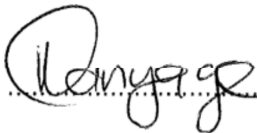

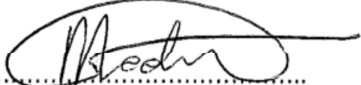


	Specification	Technology
--	----------------------	-------------------

Title: **Grootvlei Solar PV Plant Works Information** Unique Identifier: **374-SPV-AABZ18-PN0017-1**
 Alternative Reference Number: **GRV-PVWI-01**
 Area of Applicability: **Engineering**
 Documentation Type: **Specification**
 Revision: **2**
 Total Pages: **150**
 Next Review Date: **N/A**
 Disclosure Classification: **CONTROLLED DISCLOSURE**

Compiled by  MJ Manyage Chief Engineer Date: <u>10/07/2015</u>	Functional Responsibility  T Railo Electrical Design Application Manager (acting) Date: <u>10/07/2015</u>	Authorised by  P Madiba EC&I Senior Manager Date: <u>10/07/2015</u>
--	--	--

CONTENTS

	Page
1. INTRODUCTION	8
1.1 EXECUTIVE OVERVIEW.....	8
1.2 THE <i>EMPLOYER'S</i> OBJECTIVES AND PURPOSE OF WORKS	8
1.3 INTEPRETATION AND TERMINOLOGY	8
2. GENERALREQUIREMENTS.....	11
2.1 THE CONTRACTOR'S SCOPE OF WORK.....	11
2.2 CONTRACTORS' EXPERIENCE.....	11
2.3 GENERAL AND ADMINISTRATIVE	11
2.4 PROCUREMENT, PERMITS AND SITE ESTABLISHMENT	13
2.5 QUALITY MANAGEMENT	13
2.6 OPERATION AND MAINTENANCE	14
2.7 TRAINING	14
2.8 KEY MILESTONES	15
3. TECHNICAL REQUIREMENTS.....	16
3.1 PROJECT DEFINITION	16
3.1.1 Plant Description	16
3.1.2 Location.....	18
3.1.3 Site Conditions Survey.....	18
3.1.3.1 General	18
3.1.3.2 Site Access	19
3.1.3.3 Soil Condition - Geotechnical Study	20
3.1.3.4 Possible Area for Utilities and Temporary Construction Yard	20
3.1.3.5 Point of Connection.....	20
3.1.3.6 Meteorological Situation (Solar Resource and Temperature)	24
3.1.4 Design Definition	24
3.1.5 Material Quality Specification.....	26
3.2 CIVIL WORKS.....	28
3.2.1 Introduction.....	28
3.2.2 Scope of Work.....	28
3.2.2.1 General	28
3.2.2.2 Preparation and Site Establishment Phase	28
3.2.2.3 Design Phase.....	29
3.2.2.4 Prior to Fabrication and Construction	30
3.2.2.5 Fabrication and Construction	31

CONTROLLED DISCLOSURE

3.2.3 Civil Design Requirements	31
3.2.3.1 General	31
3.2.3.2 Geotechnical Investigations	32
3.2.3.3 Foundations	32
3.2.3.4 Mounting Structures	32
3.2.3.5 MV Cabin	32
3.2.3.6 O&M Building	32
3.2.3.7 Access Roads, Ring Road and Internal Roads	33
3.2.3.8 PV Plant Substation	33
3.2.3.9 Drainage.....	34
3.2.4 Construction Specifications	34
3.2.5 Project Co-Operation	34
3.2.6 Codes and Standards	34
3.3 ELECTRICAL WORKS.....	36
3.3.1 PV Capacity.....	36
3.3.2 PV Modules	36
3.3.3 DC Combiner box.....	37
3.3.4 DC Fuse Box	38
3.3.5 Inverters	38
3.3.6 MV Cabin (Inverter Transformer Shelter).....	39
3.3.6.1 LV/MV Step Up Transformer.....	40
3.3.7 Ring Main Unit (RMU 6.6 kV) - MV Switchgear in MV Cabin	40
3.3.8 PV Plant Substation	41
3.3.8.1 PV Plant MV Switchgear.....	41
3.3.8.2 Auxiliary Transformer (MV/LV Step-Down 6.6/0.4 kV)	42
3.3.8.3 Auxiliary Supplies Distribution Board (DB)	43
3.3.8.4 PV Plant Energy Meters.....	43
3.3.8.5 Battery Tripping Units	44
3.3.9 Cabling	44
3.3.9.1 DC Cabling.....	45
3.3.9.2 DC Connectors.....	45
3.3.9.3 AC Cabling	45
3.3.10 Earthing	46
3.3.11 Surge and Lightning Protection.....	47
3.3.12 6.6kV Overhead Line	47
3.3.13 Overhead Line (OHL) Protection and Interlocking.....	48
3.3.14 MV Switchgear at POC	48
3.3.15 Metering and Measurements at POC	49
3.3.16 Grid Code Compliance.....	49

