to lay new cables provided there is sufficient space. Should the space on existing cable racks / ways not be sufficient to accommodate all new cables that form part of the scope of this project, the *Contractor* proposes modifications to existing cable racks or installation of new cable racks / ways to supply all loads/equipment to ensure a fully functional system.
- h) The *Contractor* designs, supplies and install cable racks / ways and supplementary steelwork for cable racking. The *Contractor* submits all documentation for new cable racking or modifications of cable racks for acceptance before procurement or modification of any equipment.
- i) Cables crossing roads and paved, or concrete surfaces are installed in PVC pipes.
- j) Care is taken during installation to avoid disrupting other services such as other power cables, telecommunication, water, and drainage services where practically possible. Where required, the Contractor makes provision to scan the cable route area to establish if any other services exist which could be affected by excavation.
- k) The power cable enters from the bottom of the mini substation, junction boxes, distribution boards and Inverters.
- l) All cables in the Plant have to be fastened adequately to avoid swinging and tension and durable mounted (to prevent abrasion) in such a way as to protect them from rodent attack, weathering and UV radiation.
- m) All cables are uniquely numbered to facilitate easy traceability & fault location. Circuits and cables are planned and installed to ensure accessibility and ease of maintenance.
- n) Three-phase, (4 wire + Earth), PV supply cables connect the AC terminals of the inverters to the AC distribution board and respective point of connection.
- o) The AC cables are rated for outdoor condition, and suitable for working environment with design life of at least 25 years. The cables are halogen free, fire resistant, rated for 1kV.
- p) A **datasheet** from the OEM is provided to support the AC cable technical requirements.

3.3.1.5 Earthing

- a) The *Contractor* provides an earthing system for the PV system that eliminates the risk to personnel or animals of electric shock under normal operating conditions as well as fault conditions. Furthermore, the earthing system ensures the functionality of electrical protection equipment during electrical faults and tie in into the existing earth bar at point of connection.
- b) The *Contractor* designs the earthing system in accordance with Solar PV industry best practice and in compliance with SANS10200, IEEE80 and SANS10292.

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- c) The *Contractor* provides an earthing proposal including a project specific earthing system diagram, Data sheets of main products used, proposed test procedure.
- d) The *Contractor* conducts tests on the earthing system to fully verify the safety of the site.

3.3.1.6 Surge and Lightning Protection

- a) The *Contractor* carries out a risk assessment for lightning and install an adequate lightning protection system.
- b) The *Contractor* designs the Lightning Protection system in accordance with the latest edition of the SANS/IEC 62305 standards.
- c) The protection complies to the relevant standards; SANS10313, SANS1063, SANS10199, SANS61312-3, SANS62305, SANS10313, IEC61009 and SANS61024.
- d) The lightning protection system protects PV modules, inverters, control and monitoring systems and any other electrical and mechanical equipment against damage caused by lightning strikes. The PV system lightning protection is independent and discharge to ground via earthing electrodes.
- e) The *Contractor* submits proposals to *Employer* for ensuring adequate design against lightning induced overvoltage risk.
- f) Overvoltage protection shall be installed at the DC side as well as AC side of the inverter and within the PV arrays.
- g) A **datasheet** from the OEM is provided to support the Surge protection device technical requirements

3.3.2 Kriel Carpark Requirements

3.3.2.1 PV DC String Box (PV DC-DB)

- a) The PV DC-DB includes **String Circuit Breaker** for each string for protection and isolation. The DC circuit breaker rating is sized according to the module current ($I_{mp} \times 1.25$) and not less than 20A.
- b) The *Contractor* determines the number of DBs to achieve optimum output and allow suitable access for O&M purpose.
- c) Each DB is equipped with lightning current and overvoltage surge arrestor for each string.
- d) Each DB has ingress protection of IP65 or higher, accessible from the ground and lockable with a design lifespan of 25 years.
- e) Each DB is installed under the PV modules shaded area. The area is protected from unauthorised personnel, lockable with safety warning signs.
- f) The cable labelling, single line and wiring diagram of connections inside the box is kept on each box.
- g) A **datasheet** from the OEM is provided to support the DC circuit breaker technical requirements.

3.3.2.2 Inverters

- a) The *Contractor* provides an inverter arrangement for the PV Facility that is selected to give overall optimal energy yield from the PV Facility over the life of the Project, considering the site conditions and the proposed module layouts, shading, orientations and string monitoring requirements. The inverter has power limit and energy export control functionality.

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- b) The *Contractor* selects string inverters with minimum rating of 100kWac per inverter. All inverters supplied for the Plant are of the same type, size and from a single manufacturer with efficiency greater than 97% and total harmonic distortion level less than 3%.
- c) The *Contractor* selects the string inverters from a list of inverters in Appendix D to comply with **NRS-097-2-1** for South Africa Grid Code requirements for renewables.
- d) Inverters not in the list must have NRS 097-2-1 inverter compliance certificate from a 3rd party test institute. The certificate must be provided along with tender documents.
- e) The inverter has the following certificates IEC 62109-1/-2, IEC 62116, IEC 61727, IEC 60068, IEC 61683 and NRS-097-2-1 issued by reputable testing institutions according to IEC and other standards.
- f) The *Contractor* submits calculations for ensuring electrical compatibility between the inverters and the modules selected including, selection of appropriate inverter dimensioning factor and ensuring system voltages lie within acceptable MPPT ranges across the range of operating conditions for the site and for the long-term operation of the project.
- g) PV string from different orientations shall not be connected to the same MPPT input of the inverter.
- h) Inverters are equipped with communication capabilities to the CMS; all inverters are controlled / supervised by the same software. The minimum communication protocol for each inverter is RS485.
- i) The local monitoring is provided through RS485 and USB, and also accessible through Bluetooth and APP. The APP is provided to the *Employer* as part of the tender.
- j) Inverters specifications are selected with respect to the local climatic and environmental condition with ingress protection of IP65 or higher. The inverter is installed under the PV modules shaded area. The area is protected from unauthorised personnel, lockable with safety warning signs.
- k) Operating temperature range is without power derating for the maximum site ambient temperature of 50°C.
- l) The inverter manufacturer is established in the market and have at least 5 years manufacturing experience.
- m) The quality of equipment supplied is controlled to meet the guidelines for engineering design included in the standards and codes listed. All transportation, storage, handling and installation of the inverters is in accordance with the specifications from the manufacturer, as to not to void the inverter manufacturer's warranty.
- n) The *Contractor* is required to confirm the inverter manufacturer's warranties for the given environment and installation type. The minimum warranty is 10 years with an extension option.
- o) The inverter minimum protection includes Overvoltage, Overcurrent, DC reverse-polarity, String fault monitoring, Overtemperature, Anti-islanding and DC insulation resistance detection.
- p) A **datasheet, certificates, warranty, installation and O&M manuals** from the OEM are provided to support inverter technical requirements.

3.3.2.3 PV AC Distribution Board (PV AC-DB) and Sub-Distribution Board.

- a) In between inverters and point of connection (POC), the PV AC-DB combines strings inverters output cables to connect the PV system via a single PV main cable to the 400V POC. The PV AC-DB also supplies the Sub-distribution board for future EV Charging Stations (1DC and 1AC).
- b) The *Contractor* designs, manufacturer, supply and install all switchboards for the required design life under the prevailing site environmental conditions, which shall be determined by the *Contractor*.
- c) The PV AC-DB contains a minimum of:

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1. Three-phase, 4pole circuit breakers for each PV string inverter,
 2. Three-phase, 4pole circuit breaker for PoC supply,
 3. Three-phase, 4pole, 250A circuit breaker for Sub-DB supply,
 4. Single phase circuit breakers for 230V supply EMI, CMS, lighting, etc.
 5. Bi-directional Energy Meter for PV energy production
 6. AC overvoltage protection devices and anti-islanding protection relay.
- d) The Sub-DB contains a minimum of:
1. Three-phase, 4pole 250A circuit breaker.
 2. 50m x 120mm² 4 core cable from AC-DB to Sub-DB
 3. Empty space and mounting rack to accommodate 2 three-phase, 4pole circuit breakers (200A and 80A MCCBs sizes)
- e) The outdoor AC-DB and Sub-DB are fabricated from corrosion resistant steel with a minimum thickness of 2mm. The construction of the DB consists of an internal and external door. The internal door has cut outs exposing the toggles of the MCB's and the MCB locking brackets. At least one square key catch of the internal door must be padlockable. The DB is vermin proof with a minimum IP rating of 54.
- f) The *Contractor* optimises the location of PV AC-DB to ensure accessibility and safety. The area is protected from unauthorised personnel, lockable with safety warning signs.
- g) The distribution board complies with SANS 10142-1, IEC 60898, IEC 61009, SANS 1973-1, SANS 1765, IEC 60529.
- h) The cable labelling, single line and wiring diagram of connections inside the box is kept on each box.
- i) **Datasheets** from manufacturers are provided to support the circuit breakers, AC surge arrestors and anti-islanding relay technical requirements.

3.3.2.4 Extension Distribution Board and Point of Connection

- a) The PV system cable from PV AC-DB connects into the 400V LV side of Kriel Finesse Minisub in Figure 3-7 and as shown in Appendix A. The point of connection is through a new ground mounted Extension Distribution Board (Ext-DB) since there is no space to install a new 3P, 4 pole, circuit breaker and also accommodate a new 3P, 4pole EV charger circuit breaker.
- b) The *Contractor* ensures that the outdoor Ext-DB and the equipment used are compatible with the existing design and equipment and provides a Certificate of Compliance (CoC). The distribution board complies with SANS 10142-1, IEC 60898, IEC 61009, SANS 1973-1, SANS 1765, IEC 60529. The Ex-DB is labelled with material that will not fade.
- c) A bi-directional energy meter is required to measure the Grid import and export energy at the Finesse Minisub. The energy meter complies with 240-52840736, installed in the new Ext-DB and communicates with the CMS.
- d) The *Contractor* reroutes the existing EV charger cable or install a new cable from the orange Sub-DB to the Ext-DB. A new 3P, 4pole EV Charger MCCB is to be installed in the Ex-DB.