CONTROLLED DISCLOSURE

3.3.17 Codes and Standards	49
3.4 CONTROL, MONITORING AND COMMUNICATION WORKS.....	55
3.4.1 General.....	55
3.4.2 Control and Monitoring System (CMS) Servers.....	57
3.4.3 Operator System Thin Clients	58
3.4.4 CMS Plant Information Server Requirements.....	63
3.4.5 Network Switch.....	67
3.4.6 Network Time Synchronisation	67
3.4.7 Miscellaneous Network Equipment.....	68
3.4.8 CMS Field Equipment Panels	68
3.4.9 Server Room Network Cabinets.....	69
3.4.10 Building management system (BMS).....	69
3.4.11 Fire detection System	70
3.4.12 Third Party Network Access into the CMS Network.....	70
3.4.13 CMS Power Supply and Power Distribution.....	72
3.4.14 Field Equipment, Cabling and Installation Requirements	73
3.4.15 CMS Control Room, Server Room, Equipment Rooms	74
3.4.17 Software Management.....	74
3.4.18 Labelling and Codification	75
3.4.19 Vendor Document Submittal Schedule (VDSS).....	75
3.4.20 Codes, Standards and Guidelines	76
3.5 INFORMATION MANAGEMENT WORKS.....	77
3.6 METEOROLOGICAL SYSTEM WORKS	77
3.7 HEATING VETILATION AND AIR CONDITIONING (HVAC) WORKS.....	79
3.7.1 Design Conditions	79
3.7.2 HVAC System Description	80
3.7.3 HVAC System Commissioning.....	81
3.7.4 HVAC applicable Codes, Standards and Guidelines.....	81
3.8 FIRE PROTECTION SYSTEM WORKS	83
3.8.1 Fire Protection System applicable Codes, Standards and Guidelines	83
3.9 WET SERVICES WORKS.....	84
3.9.1 Wet Services System Description.....	84
3.9.1.1 Borehole System.....	85
3.9.2 Wet Services applicable Codes, Standards and Guidelines.....	85
3.10 CHEMICAL WORKS	87
3.10.1 Scope of Work.....	87
3.11 SECURITY SYSTEM WORKS.....	89
3.11.1 General.....	89
3.11.2 Perimeter Fencing.....	89

CONTROLLED DISCLOSURE

3.11.3 Closed Circuit Television (CCTV)	91
3.11.4 Lighting.....	92
3.11.5 Security Alarms	93
3.11.6 Integrated Access Control.....	94
3.11.7 Interface to Power Station.....	95
3.11.7.1 CCTV and Alarm.....	95
3.11.7.1.1 Integration with CCTV cameras.....	95
3.11.7.1.2 Integration with panic buttons	95
3.11.7.1.3 Integrated Alarm management	96
3.11.7.1.4 Arming and Disarming system.....	96
3.11.7.1.5 Integrating system / controller.....	96
3.11.8 Power Supply to Security System.....	97
3.11.9 Codes and Standards	97
3.12 INSPECTION, TESTING AND COMMISSIONING WORKS	100
3.12.1 General Requirements	100
3.12.1.1 Standards.....	100
3.12.1.2 Personnel and Facilities.....	100
3.12.1.3 Instruments	101
3.12.1.4 Defects and Delays.....	101
3.12.1.5 Test Protocols and Reports	101
3.12.2 Training during construction and Commissioning.....	102
3.12.3 Test before Installation.....	102
3.12.3.1 Factory Acceptance Test - FAT	102
3.12.3.1.1 PV Module	103
3.12.3.1.2 Inverter.....	105
3.12.3.1.3 Transformer	106
3.12.3.1.4 Switchgear	107
3.12.3.1.5 CMS Test.....	108
3.12.3.2 Site Acceptance Test.....	109
3.12.4 Test after Installation.....	109
3.12.4.1 Test Pre-Requisite – Minimum System Documentation Requirement	109
3.12.4.2 Mechanical Completion Test.....	111
3.12.4.3 Electrical Completion Test	113
3.12.4.4 Reporting.....	115
3.12.5 Test on Completion	116
3.12.5.1 Provisional Acceptance Test - Pre-Requirement.....	116
3.13 CONTRACTORS GUARANTEE ON PERFORMANCE AND AVAILABILITY	117
3.14 PROVISIONAL ACCEPTANCE TEST (PAT) WORKS.....	119
3.14.1 Test Procedure.....	119

CONTROLLED DISCLOSURE

3.14.1.1 Parameters and Instrumentation.....	119
3.14.1.2 PAT Stopping and Restarting Procedure.....	119
3.14.1.3 PR Evaluation Procedure.....	120
3.14.1.4 Plant Availability Evaluation.....	121
3.14.1.5 Criteria for PAT Acceptance.....	122
3.14.1.6 Criteria for Issuance of Substantial Completion Certificate.....	122
3.14.2 Test after Completion.....	122
3.14.2.1 Performance Ratio Test.....	123
3.14.2.2 Availability Tests.....	124
3.14.2.3 Visual Inspection.....	125
3.14.2.4 Electrical Measurements.....	126
3.14.2.5 Criteria for Acceptance of FAT.....	126
3.15 OPERATION AND MAINTENANCE WORKS.....	127
3.15.1 General.....	127
3.15.2 Preventive Maintenance.....	128
3.15.3 Corrective Maintenance.....	132
3.15.4 O&M Training.....	133
3.15.5 Spares.....	134
4. DOCUMENTATION MANAGEMENT AND SUBMITTALS.....	135
4.1 TENDER PHASE.....	135
4.2 CONTRACT PHASE.....	135
4.2.1 Document Submittals.....	135
4.2.2 Design Review.....	135
5. APPENDICES.....	136
APPENDIX A : PREVIOUS STUDIES AND SITE LAYOUT.....	137
APPENDIX B : TMY DATA SET.....	138
APPENDIX C : PV ARRAY LAYOUT AND SINGLE LINE DRAWINGS.....	139
APPENDIX D : BOARD VOLTAGE PROFILE.....	140
APPENDIX E : SPARE PART LIST.....	141
APPENDIX F : FACILITY PERFORMANCE GUARANTEES.....	142
APPENDIX G : DOCUMENT REQUIREMENT.....	143
APPENDIX H : PERFORMANCE LIQUIDATED DAMAGES.....	144
APPENDIX I : CMS NETWORK DIAGRAM.....	145
APPENDIX J : CMS LIST OF PARAMETERS.....	146

CONTROLLED DISCLOSURE

APPENDIX K : O&M REPORTING REQUIREMENT..... 147

APPENDIX L : LCOE MODEL AND INSTRUCTION TO TENDERERS..... 148

APPENDIX M : TENDER TECHNICAL SCHEDULES..... 149

APPENDIX N : SECURITY SYSTEM REQUIREMENTS 150

CONTROLLED DISCLOSURE

When downloaded from the EDMS database, this document is uncontrolled and the responsibility rests with the user to ensure it is in line with the authorised version on the database.

1. INTRODUCTION

1.1 EXECUTIVE OVERVIEW

- a) This document provides the Works Information for the installation of an 8 MWac ground-mounted PV Plant at Eskom Grootvlei Power Station in the Mpumalanga Province. The site is owned by Eskom Holdings Limited (henceforth referred to as the *Employer*).
- b) This document sets the technical requirements for the *Contractor* to perform Detailed Design, Procurement, Construction, Commissioning, Operations & Maintenance and Handover of the PV Plant. It also includes quality management requirements, minimum codes and standards and training requirements.
- c) The scope is inclusive, but not limited to, PV, Civil & Infrastructure, Electrical, Control & Instrumentation, Low Pressure Services, Chemical and Security *works*.
- d) This document is read in conjunction with the following documents:
 - 1) The NEC3 Engineering & Construction Contract,
 - 2) Codes and Standards.

1.2 THE *EMPLOYER'S* OBJECTIVES AND PURPOSE OF WORKS

The *Employer's* main objectives for the installation are as follows:

- a) To reduce the amount of electricity drawn for self-consumption at Grootvlei Power Station and carbon footprint whilst maintaining a competitive Levelised Cost of Energy (LCOE),
- b) To provide a facility that can showcase the *Employer's* involvement in renewable energy.