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Figure 3-7: Kriel Finesse 500kVA/800A Minisub

- a) **Datasheets** from manufacturers are provided to support the MCCBs and Energy meter technical requirements.

3.3.2.5 DC and AC isolations

- a) The *Contractor* provides AC rated on-load isolator on the AC output side of each string inverter. This is required to totally isolate the inverter for maintenance and repair/replacement.
- b) The AC on-load isolator is located next to the respective inverter.
- c) The isolators are padlockable and numbered/labelled correctly. New padlocks and keys are made available to the *Employer* at the end of the maintenance contract.
- d) DC string isolation is included in the PV DC-DB through DC string circuit breakers.
- e) A **datasheet** from the OEM is provided to support the AC Disconnectors technical requirements.

3.3.2.6 Metering and Measurements

- a) The *Contractor* designs, supplies and installs an energy meter on a separate CMS kiosk next to AC-DB to measure PV export and Grid import power.
- b) The *Contractor* provides an energy meter with bi-directional energy measurements that complies with 240-52840736 Standard for Three Phase Programmable Energy Meters.
- c) The energy meter communicates with the CMS datalogger. The minimum communication protocol is RS485.
- d) Metering complies with 240-52840736 and other relevant IEC, NRS and SANS standards.
- e) A **datasheet** and a **User Manual** from the OEM are provided to support the Energy meter technical requirements.

3.3.2.7 Abnormal Operations

- a) In the event of a grid failure or supply parameters (voltage and frequency) drifting outside of the pre-set operating windows, the protection relay shuts down the inverters and prevent the system from exporting electricity into the building. When the grid parameters return to normal levels the

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relay allows the inverters to turn on, synchronise and connect to the grid again. The relay is open when de-energised.

3.3.3 Admin Carpark Requirements

3.3.3.1 DC Combiner Box

- a) The DC combiner box is designed for outdoor use with IP65 rating, 2000m altitude and operating temperature range of -5 to 50 degrees Celsius without derating with minimum design lifetime of 25 years.
- b) The combiner box includes string fuse for each string, one fuse on the positive terminal and another fuse on the negative terminal. The fuse rating is in accordance with module short circuit rating (Isc) and not less than 20A.
- c) The combiner box includes monitoring of string currents, DC bus voltage and breaker status as a minimum and communicates to CMS through RS485. The power supply for monitoring system is derived within the combiner box.
- d) The DC combiner box includes lightning current and overvoltage surge arrestor.
- e) The DC combiner box includes array output breaker or on-load disconnect switch for isolating array for maintenance and emergency purpose and is lockable.
- f) The box is installed under the PV modules shaded area and accessible from the ground with safety warning signs.
- g) The cable labelling and single line and wiring diagram for connections inside the combiner box is kept on each combiner box.
- h) Further DC fuse box to combine string boxes, where required, has similar environmental and communication requirements.
- i) A **datasheet** and a **User Manual** from the OEM are provided to support the DC Combiner box technical requirements

3.3.3.2 Hybrid inverter

- a) The *Contractor* provides an inverter arrangement for the PV Facility that is selected to give overall optimal energy yield from the PV Facility over the life of the Project, considering the site conditions and the proposed module layouts, shading, orientations and string monitoring requirements.
- b) The *Contractor* selects one inverter to meet the minimum plant AC output rating 600kWac. The minimum rating per inverter is 150kWac to limit paralleling of inverters to four. All inverters supplied for the BESS plant are of the same type, size and from a single manufacturer with efficiency greater than 97% and total harmonic distortion level (voltage and current) less than 3%.
- c) The *Contractor* selects an inverter which comply with NRS-097-2-1 for South Africa Grid Code requirements for renewables issued by reputable testing institutions. The NRS certificate is provided along with tender documents. Other certificates are IEC 62109-1&2 and IEC/EN 61000 according to IEC and other standards.
- d) The *Contractor* selects an inverter that is compatible with SCC of the same manufacturer if the two are separate.
- e) Inverter specifications is selected with respect to the local climatic and environmental condition with ingress protection of IP20 or higher. The inverter is installed in the BESS container. The area is protected from unauthorised personnel and lockable with safety warning signs.

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- f) The inverter minimum protection includes overvoltage, overcurrent, DC reverse-polarity, overtemperature, overload and DC insulation resistance detection. The emergency button is available and accessible to switch off the inverter.
- g) The inverter is equipped with communication capabilities as required by CMS, BMS, SCC, etc. through RS485 or CAN; all inverters are able to be controlled / supervised by the same CMS system.
- h) The minimum local communication for each inverter is RS485.
- i) The inverter has a touch screen display for local monitoring and settings. The modes of operation allow for on-grid with export capability and off-grid operations with generator support mode.
- j) The inverter is equipped with DC and AC lightning current and overvoltage surge arrestors for each string.
- k) The inverter operates at site ambient temperature of 50°C and altitude of 2000m without power derating.
- l) All transportation, storage, handling and installation of the inverters is in accordance with the specifications from the manufacturer, as to not to void the inverter manufacturer's warranty.
- m) The *Contractor* is required to confirm the inverter manufacturer's warranties for the given environment and installation type. The minimum warranty is 5 years with extension option.
- n) The inverter manufacturer is established in the market and have at least 5 years manufacturing experience.
- o) A **datasheet, certificates, warranty, installation and O&M manuals** from the OEM are provided to support inverter technical requirements.

3.3.3.3 Solar Charge Controller (SCC)

- a) The *Contractor* selects the solar charge controller (s) rated to accommodate the minimum PV Modules DC power capacity stated in this document. All SCC supplied for the Plant are of the same type and from a single manufacturer with efficiency greater than 98%.
- b) The SCC specifications is selected with respect to the local climatic and environmental condition with ingress protection of IP20 or higher; and is installed in the BESS container. The area is protected from unauthorised personnel and lockable with safety warning signs.
- c) The SCC minimum protection includes overvoltage & undervoltage, overcurrent, short-circuit, lightning protection and overtemperature. The emergency button is available and accessible to switch off the SCC.
- d) The SCC MPPT number is selected based on the PV module orientations to optimise PV output.
- e) The *Contractor* selects charge controller of the same manufacturer with PCS and that communicates the BESS equipment through RS485/CAN and CMS through RS485 as a minimum.
- f) The SCC has a touch screen display for local monitoring and settings.
- g) The SCC operates at site ambient temperature of 50°C and altitude of 2000m without power derating.
- h) All transportation, storage, handling and installation of the SCC is in accordance with the specifications from the manufacturer, as to not to void the SCC manufacturer's warranty.
- i) The Contractor is required to confirm the SCC manufacturer's warranties for the given environment and installation type. The minimum warranty is 5 years with extension option.
- j) The SCC manufacturer is established in the market and have at least 5 years manufacturing experience.

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- k) A **datasheet, certificates and User manual** from the OEM are provided to support the SCC technical requirements.

3.3.3.4 Batteries

- a) The *Contractor* selects Lithium-ion batteries with minimum rating of **280Ah** per battery. All batteries supplied for the Plant are of the same type, size and from a single manufacturer with minimum charge/discharge rate of 0.5C.
- b) The battery voltage is sized in accordance with SCC and PCS manufacturers requirements to ensure that full battery charging and warranties.
- c) The battery cycle life is 6000 with a warranty of 10 years under the prevailing service / operating conditions.
- d) The battery minimum protection includes cell overvoltage and undervoltage, overcharge and undervoltage, overtemperature, over current and short circuits with 3-level BMS system.
- e) The minimum monitoring parameters are cell voltage, temperature, charge and discharge current, battery voltage, SOC, warning and faults.
- f) The minimum communication from BMS is CAN and RS485
- g) The batteries are installed in the container within racks, protection and cooling as specified in Section 3.3.3.5. A DC battery cabinet with touch screen display is installed to monitor each battery rack parameters through the Master BMS and to isolate racks for maintenance.
- h) A **datasheet, test reports and certifications** from the OEM are provided to support the battery technical requirements.

3.3.3.5 BESS Container

- a) The BESS equipment container houses the indoor-rated equipment such as Batteries, DC cabinets, SCC, PCS, Transformer, Auxiliary DB, UPS and CMS.
- b) The container is approved by the inverter manufacturer and does not violate any warranties for charge controllers and inverter.
- c) The container includes the proper cooling/ventilation system (HVAC) which should allow batteries, SCC, inverter to operation always within manufacturer's recommended operating range without derating of the output power. The *Contractor* designs an HVAC system that will keep the temperature within manufacturer's recommended range for the equipment installed.
- d) The container selected has a minimum of 10 years product guarantee against manufacturing defects.
- e) The container is designed/protected to withstand in outdoor conditions for 25 years period and the cabin includes **Fire Detection and Suppression system**.
- f) The batteries and DC cabinet are located in separate compartment from SCC, PCS, Auxiliary DB, CMS, UPS, etc. and have separate access doors, lockable with protection.
- g) The *Contractor* sizes the UPS required for essential loads for BESS and CMS.
- h) The *Contractor* identifies the optimal location for BESS containers and proposes to the *Project Manager*.