1.3 INTERPRETATION AND TERMINOLOGY

Abbreviation	Description
AC	Alternating Current
C&I	Control And Instrumentation
CAD	Computer Aided Drawing
CMS	Control And Monitoring System
CoE	Centre Of Excellence
CPU	Central Processing Unit
DC	Direct Current
DIN	Deutsche Industrie Norm
DMZ	Demilitarised Zones
DNI	Direct Normal Irradiance
DVD	Digital Versatile Disc

CONTROLLED DISCLOSURE

Abbreviation	Description
EPC	Engineering, Procurement And Construction
FAT	Factory Acceptance Testing
FO	Fibre Optic
GHI	Global Horizontal Irradiation
GPS	Global Positioning System
GSM	Global System for Mobile Communication
HDMI	High Definition Multimedia Interface
HMI	Human Machine Interface
I/O	Input/Output
IM	Information Management
IP	Ingress Protection
IP	Internet Protocol
IPSec	Internet Protocol Security
IT	Information Technology
LAN	Local Area Network
LCOE	Levelised Cost Of Energy
LED	Light Emitting Diode
LV	Low Voltage ($0 < Lv < 1000v$)
MCB	Mini Circuit Breaker
MCCB	Moulded Case Circuit Breaker
Modem	Modulator-Demodulator
MS	Microsoft
MWP	Megawatt Park
Ni-Cad	Nickel Cadmium
NIDS	Network Intrusion Detection System
NTP	Network Time Protocol
O&M	Operating And Maintenance
OEM	Original Equipment Manufacturer
OHS	Occupational Health And Safety
OPC	OLE for Process Control
OPC-DA	Object Linking And Embedding (OLE) For Process Control Via Data Access

CONTROLLED DISCLOSURE

When downloaded from the EDMS database, this document is uncontrolled and the responsibility rests with the user to ensure it is in line with the authorised version on the database.

Abbreviation	Description
OS	Operating System
OT	Operational Technology
PDS	Plant Data System
POA	Plane Of Array
PPE	Personal Protective Clothing
PV	Photovoltaic
QA	Quality Assurance
QC	Quality Control
QCP	Quality Control Procedure
QMP	Quality Management Programme
TCP/IP	Transmission Control Protocol / Internet Protocol
TMY	Typical Meteorological Year
UPS	Uninterrupted Power Supply
URS	User Requirement Specification
USB	Universal Serial Bus
VPN	Virtual Private Network

CONTROLLED DISCLOSURE

When downloaded from the EDMS database, this document is uncontrolled and the responsibility rests with the user to ensure it is in line with the authorised version on the database.

2. GENERAL REQUIREMENTS

2.1 THE CONTRACTOR'S SCOPE OF WORK

- a) The *Contractor* is responsible for surveying, design, engineering, manufacture, procurement & supply of all materials and labour, manufacture, delivery to site, offloading, construction, erection, installation, off-site testing, on-site testing, commissioning, performance testing, provision of samples, preparation of all detail design drawings, as-built record drawings, maintenance manuals and instructions for the *works*, in accordance with the general requirements and performance requirements as detailed in this document. The scope of work also includes the O&M activities during first two operational years, according to minimum requirements presented in this document.
- b) The *Contractor* Provides the Works as per this document.

2.2 CONTRACTORS' EXPERIENCE

The *Contractor*:

- a) Demonstrates proven experiences in engineering, procurement, execution and operation and maintenance of ground-mounted utility scale PV power plants.
- b) Have successfully executed minimum one utility scale ground mounted PV project as lead EPC Contractor with the capacity of each project being equal to or greater than 5 MW.
- c) Provides the name, location, size, photos and date of commissioning of PV projects along with the tender document.

2.3 GENERAL AND ADMINISTRATIVE

- a) The *Contractor* Provides the Works in a professional and highly skilled manner consistent with such good industry practices as are customarily employed and are 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*, then *Employer* has choice to correct Defects or procure that from others to do so and the *Contractor* bears all costs incurred as a result thereof and the *Employer* is entitled to deduct the whole or any cost so incurred from any amount due to *Contractor* under this Contract or from any others dues from any other Authorities/Ministries.
- 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.

CONTROLLED DISCLOSURE

-
- e) The *Contractor* conducts visit to the site to collect data and approvals that may be necessary to complete the *works*. When the *Employer* receives the Tender documents, it is understood that the *Tenderer* has visited the site and has satisfied himself 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* when making his tender is deemed to have studied the Works Information in detail, the General and Special Conditions of Contract and Technical schedules, drawings and plans annexed thereto or referred to therein and to have obtained on his own responsibility and expense any additional information which he considers necessary for the completion of his tender and for the execution of the *works*.
- g) The *Contractor* is responsible for obtaining the approval from the *Project Manager* prior to the performance of the *works* at site. Whenever the performance of the *works* on the *Employer's* site coincides with the activities or operations of *Others* at the Power Station, the *Contractor* obtains the *Project Manager's* prior 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, safety, security and welfare.
- i) The *Contractor* is solely responsible for and, where applicable, provides at its sole cost and expenses all passports, visas, no objection certificates, work permits, residence visas, certificate of medical fitness, drivers licence 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.
- m) The *Contractor* and *Subcontractors*, whilst in the Republic of South Africa respects the laws and customs of the Country.

CONTROLLED DISCLOSURE

2.4 PROCUREMENT, PERMITS AND SITE ESTABLISHMENT

- a) The *Contractor* is responsible for the procurement of all equipment and services which are required in order to complete the *works* in accordance with the performance specifications for the whole of *the works*.
- b) The *Contractor* undertakes all necessary enquiries and investigations regarding the Project Site and Site Conditions.
- c) The *Contractor* acknowledges and agrees that it 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.
- d) 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*.
- e) The Project has already received Environmental Approval but awaits for the issue of water use license. The *Contractor* provides all requirements not limited to final design, drawings, construction methods, to Department of Energy (DoE) and Department of Water and Sanitation (DWS) for final approval of plant design in order to comply with Environmental Impact Assessment Approval and Water Use License Approval.
- f) 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.
- g) The *Contractor* constructs the PV Plant with due consideration to the Site Rules, as those have or will be defined by the *Employer*.
- h) 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 *Employer* expects the *Contractor* to engage 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, 'Grootvlei Photovoltaic Solar, document identifier 240-101708826.

CONTROLLED DISCLOSURE

2.6 OPERATION AND MAINTENANCE

- a) The *Contractor* is responsible for the all-inclusive operations and maintenance (preventive, corrective and spare parts replacement) of the facility during the first **twenty-four (24) months** of operation and maintenance (called Defects Period) in accordance with the Performance Requirements detailed in section 3.15 of this document.
- b) The Defects Period is **twenty-four (24) months** from the Substantial Completion Date.

2.7 TRAINING

- a) The *Contractor* is responsible for the training of chosen Eskom staff during the construction, operation and maintenance of the PV Plant. The *Employer* requires 10 staff to be trained on operations and maintenance of the PV Plant.
- b) Training is an essential requirement from the *Employer*. Classroom and on-job operation and maintenance training must form part of the overall Contract. The *Contractor* needs to identify the required training to operate and maintain the plant. The purpose of this training is to gain hands on experience and exposure to the day-to-day operations and maintenance activities.
- c) *The Project Manager* is notified on and involved in any scheduled or unscheduled on-site maintenance activities. In addition, continuous formal training must be provided primarily for O&M staff.
- d) The *Contractor* provides training in following manner:
 - 1) Training on Design, Construction and Commissioning: Introduction to Project design, construction and commissioning on the project and equipment is provided by the EPC *Contractor* prior to Test on Completion of the PV Plant (**Appendix G**), such that those *Employer*' representative 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 is on class room and on site. The classroom training sessions are intended to provide concentrated instruction in the design, capability, operation, inspection, and control of the Equipment and systems within the project.
 - 2) Training on Operation and Maintenance: Formal class room and on-site training of the operations, maintenance of the plant is essential to ensure the Trainees have a sound understanding of the plant functionality and O&M requirements. The Training requirements are presented in section 3.17.4 of this document.
- e) The training to be conducted by knowledgeable instructors with
 - 1) minimum 3 years' experience in MW scale solar PV construction and commissioning for training on design, construction and commissioning;
 - 2) minimum 5 years' experience in operation and maintenance of MW scale solar PV for training on Operation and Maintenance
- f) 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.