3.3.3.6 AC Distribution Board (AC-DB) and Sub-distribution Board (Sub-DB)

- a) The *Contractor* designs an AC distribution board to supply power to EV Charger Sub-DB, lighting, etc. The AC-DB takes supply for either Board A or Board B circuit. A changeover switch is provided

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- to run the DB from either Board A or B, and the DB can be switched off when running on DG supply only.
- b) The *Contractor* installs the AC-DB in protected from unauthorised personnel, lockable with safety warning signs. The AC-DB and Sub-DB are located at the Admin carpark and final position to be agreed with the *Project Manager*.
 - c) AC-DB contains the following minimum components:
 - 1. Three-phase, 4pole incomer circuit breaker for isolation,
 - 2. Three-phase 350A circuit breaker for EV charger connection,
 - 3. Single phase circuit breakers for 230V supply Weather Station, lighting, etc.
 - 4. AC overvoltage protection devices.
 - d) The Sub-DB contains a minimum of:
 - 1. Three-phase, 4pole 350A circuit breaker.
 - 2. 50m x 240mm² 4 core cable from AC-DB to Sub-DB.
 - 3. Empty space and mounting rack to accommodate 3 three-phase, 4pole circuit breakers (200A and 3x80A MCCBs sizes)
 - e) The outdoor AC-DB and Sub-DB are fabricated from corrosion resistant steel with a minimum thickness of 2mm. The construction of the DB consists of an internal and external door. The internal door has cut outs exposing the toggles of the MCCB's and the MCCB locking brackets. At least one square key catch of the internal door must be padlockable. The DB is vermin proof with a minimum IP rating of 54.
 - f) The distribution board complies with SANS 10142-1, IEC 60898, IEC 61009, SANS 1973-1, SANS 1765, IEC 60529.
 - g) The cable labelling, single line and wiring diagram of connections inside the box is kept on each box.
 - h) **Datasheets** from manufacturers are provided to support the circuit breakers and AC surge arrestors technical requirements.

3.3.3.7 Point of Connection Requirements

- a) Each BESS hybrid inverter output supply is to be connected to the 400V LV Admin Board A and Board B respectively through a new Switching Station with equipment and switching circuits (breakers and contactors) that do not damage the load equipment.
- b) The Grid power supply cables from each transformer, Generator supply cables from each DG and Load power supply cables to Board A and Board B are to be rerouted and/or extend to the new switching station.
- c) The Switching Station connects the power supplies for BESS, Grid and Generator to the Admin Building load and controlled to operate automatically in on-grid and off-grid by the BESS PCS or a control system proposed by the *Contractor*.
- d) The Switching Station to have an Automatic Transfer Switch (ATS) for Grid and DG supplies and a Bypass circuit to power the load directly from the Grid or Generator supply when the PV/BESS supply is not available or isolated per Board.
- e) The Switching Station equipment for integrating the two BESS Plants is housed inside one new container to be located near the Diesel Generators and 400V LV Admin Board A or Board B as shown in Figure 3-5.

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- f) The container is designed/protected to withstand in outdoor conditions for 25 years period with product warranty of 10 years and the cabin includes a fire detection and suppression system and UPS for essential loads.
- g) Two energy meters per board are required to measure the PV/BESS production and Grid Import/Export energy. The energy meters comply with 240-52840736 and communicate with CMS.
- h) The *Contractor* is allowed to propose other connections methodology that meet the minimum connection requirements without switching station container. There is an option of having the switching equipment, bypass circuits and energy meters at each BESS container depending on the type of hybrid inverter chosen.

3.4 CONTROL, MONITORING AND COMMUNICATION REQUIREMENTS

3.4.1 General

- a) The *Contractor* design, procure, install, test and commission the entire Control and Monitoring System (CMS) scope as specified in this document. The CMS achieves the same availability as that of the plant.
- b) The selected CMS is established in the market and procured from a manufacturer with at least 5 years manufacturing experience. The CMS is **compatible** with the plant devices i.e. Inverters, Weather stations and metering for communication and have local and remote access capabilities.
- c) The *Contractor* provides a suitable labelling and codification system to help identify all instruments, cables, cable cores, equipment enclosures, network hardware, power supply systems, signals, tags, etc.
- d) The *Contractor* provides system specification showing operation, monitoring and graphics describing the operating philosophies. Functionality of the local CMS and remote application is described in detail.
- e) The protection and running parameters are set and monitored in the CMS with password protection. Operation logs are available to view access to parameter changes.
- f) The system retains critical data in the event of power supply failure. This includes all plant information generated by the sub systems of the plant as well as calculated data. Comprehensive reports of all plant data are saved on .CSV or .xls file formats for further processing and analysis.
- g) The *Contractor* provides a network port to interface to Eskom's corporate network. Data communication to be implemented in protocols required by the *Employer*.
- h) During the O&M period, the *Contractor* is required to remotely monitor the plant data in real time therefore, the *Contractor* provides a medium to acquire this data. The *Contractor's* remote access into the CMS network only allows monitoring of data only. No system modification or software updates are allowed via the remote link. All CMS modifications take place at the plant when both parties are present.
- i) If the software expires on any plant device, a warning is displayed on the CMS and devices continue operating normally (for the life of the plant) without shutting down the CMS system or any plant sub-system.
- j) If software version updates are required during the O&M period, the *Contractor* conducts the exercise together with the *Employer's* representative. All CMS modifications and updates are logged into the maintenance manual and signed off. The *Contractor* provides a list of all CMS software to the *Employer*. Updated software is provided to the *Employer* by the *Contractor*. All passwords of the CMS remain the property of the *Employer*.

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- k) The *Contractor* ensures installation of an Eskom RTU and commissions the critical alarms to the Regional NMC (Network Management Centre).

3.4.2 Meteorological system

- a) Each Solar PV Carport has one meteorological station which comprises of following equipment,
- 1) One (1) horizontally mounted and completely unshaded calibrated Pyranometer to measure the global horizontal irradiation according to Secondary Standard as stipulated in ISO 9060
 - 2) Two (2) high-accuracy reference cells per array orientation with the same technology and type as in-installed PV modules. The calibration of the reference cell has to performed according to IEC 60904-2: Photovoltaic device – Part 2: Requirements for reference solar devices;
 - 3) One (1) shielded ventilated thermal sensor to measure the ambient temperature with a measurement accuracy of $\pm 1^{\circ}\text{C}$ (Pt 100 class B according to IEC 60751);
 - 4) One (1) thermal sensor (Pt 100 class B according to IEC 60751) to measure module temperature with a measurement resolution up to $\pm 1^{\circ}\text{C}$ at the back sheet.
- b) Each station is monitored in the respective CMS system specified in 3.4.3 and 3.4.4.
- c) The *Contractor* provides the technical data sheet and calibration certificates of meteorological systems.

3.4.3 Kriel Carpark CMS Requirements

- a) The *Contractor* designs a CMS that comprises of a **smart datalogger** which connects to the devices using RS485 protocol and have local and remote interface capability. The CMS has a local display for monitoring and settings.
- b) The *Contractor* supplies CMS for the PV plant that is responsible for data acquisition and monitoring of:
1. String Inverters,
 2. Environmental Monitoring Instrument (EMI), - Weather station
 3. Energy meters
- c) The CMS is installed in an outdoor kiosk with minimum of IP54 rating and lockable. The equipment has wide operating temperature range (-40°C to $+75^{\circ}\text{C}$).
- d) The power supply for the CMS is from the PV AC-DB and is converted to the voltage required by the CMS devices.
- e) The CMS has local connectivity using a laptop.
- f) The CMS stores and displays the following minimum parameters:
1. Plant running information:
 - a. Power and Energy from PV, Load, Grid, (Values and Waveforms).
 - b. Weather Station: Ambient & PV Module temperature, global and plane irradiance, etc).
 2. Performance data and Historical data (daily, monthly and yearly).
 3. Device status and Alarm data (ID, description, device, severity, etc.).
 4. System parameters.

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- g) The Contractor provides a CMS design report with plant operating philosophy, network diagram, measured parameters, data acquisition system, User and O&M manuals.

3.4.4 Admin Carpark CMS Requirements

- a) The *Contractor* designs a CMS that controls and monitors the BESS-SPVC, Grid and Diesel Generators for both Board A and Board B Plants.
- b) The *Contractor* supplies a CMS **smart datalogger** responsible for data acquisition and monitoring of;
1. DC string combiner boxes,
 2. Hybrid inverters (Solar Charge Controller and Inverter)
 3. Battery MBMS,
 4. Environmental Monitoring Instrument (EMI)/ Weather Station,
 5. Energy meters.
- c) The CMS is installed in BESS or Switching Station container or location determined by the *Contractor* and accessible for Plant monitoring.
- d) The power supply for the CMS is derived from the UPS supply and converted to the voltage required by the CMS devices. The UPS with lithium-ion battery has minimum standby power of a 4 hours.
- e) The CMS stores and displays the following minimum parameters:
1. Plant running information:
 - a. Power and Energy from PV, Battery, Load, Grid, Generator (Values and Waveforms)
 - b. Battery cell voltage, temperature, total voltage and current, %SOC,
 - c. Weather Station PV Module temperature, global and plane irradiance, etc)
 2. Performance data and Historical data (daily, monthly and yearly)
 3. Device status and Alarm data (ID, description, device, severity, etc.)
 4. System parameters
- f) Over and above the Plant data acquisition system, the *Contractor* designs a system that automatically monitors and control the operation plant modes of the Admin facility (both Board A and Board B plants) in the following order of priority.
1. PV, BESS and Grid (On-grid operation): PV supplies power to the Admin building load, charge the battery and excess PV power is exported to the grid.
 2. PV and BESS alone (Off-grid operation during grid failure): PV and BESS supply power to the Admin building load with PV power as priority and a battery power as support.
 3. BESS alone (Off-grid operation during grid and PV failure): BESS supplies power to the Admin building load and initiate generator start on set SOC.
 4. Generator alone (Off-grid operation during Grid, PV and BESS failure) and shedding of non-essential loads (e.g. EV charging stations).
 5. Reinstating the normal operation (on-grid operation) when Grid supply is restored.
- g) The *Contractor* provides a CMS design report with plant operating philosophy, network diagram, measured parameters, data acquisition system, User and O&M manuals.

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3.5 INFORMATION MANAGEMENT SCOPE

- a) To be provided by *Others*. This is the scope to interface with Eskom Server for remote monitoring of the PV facility at Kriel Carpark and BESS/PV facility at Admin Building Carpark

3.6 SAFETY AND SECURITY REQUIREMENTS

- a) The *Contractor* conducts a risk assessment and put in place all measures in order to ensure that the plants, building and its inhabitants are sufficiently protected from a potential fire caused by the new SPVC and BESS installations.
- b) The *Contractor* ensures that the installation complies with the following standards with respect to fire safety.
- 1) SANS 10400-T:2011 South African National Standard Part T: Fire Protection
 - 2) International Fire Code 2012
- c) The *Contractor* ensures that sufficient signage is placed at the entrance to the facility to warn fire fighters that it is a solar PV system and that there are potentially high voltage DC cables exposed. The signage should also include minimum standing distances that must be adhered to by the fire fighters in the case of using water to douse the flames.
- d) The *Contractor* provides the following, mounted on the wall at a convenient location to be agreed upon between the *Contractor* and the *Employer* near the entrance to the electrical equipment room or fenced areas:
- A description of the procedure in case of a fire
 - Fire extinguishers with mounting structure (location to be discussed and agreed upon between The *Contractor* and The *Employer*).
- e) The *Contractor* provides the necessary fire detection and protection for all Equipment containers and also controlled access points for security.

3.7 INSPECTION, TESTING AND COMMISSIONING REQUIREMENTS

- a) This section describes the type of inspections, tests and performance verification that the *Contractor* demonstrates during execution and operation of the Kriel SPVC and Admin SPVC-BESS (henceforth referred to as **Plants**). These tests are defined under:
- 1) Tests before Site Installation including Factory Acceptance Testing;
 - 2) Tests after Installation (Pre-commissioning and Commissioning (cold and hot));
 - 3) Tests on Completion (Substantial Completion – Performance test)
 - 4) Tests after Completion (Final Test before final hand-over of the Plants)
- b) Test methodologies and acceptance criteria are prepared according to general requirements defined in Section 3.7.1.1. and according to the current best commissioning practice. The *Employer* along with the *Contractor* agrees on test methodology and acceptance criteria, prior running the tests. The following information are submitted as part of Quality Control Plan (QCP) and Inspection Test Plan (ITP):
- 1) Test program and standards;
 - 2) Schedule of the *Contractor* for performing the tests forms of test records and report;
 - 3) Description of instrumentation to be used and calibration;
 - 4) Method of data recording and evaluation method and acceptance/rejection criteria.

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3.7.1 General Requirements

The *Contractor* :

3.7.1.1 Standards

- a) Refer to IEC 62446-1: Grid connected photovoltaic systems – Documentation, commissioning tests & Inspection,
- b) Refer to IEC 62337 Commissioning of Electrical, Instrumentation and Control systems,
- c) Refer to SANS 10142-1: Low Voltage Electrical installations,
- d) Refer to **User installation manuals** for each equipment or components.

3.7.1.2 Personnel

- a) Inspect, test, commission and perform all relevant tests of the Plants to demonstrate compliance with the Contract, as built (design) documents and standards.
- b) Provide staff with the relevant skills and competence for the inspection, testing, commissioning, performance testing and witnessing required.
- c) Provide an ECSA registered professional engineer or technologist to declare the installation complies with all standards & requirements.
- d) Ensure that the supervising commissioning engineer has a minimum of 2 years' experience in the commissioning and performance testing of similar installations.
- e) Be responsible for all Health & Safety requirements during commissioning. The *Contractor* provides a Safety Briefing for all personnel who will carry out or witness the tests and ensures that such personnel comply with all applicable Health & Safety procedures at all times during the tests. The *Contractor* ceases any testing in the event that any unsafe conditions rise.
- f) Provide the opportunity to the *Employer* to witness all commissioning tests. The *Employer* provides reasonable and adequate notice to the *Contractor* that other parties have been invited to witness the tests and the *Contractor* provides all facilities and support that are reasonably required by The *Employer* for such parties to witness the tests.
- g) Commence commissioning activities respecting all legal, environmental and administrative requirements.

3.7.1.3 Instruments

- a) Ensure that instruments used for survey work, checking, inspection, testing, commissioning and performance monitoring are correctly calibrated according to their relevant standards. The *Contractor* shall submit the valid calibration certificates with method statements and test records.
- b) Employer has a right to review the accuracy, quality and performance of the instruments used.

3.7.1.4 Defects and Delays

- a) Submit without delay any record that indicates that any part of the Plants inspected or tested does not comply with the Contract Documents along with a method statement for the proposed remedial works including measures to be taken to prevent any delay to the programme for the project.
- b) Rectify any defects that become apparent during inspection, testing, commissioning and performance testing. Retest defective parts of the Plants, and any associated interdependent systems, and demonstrate that the Plants operates in accordance with the Contract documents and standards.

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3.7.1.5 Test Protocols and Reports

- a) Provide the detailed test protocol to the *Employer* at least two (2) weeks before the commencement of any tests during commissioning. The *Employer* and the *Contractor* agree on test protocol before the commencement of any tests. The Test protocol includes but not limited to:
 - 1) Definition of each test type and test methods
 - 2) List of equipment to be used along with their specification and relevant certificates.
 - 3) Duration of each test
 - 4) Test evaluation method and Acceptance/Rejection criteria
- b) Provide the report to the *Employer* upon the successful commencement of any tests during commissioning. The report includes the following but not limited to:
 - 1) Agreed final test protocol.
 - 2) Test raw data (un-processed)
 - 3) Evaluation of raw data
 - 4) Final result indicating the acceptance/rejection of each test types.

3.7.2 Test before Site Installation

- a) Test before site installation refers to inspection and verification of minimum technical requirements of major plant components of the Plants. The *Contractor* provides all relevant data and documents to the *Employer* including **User manuals** with manufacturer's installation procedures for review and acceptance.
- b) The *Contractor* installs all equipment as per manufacturers' User Manuals to avoid warranty void.

3.7.2.1 PV Module

- a) Quality acceptance test for PV modules is be performed before installation. The goal of the acceptance tests for PV modules is to verify the power of delivered PV modules according to the manufacturer power guarantee levels. For this purpose, Nominal vs. Manufacturer Flash Test Power Comparison is employed.
- b) The *Contractor* verifies that all the PV modules that will be supplied for the project have been quality checked and successfully passed the evaluation.

Nominal vs. Manufacturer Flash Test Power Comparison

- c) The module supplier/manufacturer provides the measurement data of major electrical parameters (Isc, Voc, Imp, Vmpp, Pmpp and Fill Factor) for every individual module supplied to the Site in PDF and table format. The common term for such kind of measured data is called **flash test data**.
- d) The *Contractor* verifies that all the PV modules supplied are within guaranteed nominal power and tolerances on power. Those modules of which power is beyond the specified rating and the respective tolerance are rejected and replacement modules with adequate power level are installed.
- e) The *Contractor* provides the flash test data and analysis report to the *Employer* for review.

3.7.2.2 Inverter (Factory Acceptance Testing)

- a) The solar and battery inverters are tested by the manufacturers at their respective factories and include all certificates and reports according to valid IEC and South African Grid Code standard.

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- b) The *Contractor* provides the factory acceptance reports. /certificates to the *Employer* for review.

3.7.2.3 Battery (Factory Acceptance Testing)

- a) The batteries are tested by the battery manufacturer at their factory and include all certificates and reports according to valid IEC standards. The tests include electrical test, functional test, CMS test and safety tests.
- b) The *Contractor* provides the factory acceptance reports/certificates to the *Employer* for review.

3.7.3 Test after Installation (Pre-commissioning and Commissioning)

- a) Test after Installation refers to “Mechanical Completion Test and Electrical Completion Test”. These tests are the inspection and tests that are performed on site after the completion of mechanical and electrical **installation work** (known as Construction) by the *Contractor*. These tests are related to document check, visual inspections on site, electrical measurements, and safety check.
- b) The tests after Installation demonstrate:
- 1) Completeness of the mechanical and electrical construction works.
 - 2) Correctness of the assembly and installation
 - 3) Safety and reliability of the *works* under all operating conditions
 - 4) Inspection and functional tests.
 - 5) Proper functioning of the components and system under all operating conditions
- c) Tests after Installation are considered successful if the respective Plant passes requirements, inspections and tests defined for each type of inspections described below.
- d) Copies of all tests and data are provided to the *Employer* for review and approval.

3.7.3.1 Test Pre-Requisite – Minimum System Documentation Requirement

- a) Upon giving notice on readiness for Tests after Installation and prior to the commencement of Mechanical and Electrical Completion Inspection, the *Contractor* provides As Built Drawings as well as the Operation and Maintenance Manuals of the Plants to the *Employer*.
- b) The completeness of the documentation is reviewed by the *Employer* and accepted before commencement of the tests. Furthermore, the accuracy of installation works is checked against the As-Built Drawings, manufacturers’ User manuals and other documents listed and referenced in Section 4 .

3.7.3.2 Mechanical Completion Test (Pre-commissioning)

- a) Prior to the Mechanical Completion Inspection, the *Contractor* conducts an internal inspection that verifies the compliance of the works with the design and *Employer’s* requirements. Their internal inspection is documented on a corresponding Punch-List for the respective Plant parts. The Punch Lists is signed by the site manager of the *Contractor*. Punch list does not contain any outstanding issue which has an effect on safe operation, plant performance and administrative/legal requirements.
- b) The *Employer’s* inspection is conducted upon completion of the *Contractor’s* internal inspection of the installation works. The purpose is to verify that the *Contractor* has executed all installation Works in accordance with the Contract and As Built design and is compliant with applicable norms and standards. At this inspection it is tested that the Works prove to be of good workmanship established

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in the PV and BESS industry and are free from any material and construction defects. During the inspection, the correctness of the documentation of the Works in the As-Built Drawings is checked.

c) The *Contractor* undertakes the following, which will be inspected and verified by the *Employer*:

1) General:

- Verify all parts of the Plants are in line with the accepted Final Detail Design;
- Verify the Plants construction is according to the provisions of the Contract;
- Verify all equipment and parts are installed according to their manufacturers' installation manuals.

2) PV Modules:

- Inspect Modules as installed and verify absence of any breakages, frame distortions and bending or any other signs of incorrect or incomplete installation;
- Verify that Modules are sorted according to their Flash Test Data; and
- Verify the module surface are clean.