CONTROLLED DISCLOSURE

2.8 KEY MILESTONES

Key Milestones and their definitions are listed below:

- a) Notification of Preferred *Contractor* – This is the date upon which the preferred *Contractor* is announced subsequent to the tender evaluation.
- b) Contract Signature Date – Subsequent to the finalisation of the Engineering, Procurement and Construction Contract negotiation, the date upon which contract signature takes place. The issue of water use license is also pre-requisite prior to contract signature.
- c) Design Document Submittal and Review – The date upon which the final design documentation is submitted by the *Contractor* to the *Project Manager* and the design documentation is reviewed and accepted by the *Project Manager*. The detailed design of the PV Plant is to be completed and frozen within 60 calendar days after Contract Signature date.
- d) Mechanical Completion – When the *Contractor* completes the Mechanical Completion Test of the Solar PV Plant successfully as described in Section 3.12 and then the *Project Manager* issues a Mechanical Completion Certificate.
- e) Electrical Completion – When the *Contractor* completes the Electrical (including C&I and power evacuation line) Completion Test as described in Section 3.12. The *Contractor* provides a Certificate of Compliance (COC) and Grid Code test report of the PV Plant certified by the responsible person and then the *Project Manager* issues a Commissioning Certificate.
- f) Substantial Completion - The Provisional Acceptance Test (PAT) as described in Section 3.14 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.
- g) Final Completion - The duration of the Final Acceptance Test (FAT) as described in Section 3.14 is 24-month period after the issuance of Substantial Completion Certificate and runs parallel with the Defects Period. 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.

CONTROLLED DISCLOSURE

3. TECHNICAL REQUIREMENTS

3.1 PROJECT DEFINITION

3.1.1 Plant Description

- a) The *works* comprises of one ground-mounted solar photovoltaic (PV) Plant as well as all associated infrastructure and balance of plant with an installed capacity of an 8MW (AC Capacity), to be installed on the site in Eskom Grootvlei Power Station in Mpumalanga Province, and to be owned by the *Employer*.
- b) The *Contractor* provides a PV Plant with a design life of 25 years with annual guarantee performance and availability as presented in section 3.13.
- c) The PV Plant operates in an automatic mode producing electrical power for use by the existing power station whenever sufficient sunlight is available, and is monitored and operated as per the requirements in this document.
- d) The following table summarizes the main equipment of the PV Plant.

Component	Description
PV Modules	Crystalline Silicon or Thin Film technology PV modules of same type, size and from the same manufacturer.
Mounting Structures and foundations	Fixed mounting structure, foundation to be designed according to results from geotechnical investigation and compliance with Environmental and Water use license approval.
Combiner boxes/Fuse box	Combining strings/combiner boxes with adequate protections and monitoring before connecting to inverter.
Inverters	Central inverter concept suited to operating temperature at site condition and with the application of proper ventilation system
MV cabins	MV cabin (>=1MVA) hosting inverter/s, transformer and Ring Main Unit with adequate protections. Standard step-up transformers LV/6.6 kV, to be installed in MV cabin. RMU to connect to other adjacent cabins and for cabin isolation and protection, to be installed in each MV cabin. MV cabins to be arranged into two sets of 4 MVA each.
PV Plant substation building	PV Plant substation hosts MV Switchgear, two auxiliary transformers, two Battery Tripping Units with HVAC and Fire protection. The connection in MV switchgear divides two separate 4 MVA lines which connects to two separate interconnection points at 6.6 kV Station Boards 1 and 2 Maintenance Isolator Boards at Grootvlei Power Station.
Auxiliary Transformers	Two standard step-down transformers 6.6/0.4 kV, one on each busbar of