3) PV String DB:

- Verify that PV String cables is marked and numbered according to the Contract and in line with respective Cable Schedules;
- Check cable Pulling Test records;
- Inspect DC cabling between modules and verify that cable types, sizes and lengths as well as cable connector types are in accordance with the Contract;
- Verify the ratings and integrity of Surge Protection Devices and all Earthing connections;

4) PV Mounting Structures:

- Verify correct Orientation and Inclination angles for the PV Modules;
- Verify that the waterproof installation between modules to allow water runoff to the bottom edge.
- Verify fastening with recommended torque, overall set-out distances, surfacing, alignment and completeness of the assembly.

5) PV Inverters and Battery Inverters:

- Verify that all cables and switches are marked and numbered according to the Contract and in line with respective Cable Schedules;
- Inspect all DC & AC cabling and verify that cable types, sizes and lengths are in accordance with the Contract and in line with respective Cable Schedules; and
- Verify all inverter parameters are set up within Manufacturer's recommendations and local regulations.

6) Batteries and BESS auxiliaries:

- Verify that all cables and switches are marked and numbered according to the Contract and in line with respective Cable Schedules;
- Inspect all DC cabling and verify that cable types, sizes and lengths are in accordance with the Contract and in line with respective Cable Schedules; and
- Verify all Battery parameters are set up within Manufacturer's recommendations.

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- Verify that all auxiliaries (HVAC, fire protection, UPS, etc) are installed as per manufacturers recommendations.

7) LV AC Boards and Switchgear:

- Verify that all cables and switches are marked and numbered according to Contract and in line with respective Cable Schedules;
- Inspect AC cabling and switches and verify that types, sizes and lengths are in accordance with the Contract and in line with respective Schedules;
- Inspect Insulation Test records on all cables and circuits.
- Proper Installation and safety during operation

8) Control and Monitoring System :

- Verify all system components and respective electrical and data connections are according to provisions of Contract and Final design;
- Verify all Calibration Certificates and
- Verify broadband equipment and connections.

9) Labelling & Identification :

- Verify all circuits, protective devices, switches and terminals are suitably labelled.
- Verify all DC junction boxes (PV generator and PV 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.

- d) Upon the successful completion of Plants inspection by the *Employer*, a Mechanical Completion Certificate per Plant will be issued by the *Project Manager*.

3.7.3.3 Electrical Completion Test (Cold and Hot Commissioning)

- a) Electrical Completion Test is performed to verify the proper functionality, configuration and installation of the Plants. The electrical configuration tests are considered as minimum requirement and shall be performed according to IEC 62446, IEC 60364-6, SA Grid code for renewables and current best practice. The tests shall be witnessed by the Employer and Employer's representative.
- b) The *Contractor* undertakes the following, which will be inspected and verified by the *Employer*:
- 1) Tests on AC circuits of all Plants in accordance with SANS10142-1 and IEC 60364-6
 - Continuity, Insulation resistance, Polarity test and phase sequence of the electrical installation.
 - Functional tests and Verification of voltage drop.
 - 2) Tests on PV DC circuits in accordance with IEC 62446
 - Continuity of protective Earthing and/or equipotential bonding conductors

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- Polarity Test in all DC cables checked to ensure they are correctly identified and correctly connected into system devices such as switching devices or inverters.
 - PV array Insulation resistance test
 - I-V curve measurement on all strings – The nominal power of strings is measured and their respective power shall be verified against the sum of name plate power of modules connected to string. Open circuit voltage and PV current are verified according to IEC 62446
- 3) Grid-tied PV Functional tests in accordance with IEC 62446 Ed.1 Clause 5.4.6
- Switchgear and other control apparatus are tested to ensure correct operation and that they are properly mounted and connected.
 - All inverters forming part of the PV system are tested to ensure correct operation. The test procedure should be the procedure defined by the inverter manufacturer/supplier. During electrical completion test, the Contractor provides a proof of inverter commissioning test report/certificate which shall verify that all the inverters installed on site fulfils the requirements defined by manufacturer for the safe and efficient long-term operation.
 - A loss of mains test is performed: With the system operating, the main AC isolator is opened – it should be observed (e.g. on a display meter) that the PV system 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.
- 4) BESS-PV Hybrid System Functional tests:
- All inverters, charge controllers, batteries and auxiliaries forming part of the BESS system are tested to ensure correct operation. The test procedure should be the procedure defined by the manufacturer/supplier.
 - Switchgear and other control apparatus are tested to ensure correct operation and that they are properly mounted and connected.
 - The *Contractor* tests the Plant operation mode of the Admin facility as follows:
 1. BESS/PV and Grid (On-grid operation): PV supplies power to the Admin building load, charge the battery and excess PV power is exported to the grid.
 2. BESS/PV alone (Off-grid operation during grid failure): PV and BESS supply power to the Admin building load with PV power as priority and a battery power as support.
 3. BESS alone (Off-grid operation during grid and PV failure): BESS supplies power to the Admin building load and initiate generator start on set SOC.
 4. Generator alone (Off-grid operation during Grid, PV and BESS failure)
 5. Reinstating the normal operation(on-grid operation) when Grid supply is restored.
- 5) Functional Test of Meteorological System and CMS,
- Functional test procedure and check sheets are provided to ensure that the CMS meets the requirements as specified in the Scope of work.
 - CMS Commissioning procedure is provided prior to commissioning.
 - All meteorological stations signals are working properly and the data are being recorded into the monitoring system.
 - Commissioning of CMS is according to IEC62337 Commissioning of Electrical, Instrumentation and Control systems.
 - Test communications with inverters, weather stations, energy meters and BESS;

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- Demonstrate PR measurements for Kriel PV Plant and Admin BESS/PV Plants
- Inspect all system displays, event recording, data storage and upload from local to remote. Control of remote system access and data downloading;

6) Infrared Thermography

- Infrared scanning on all PV modules as well as in electrical connections are performed in order to verify that modules are free from any hot spots and electrical connections are properly made. Infrared scanning shall be done when irradiation on module plane is greater than 500 W/m².
- c) The *Contractor* conducts Grid Connection Test for all Plants witnessed by the *Employer*.
- d) The *Contractor's* ECSA registered professional engineer or technologist declares the installation complies with all standards and design requirements.
- e) Upon the successful completion of Electrical Completion Test, the *Contractor* provide a Certificate of Compliance (COC) per Plants (one of Kriel and One for Admin) certified by the responsible person.

3.7.3.4 Reporting

- a) Once the Electrical Completion tests are successfully performed, the *Contractor* provides to *Employer* the report including the following,
- 1) A report, signed by the *Contractor*, summarizing each test performed and their acceptance or rejection according to relevant standards and requirements.
 - 2) Test raw data.
 - 3) Final Test protocol along with list of measurement equipment considered and their specification.
 - 4) The Commissioning Certificate for the Plants is issued by the *Project Manager* upon the successful completion of the Mechanical & Electrical completion tests by the *Contractor*.

3.7.4 Test on Completion

- a) Test on Completion refers to the "Provisional Acceptance Test (PAT)" which verifies the performance and availability of the PV plant against the *Contractor's* guarantee.
- b) The test introduction, test methodology and evaluation procedures are defined in Section 3.9 of this document.
- c) PAT is witnessed by the *Employer*.

3.7.4.1 Provisional Acceptance Test - Pre-Requirement

The following is completed before the start of PAT,

- a) All commissioning tests have been successfully completed,
- b) Mechanical Completion Certificate, Certificate of Compliance (COC) and Commissioning Certificate have been issued by the *Project Manager and Contractor*.
- c) The *Contractor* has provided O&M Manual to the *Employer* and the *Employer's* representative, which includes minimum but not limited to,
 - 1) Procedures for verifying correct system operation (Start-up / Shut down of PV plant , HMI operation, Single line diagram, Regular Maintenance on Modules, Inverter first line maintenance, transformer, switchgear, ups, etc.)

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- 2) Preventive and corrective maintenance procedures
 - 3) scheduling of routine maintenance
 - 4) A checklist of what to do in case of system failure.
 - 5) Emergency shutdown/isolation procedures
 - 6) Documentation on stock of spare parts and spare parts management including contact information and procedures for replacement of defective components.
 - 7) Inverter O&M Manual (troubleshooting for error codes, repair, software for inverter, Fault finding on the DC Plant)
 - 8) CMS O&M Manual (troubleshooting, equipment descriptions, repair, metering equipment downloading, weather station)
 - 9) Maintenance and cleaning recommendations (if any).
- d) Training on Construction and Commissioning to the Employer's Personnel and Operators, Facility managers have been completed.

3.8 CONTRACTORS GUARANTEE ON PERFORMANCE AND AVAILABILITY

- a) The *Contractor* provides guaranteed values for SPVC Plants below.
 1. First Year annual average Performance Ratio (PR) equal or greater than 80% for Kriel PV plant and for Admin building PV plant,
 2. Plant availability during PAT equal or greater than 99.5%,
 3. Annual Plant Availability during maintenance period FAT equal or greater than 98%.
- b) These guaranteed performances will be verified during PAT and FAT.
- c) The Contractor provides the Monthly breakdown of first year annual guaranteed Performance Ratio in Appendix E.
- d) The PR guaranteed for Provisional Acceptance Test will be the corresponding monthly average PR during which the PAT is performed. If the PAT duration covers period of two consecutive months, then the guaranteed PR during PAT should be calculated based on weighted average PR.
- e) The PR guaranteed for FAT shall be calculated monthly and averaged to meet the first-year Monthly breakdown in c).
- f) The plant rating and PR values are supported by the Simulation report provided by commercial software package with all loss calculations, assumptions and energy yield.

3.9 PROVISIONAL ACCEPTANCE TEST

- a) Provisional Acceptance Test is performed for 5 consecutive days of operation (120 hours).
- b) The *Contractor* must monitor the operation of the works (PV and BESS plants) and record all operational and performance data in the Data Acquisition system.
- c) The plant monitoring system must be all time available during the test period.
- d) The plant performance will be verified against the, both, *Contractor's* guaranteed PR and plant availability.

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3.9.1 Test Procedure

3.9.1.1 Parameters and Instrumentation

- a) 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
- | | |
|---|-----------------------|
| 1) AC Energy output at the connection point | [kWh] |
| 2) Global solar irradiation on plane of array | [kWh/m ²] |
| 3) Global solar irradiation on horizontal surface | [kWh/m ²] |
| 4) Module temperature | [°C] |
| 5) AC Energy output from each inverter | [kWh] |
| 6) Ambient air temperature | [°C] |
- b) The first two technical parameters (major parameters) mentioned above are directly used 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 stored in a 15-minute interval. The logged data will be checked for consistency and validity to be free from obvious anomalies or irregularities.

3.9.1.2 Admissible Measurement Period

- a) During the Provisional Acceptance Test (PAT) period, measurements are taken at 15-minute intervals (each a "Measurement Interval"). During each Measurement Interval the following conditions are to be met for the specific measurement to be deemed admissible for the purpose of the PAT calculation:
- 1) In the event of any disruptions due to Force Majeure, such as theft, vandalism or grid failure, the respective data is disregarded.
 - 2) The average in-plane irradiance (estimated with weighted average measurement from reference cells installed at different orientations) measured by reference cell is equal to or greater than 400W/m² (Only for PR Test) called the irradiation threshold.
- b) During each day of the Provisional Acceptance Test period, a minimum of 3 hours' worth of irradiation threshold is obtained (Admissible Measurement), otherwise all measurements of the given day are disregarded and the Preliminary Acceptance Test period is extended equally by a day. Such extension can be done up to a limit of 5 additional days or up to the *Contractor's* guaranteed substantial completion date, whichever date is longer. If despite this extension, the required number of irradiation thresholds are not achieved, then at the *Employer's* sole discretion:
- 1) the Provisional Acceptance Test is deemed completed despite the lower number of Admissible Measurements and the calculation of the Provisional Acceptance Test PR will take place based on such Admissible Measurements only; or
 - 2) The irradiation threshold is lowered to 300 W/m² to increase the number of Admissible Measurements.
- c) Despite such reduction to the irradiation threshold criterion and the increased number of Admissible Measurements does not reach or exceed the requirements, then the Provisional Acceptance Test conclusion will take place based on *Employer's* sole discretion.
- d) For the avoidance of doubt: the extension to the Provisional Acceptance Test due to Facility unavailability events remains uncapped; and if low irradiance conditions coincide with Facility unavailability occurrences, then it will be deemed that the respective measurements are non-admissible entirely and solely due to Facility unavailability. Thus, if the daily number of Admissible

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Measurements is not achieved, the consequent Provisional Acceptance Test extension will not be subject to the limit on extensions to a maximum of five days as referred to above.

3.9.1.3 PAT Stopping and Restarting Procedure

- a) If the Plant, wholly or in part, ceases to operate at any time during PAT due to causes beyond the control of the *Contractor*, then the PAT will be suspended during that time and will resume following restoration of operation, until the total PAT duration has reached the required length of 5 days.
- b) In the event of any disruptions due to Force Majeure, such as theft, vandalism or grid failure for the period longer the *Contractor's* guaranteed substantial completion dates.
- c) The *Contractor* maintains a log of any such event, including the cause, the duration and the date and time at which PAT was suspended and resumed. The *Contractor* shall provide written notice to The *Employer* within eight (8) hours following each such PAT suspension and resumption. All pre-requisites specified must remain satisfied on any such PAT resumption.
- d) If at any point during PAT the *Contractor* deems that it is unlikely to pass the PAT, then notifies The *Employer* and may discontinue the PAT. The *Contractor* may subsequently commence a new PAT, subject to compliance with all provisions and procedures within this Section.

3.9.1.4 PR Evaluation Procedure

- a) The plant Performance Ratio (PR) to be evaluated according to the equation or method agreed between the Contractor and Employer.

3.9.1.5 Plant Availability Evaluation

- a) The *Contractor* verifies the availability of the Plant during the PAT.
- b) The only exceptions for errors/malfunction and stoppage periods allowed are cases which are:
 - 1) Events caused by faults, except than Contractor (e.g. manual shut-down, inspections not attributable to the Contractor)
 - 2) required by third parties (e.g. insurance companies, authorities)
 - 3) attributable to the grid operator/Facility Operator
 - 4) the result of Force Majeure events.
- c) The availability of the Plant is evaluated based on technical availability of the inverter. The Plant delivers energy to the meter during the period where the Plant is considered as available. Otherwise, the Plant is considered as unavailable.
- d) The evaluation of Plant Availability will be 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 shall be 100 W/m². This level of irradiation is considered as the minimum level of irradiation required to overcome inverter's threshold power.

3.9.1.6 Criteria for PAT Acceptance

- a) The provisional Acceptance Test is considered successful if,
 - 1) Measured Performance Ratio (PR) is greater than or equal to Guaranteed Performance Ratio during PAT, and
 - 2) Measured Plant Availability is above guaranteed plant availability.

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3.9.1.7 Criteria for Issuance of Substantial Completion Certificate

- a) The Substantial Completion Certificate is issued by the *Employer*, if,
 - 1) The Mechanical and Electrical Completion Tests have been successfully completed and relevant certificates (Mechanical Completion, CoC, Commissioning certificates) are issued,
 - 2) PAT requirement has been successfully completed (Grid-tied SPVC).
 - 3) The complete O&M manuals have been provided.
 - 4) Punch List have been reviewed and approved by the *Employer*.
 - 5) All guarantees and Warranties are successfully transferred to the *Employer* and the plant has been substantially hand-over to the *Employer*.

3.9.2 Test after Completion

- a) Test after Completion refers to the “Final Acceptance Test (FAT)”. Final Acceptance Test will be performed 1 year after the Provisional Acceptance Test.
- b) Final Acceptance Test includes,
 - 1) Visual Inspection of the Plants
 - 2) Electrical Measurements/Tests
 - 3) Annual Performance Ratio and Plant Availability Test for the Grid-tied SPVC.

3.9.2.1 Visual Inspection

- a) Visual Inspection of the plant is performed in order to verify their correct installation and functioning.
- b) The visual inspection is performed for following major components but not limited to,
 - 1) PV Modules,
 - 2) Mounting structure and water leakage due to installation
 - 3) Batteries and BESS container
 - 4) DC Cables, cable routing, electrical connections,
 - 5) Junction box, fuses, isolation switches, Protection device
 - 6) PV-DB, Charge controllers, Inverters, and Inverter installation
 - 7) Energy meters
 - 8) Meteorological Stations
 - 9) Monitoring and C&I system
 - 10) Remote communication
- c) The *Contractor* verifies that the plant is free from any defects and the plant does not pose any risk for the safe operation.

3.9.2.2 Electrical Measurements

- a) The *Contractor* performs an infrared scanning on all PV modules of the Plants as well as electrical connections to verify that modules are free from any hot spots and electrical connections are properly made. Infrared scanning shall be done when irradiation on the module plane is greater than 500 W/m².

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3.9.2.3 Performance Ratio and Availability Test

- a) Performance Ratio and Availability Test will be performed based on the plant operation for 1 year period after the completion of Provisional Acceptance Test.
- b) The guaranteed availability for FAT shall be minimum 98%.
- c) PR test will be performed on a monthly basis during the O&M period and averaged over 12 months.
- d) Only the events caused by faults, except than *Contractor* (e.g. manual shut-down, inspections not attributable to the *Contractor*), stoppage required by third parties (e.g. insurance companies, authorities), the result of Force Majeure events shall be disregarded for the PR and availability evaluation.

3.9.2.4 Criteria for Acceptance of FAT

- a) The Final Acceptance Test can be considered successful if,
 - 1) The visual inspection is successfully completed and the plant is free from any defects, and
 - 2) Electrical measurements are successfully completed, and
 - 3) Measured Performance Ratio is greater than or equal to Guaranteed Performance Ratio
 - 4) Measured Plant Availability is above guaranteed plant availability and
 - 5) The O&M training has been successfully completed and
- b) All guarantees and Warranties are successfully transferred to the Employer.
- c) The Final Completion Certificate is issued by the *Project Manager* together with Handover Certificate for the Plants to be Taken over by the *Employer*.

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3.10 OPERATING AND MAINTENANCE

3.10.1 General

The *Contractor* is responsible for the following during the O&M period.

- a) The *Contractor* maintains Kriel SPVC and Admin SPVC and BESS plants (henceforth referred as Plants) in good faith and in accordance with best industry practice.
- b) The *Contractor* performs periodic inspection and testing of the Plants and each component and report on the status of modules, cablings, structures, inverters, monitoring system, batteries, etc.
- c) The *Contractor* maintains and repair (if necessary) the civil construction of the PV plants.
- d) The *Contractor* repairs any defect or replace any item, equipment and component.
- e) The *Contractor* performs maintenance activities as minimum as defined under preventive maintenance and corrective maintenance.
- f) The *Contractor* supplies all required tools, equipment and facilities (including water for module cleaning) which are necessary for carrying out the operation and maintenance of the Plants.
- g) The *Contractor* guarantees at all times the on-site availability of minimum spare parts (as mentioned on section 3.10)
- h) The *Contractor* guarantees the plant performance and operate the plant accordingly to meet the EPC guaranteed level.
- i) The *Contractor* maintains and ensures the compliance of the Plants in respect to safety laws and regulations, also in respect of the safety of the workers and performing the services.
- j) The *Contractor* follows the maintenance manuals provided by the *Contractor* under the EPC Contract, for entire plant monitoring including the operational manual of specific components and safety instructions.
- k) The *Contractor* protects any plant warranties and supports the *Employer* on negotiation of any warranty or the claims available to *Employer* for material or equipment supply and for the performance of work associated with the Plants.
- l) The *Contractor* responds in the shortest possible time to any alarm generated in the Plants and take the necessary actions (repair or replacement) and reports to the *Employer*.
- m) The *Contractor* operates and provides the maintenance of control and monitoring systems and meteorological stations.
- n) The *Contractor* reports 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.
- o) The *Contractor* must provide O&M training to the *Employer* along with all required material in hard copy and in electronic copy.
- p) The *Contractor* co-operates and co-ordinates with the *Project Manager* to ensure the operation and maintenance activities are performed respecting all *Employers'* requirement and not affecting the regular Building Facility's (site) normal operation and maintenance.
- q) The *Contractor* co-operates with third parties (upon request from the *Employer*) and with the respective municipality (electricity provider to the building) for verification of their requirements during project installation, commissioning and operation.
- r) The *Contractor* prepares a Daily Report, Monthly Report and Annual Report.
 - s) The *Contractor* shall provide the necessary information in the required Eskom format for SAP numbers to be generated for procurement purposes.

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- t) The *Contractor* shall compile and supply the necessary maintenance base documents.
- u) Maintenance scheduling and execution shall be performed using the relevant format and asset management system of the *Employer*.

3.10.2 Preventive Maintenance

- a) Preventive maintenance of the plant includes all necessary measures to be done by the Operator as indicated in the maintenance manuals provided by the *Contractor* under the EPC Contract, and in the preliminary maintenance plans provided under Table 3-1 to avoid or anticipate possible or future malfunctions of the Plants.
- b) The *Contractor* defines the preventive maintenance plan for the Plants including the frequency and scheduling of each maintenance activity. The frequency of preventive maintenance depends upon the level of impact on energy production that it would produce if the component stopped functioning. In this regard, the preventive maintenance of the inverters receives the greatest focus among all. The *Contractor* pays attention to such components in its O&M plan. Preventive inverter maintenance includes.
 - 1) the inspection and tightening connections,
 - 2) ensuring water and dust tightness,
 - 3) cleaning and replacing filters, lubricating moving parts like fans, handles and disconnects,
 - 4) running electronic diagnostics.
- c) Preventive maintenance also involves module cleaning, inverter servicing, battery monitoring, mounting structure maintenance and balance of system inspection. The inspection on balance of system includes but is not limited to the inspection of junction boxes, conduit runs, combiner boxes, communication equipment, monitoring equipment, cabling, etc.
- d) The following table provides the general overview as guidelines of preventive maintenance of main components. The maintenance type and frequency of maintenance may depend upon the specific component type and local grid requirements. Therefore, the *Contractor* provides the detailed preventive maintenance plan of each equipment, configuration, and systems considered in the plant.
- e) It is expected that the *Contractor* proposes suitable cleaning methods as well as frequency for the PV plant design proposed, but at least according to the requirements as mentioned below.

Table 3-1: Preventive Maintenance Plan – Guideline as Minimum Requirement for each PV Plant

S.No.	Items	Frequency
1	PV Modules	
1.1	Cleaning of modules	6M
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	24M

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S.No.	Items	Frequency
1.5	I-R Scanning of modules	A
2	Mounting structure and Installation	
2.1	Visual Inspection of mounting structure and foundation	M
2.2	Check of integrity of mounting structures and clamping	M
2.3	Inspection of corrosions in screws, structure (if any)	A
2.4	Check on grounding connection (if any)	M
2.5	Visual Inspection of Waterproofing (water leakage)	M
3	String box/Junction Box/Combiner Box	
3.1	Visual Inspection - box screw tightness, incoming and outgoing cable tightness, fuses, breakers, cable labeling, water and dust tightness, etc.	M
3.2	Check of proper functioning of string fuses, DC disconnect switch and earthing cable etc.	A
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	M
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 setting and MPPT functionality	M
5.7	Check of inverter according to manufacturer's operation and maintenance manual	MS
6	Distribution Board and Interconnection	
6.1	General Visual inspection - status, connections and functionality	M
6.3	check on maintenance of transition and protection device	M
6.4	Status and performance of electrical meters	M
7	Electrical Wiring	

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S.No.	Items	Frequency
7.1	Check on proper status of all electrical cables (from PV module to connection point)	M
7.2	Check on status of fuses, circuit breakers and safety switches	M
7.3	verification of proper earthing connections of the plant components	M
7.4	Verification of water tightness of electric cables and conduits	M
7.5	Electrical Insulation measurement of DC and AC cables	A
8	BESS	
8.1	Visual inspection of batteries, HVAC and fire protection are operating and in good condition	M
8.2	Check if each battery is operating as specified by the manufacturer with no alarm.	M
8.3	Check the battery connections and BMSs	M
8.4	Check on status of spare parts in inventory	M
8.5	Check the CMS equipment condition and operation	M
9	Meteorological Stations and Monitoring System	
9.1	Cleaning of meteorological stations (reference cell and pyranometer)	M
9.2	Calibration of meteorological equipment, if required	MS
9.3	Check of connection on meteorological components and communication with monitoring system	M
9.4	Check on online record of energy output and irradiation through remote monitoring system	D
9.5	Check on alarm, event and status database - through remote monitoring system	D
9.6	Check on online record of availability of each inverter and availability of the plant - through remote monitoring system	D
10	Reporting	
10.1	Report on plant performance ratio and plant availability	M
10.2	Report on status of plant component and status of preventive maintenance	M
10.3	Report on alarms, events and status recorded	M
10.4	List of damage and faults verified	M
10.5	List of corrective maintenance service performed	M
10.6	List of spare parts available in inventory	M

Frequency: D → Daily, W → Weekly, M → Monthly, SA → Semi-Annually, A → Annually

MS → Manufacturer specification and operation manual

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3.10.3 Corrective Maintenance

- a) Corrective maintenance always includes attending to and repairing breakdowns and failures of the components of the plant caused by wear and tear and/or breakage under normal operating conditions to ensure that the plant operates normally throughout the duration of the O&M Period.
- b) Corrective maintenance is carried out during the preventative 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:
 - 1) A problem diagnosis, performance notification and which parts needs to be replaced,
 - 2) Supplying the component parts needed to replace in the event of breakdown or anomaly,
 - 3) Repairing or Replacing, when necessary, the affected component/equipment from inventory and brining the plant back in working condition,
 - 4) Purchasing and transporting the replaced component and keeping the inventory always in the same level as defined in the section 3.11.5 (spare parts level).
- c) Where market conditions prevent the supply of parts identical to those already installed, the *Contractor* purchases the available parts of similar technical specifications and equal or higher warranty periods and terms which do not result in a reduction below the rated output or efficiency of the plant.
- d) The *Contractor* repairs or replaces the affected item immediately or, under all circumstances, within forty-eight (48) hours following the identification of failure (alarms) where this occurs on a working day or within seventy-two (72) hours following the failure (alarms) where this occurs on a non-working day. The *Contractor* shall be responsible for maintaining the plant in accordance with the laws in force at any given time.
- e) In case an immediate repair/replacement is not possible (due to the lack of sufficient availability of components in inventory), the *Contractor* is entitled to put in place a temporary technical solution allowing partial if not complete resumption of production and / or minimize production losses to a maximum. If beforehand unavailable component has been received, the *Contractor* repairs or replaces the affected item within forty-eight (48) hours.

3.10.4 O&M Training

- a) O&M Training is provided to the *Employer* within three (3) months after the issuance of Substantial Completion Certificate of the Plants. The Training is both, based on Classroom and Onsite / practical Training.
 - 1) The *Contractor* provides formal classroom training of the operations, maintenance prior to final hand-over of the plant (Final Acceptance Test) to ensure *Employer's* representatives has a sound understanding of the plant layout and functionality.
 - 2) Training material for classroom training is based on O&M manual content (O&M Manual requirement is presented in in this document) and contain evaluation criteria on each section of the plant covered in order to establish the level of *Employer's* representatives' understanding.
- b) The *Contractor* provides formal **on-site training** of the operations, maintenance prior to final hand-over (Final Acceptance Test) of the plant is essential to ensure *Employer's* representatives' have a sound understanding of the plant functionality and O&M requirements.
- c) 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.

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- d) Training shall be focused on following area,
 - 1) Operation and Maintenance of the Plants
 - 2) 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
 - 3) Data Acquisition System (CMS)
- e) The *Contractor* provides all training materials in hard copy and electronic copy to the trainees prior to the actual commencement of O&M training.
- f) Training shall be compiled in the applicable Eskom format. {Eskom training templates and guidelines to be referenced}

3.10.5 Spares

- a) The *Contractor* provides and ensure the minimum levels are always available in inventory during the plant operation.
- b) The table below provides a breakdown of the minimum stock of spare parts to be available for the Plant before the final handover of the Project (Final Acceptance Test).
- c) Submit a detailed list (BoM) of the critical and maintenance spares and maintenance tools kit that will be required during the Operating and Maintenance period.
- d) Maintains and manage the minimum level of spare parts (in the spares kit) throughout the maintenance period and provides to the Project Manager prior to the handover of the Plants.
- e) A fully stocked spares kit and maintenance equipment and tools are handed over at the end of the Operating and Maintenance period.
- f) Storage location to be mutually agreed in writing.
- g) The cost of spares is included in EPC price.
- h) The *Contractor* to include BESS minimum spares.

Item / Equipment	Unit	Amount / Number Required
PV Modules and Connectors		
Crystalline Modules	Pcs	10
Pair of module / string connectors (male + female), for each type installed	Pcs	10
Protection Devices		
Fuse holder, for each type installed (Admin)	Pcs	10
DC string fuse, for each type installed (Admin)	Pcs	10
DC Disconnect Switch (Admin)	Pcs	1
DC string breaker, for each type installed (Kriel)	Pcs	1 spare per DC box
DC SPD, for each type installed	Pcs	2

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Item / Equipment	Unit	Amount / Number Required
AC SPD, for each type installed	Pcs	2
Inverter Station		
String Inverter (cold reserve), for each type used	pcs	1
Tools		
Set of mechanical tools including any for maintenance of mounting structures, cables and connectors	set	1
Set of special tools for major equipment maintenance	set	1
Set of tools required to clean the PV modules	set	1

4. DOCUMENTATION MANAGEMENT AND SUBMITTALS

- a) Documentation management and submittals will be done according to Appendix C, Appendix E and the relevant sections (Section 2 and Section 3) in this document at various phases of the project.

4.1 TENDER PHASE

- a) The tender returnable is done according to Tender Technical Schedules to Appendix E and the relevant sections in this document.

4.2 CONTRACT PHASE

4.2.1 Document Submittals

- a) After contract award, the documentation management and submittals are done according to Appendix C and the relevant sections in this document.

4.2.2 Design Review

- a) The *Contractor* is the Design Authority as defined in the Design Review Procedure 240-53113685. The *Contractor* is responsible for following this design procedure and conducts all the reviews as specified in this procedure. The *Contractor* is responsible for conducting the following reviews:
1. Design Freeze Review and Integrated Design Review (review before construction approval)
 2. Construction Completion Review (review before commissioning)
 3. Acceptance Testing Review (review for provisional and final handover)
- b) The following process is followed during submission of documents:
1. The *Contractor* submits the documents/drawings to the Project Manager.
 2. The *Employer's* Document Controller registers the documents.
 3. The *Employer's* Document Controller will supply the documents/drawings to all relevant parties within the *Employer's* project team.

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4. The *Employer's* project team reviews the documents/drawings and will submit all comments or inputs to the Project Manager and the Project Manager submits to the *Contractor* for consideration.
5. If the *Employer* finds major deficiencies in the submitted documents/drawings, the *Contractor* revises the documents/drawings and resubmits to the *Project Manager*.
6. The *Employer* reviews the documents/drawings and if no major deficiencies are found, the *Contractor* organises a Design Review session.
7. The *Employer* and the *Contractor* conduct a Design Review.
8. If any fundamental errors were found in the designs or further actions are required, the *Contractor* record all concerns raised and revises the designs.
9. The *Contractor* organises a Design Review session once all designs were revised according to the concerns raised by the *Employer*.
10. If no fundamental errors were found in the designs during the Design Review session, the *Contractor* compiles the Design Review minutes or report and submits it to the Project Manager.
11. The *Employer's* Document Controller registers the report.
12. The *Employer's* project team reviews the *Contractor's* report/minutes. If the report/minutes are not acceptable, the *Contractor* revises the report/minutes and resubmits to the Project Manager.
13. The Project Manager will accept the *Contractor's* design once the report/minutes are accepted by the *Employer's* project team.

5. APPENDICES

Appendix A – Kriel PV Plant – Finesse Minisub Single Line Diagram

Appendix B – BESS Plant – Admin Board Single Line Diagram

Appendix C - Documentation Requirements

Appendix D – NRS 097-2-1 Certified PV inverter

Appendix E – Tender Technical Schedule A&B

6. AUTHORISATION

This document has been seen and accepted by:

Name	Designation
Thomas Jacobs	Chief Engineer
Kameel Burath	Engineer
Byron Thomas	Engineer

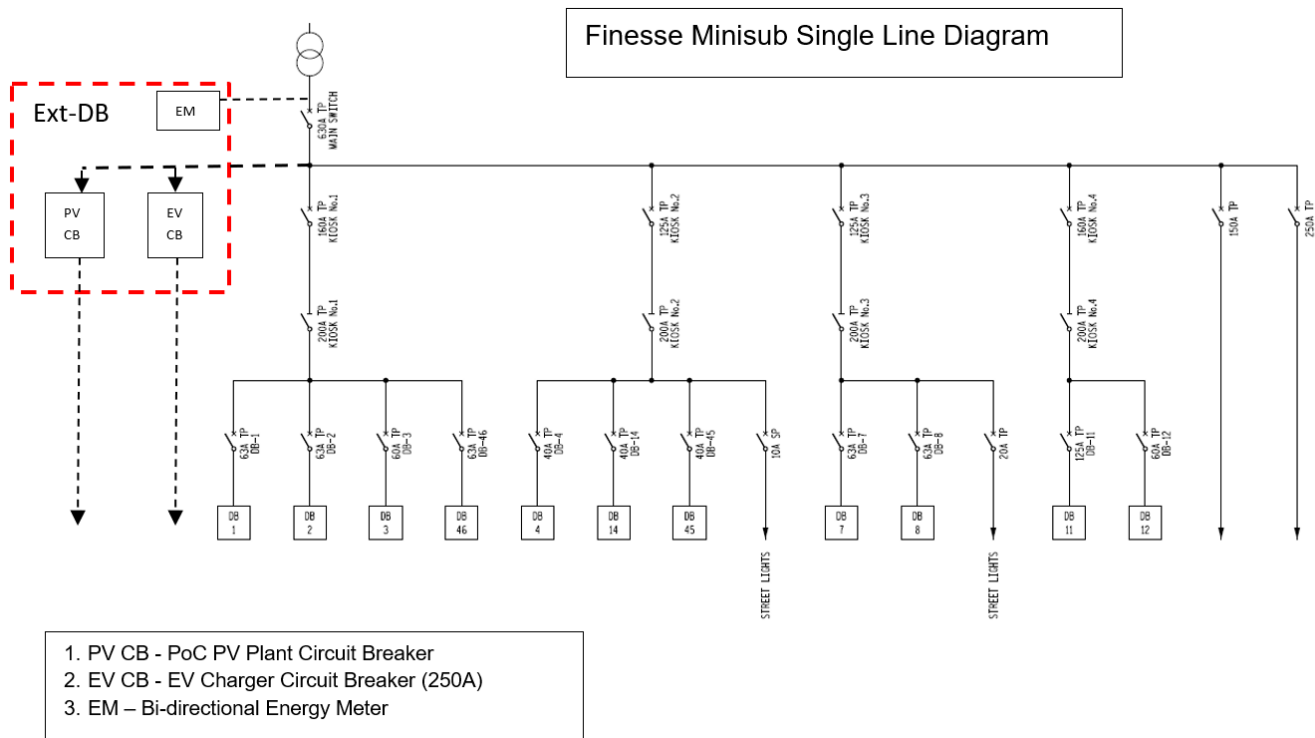
7. REVISIONS

Date	Rev.	Compiler	Remarks
January 2024	0.1	M Manyage	Draft after review
January 2024	1	K Burath / M Manyage	Final

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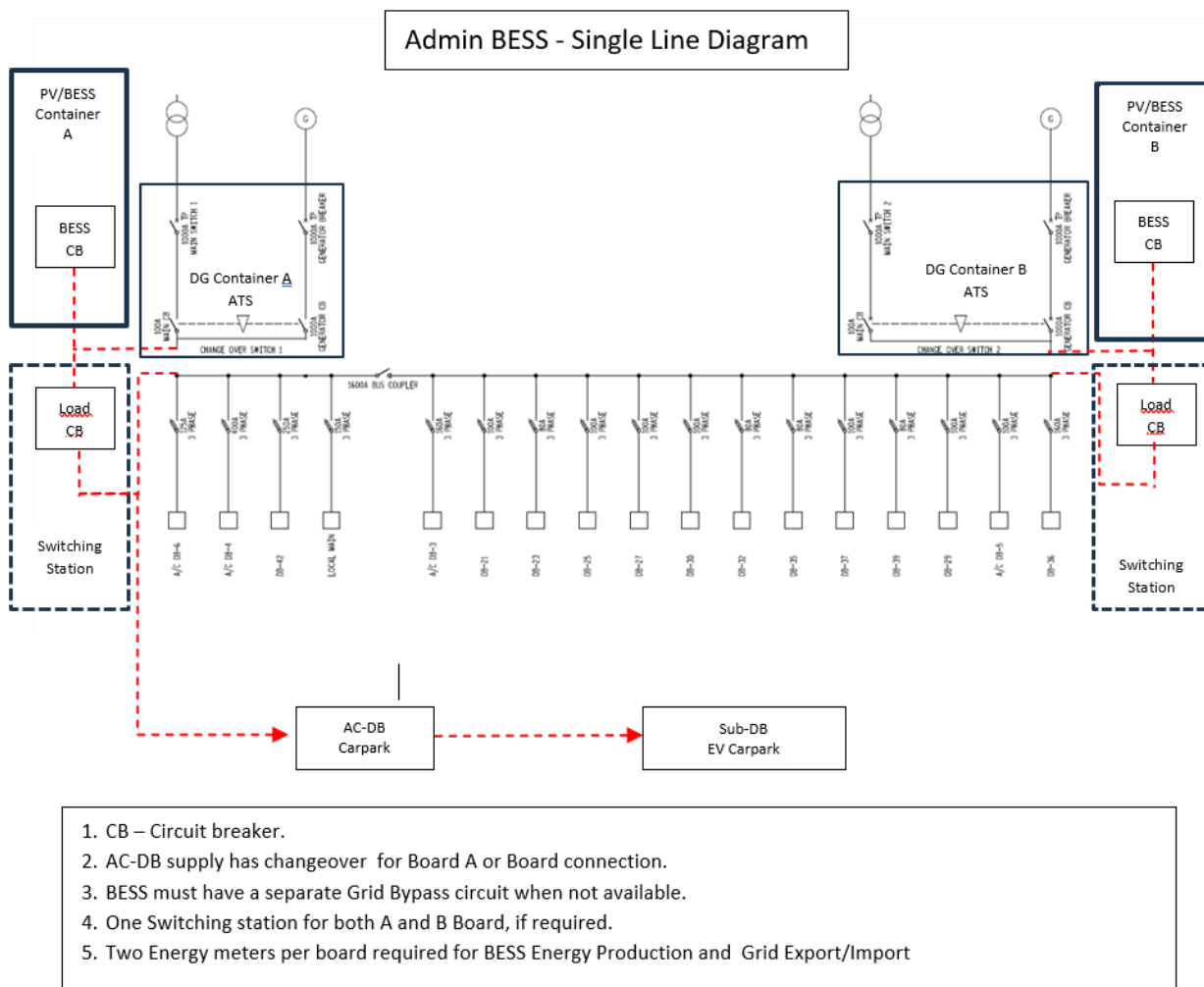
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APPENDIX A: KRIEL PV PLANT - FINESSE MINISUB SINGLE LINE DIAGRAM



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APPENDIX B: BESS PLANTS – ADMIN BOARDS SINGLE LINE DIAGRAM



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