CONTROLLED DISCLOSURE

	MV switchgear to be installed to supply PV Plant auxiliaries.
Battery Tripping Unit (BTU)	Two (2) Battery Tripping Units to be provided at the PV Plant substation to provide DC supply to the switchgear control and protection circuits.
Energy meters at Power Plant	Two energy meters to be installed at each outgoing feeder lines from MV Switchgear.
MV Interconnection line	Two 6.6kV interconnection lines to be constructed to evacuate power from the PV Plant substation to the PoC. The line to be combination of MV cables and MV over headlines.
Point of Connection (PoC)	Station Board 1 Maintenance Isolator Board and Station Board 2 Maintenance Isolator board will be the two connection points for the Project. An extension to existing boards to include 6.6 kV switchgear panel with protection and control is required.
Energy Meter at Point of Connection	Three energy meters per board are required for energy measurements at the POC. One Quality of Supply (QoS) power quality meter per board is required. A separate metering panel to be provided to house the meters.
O&M Building	O&M building hosting an office for O&M team including control room, server room, a spare part room, kitchen and sanitary facilities for the O&M team with HVAC and Fire protection.
Security system	Security system include 3-tier fencing, video surveillance, lighting, alarms and among others defined in this document, monitored and controlled through power station.
Cabling	DC and AC Cabling and trenches
Protection	Plant and equipment protection including Earthing, Lightning, Surge protection device, anti-islanding among others defined in this document. Fire detection and protection.
Portable water and Sewage	Potable water supply and its reticulation system. Sewage reticulation system from O&M ablutions to sewage conservancy tank.
Control and Monitoring System	A string monitoring system along with plant performance and metrological parameters, to be connected to Eskom PDS server and other 3 rd party network (Grootvlei power station). Control of the PV Plant.

CONTROLLED DISCLOSURE

3.1.2 Location

The proposed site in Grootvlei Power Station (Site) is located with the following address/coordinates.

- Address: Eastvaal District Council, Grootvlei, Mpumalanga, South Africa
- GPS Coordinates: 26°46'43.90"S, 28°30'41.69"E
- Cadastral Information: LPI code T0IR00000000045800000, Parcel 458, Dipaliseng Municipality

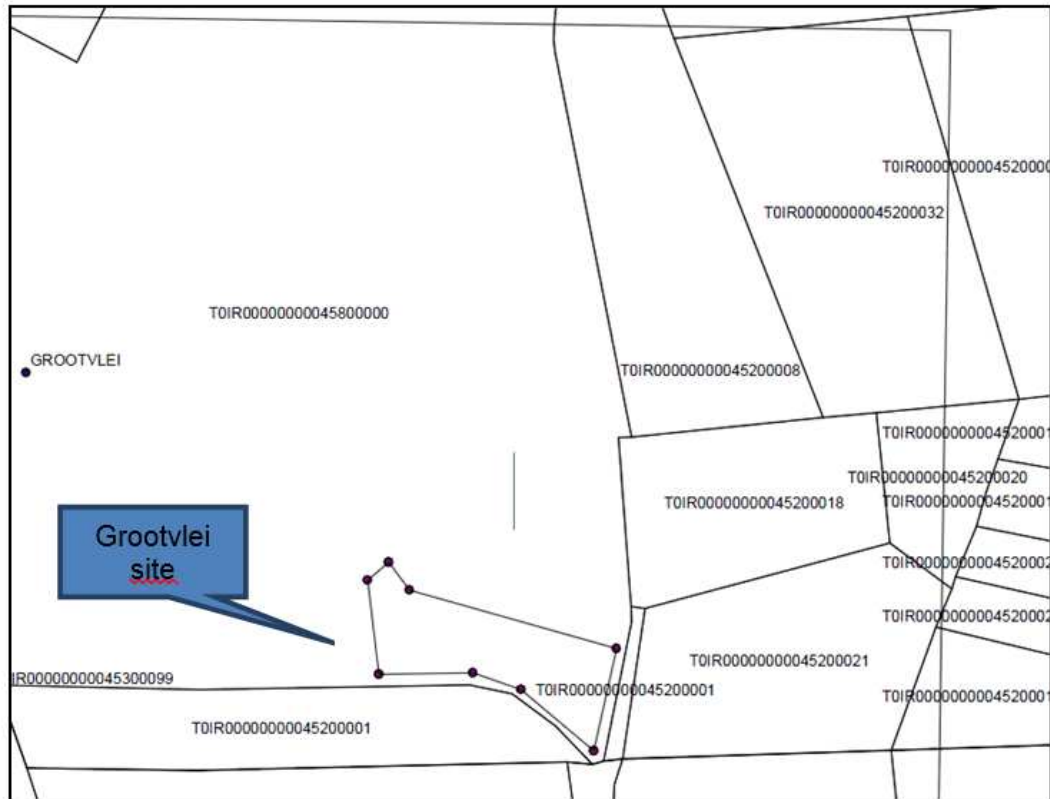


Figure 3-1: Grootvlei Cadastral Map

3.1.3 Site Conditions Survey

3.1.3.1 General

- a) The proposed site in Grootvlei is located approximately 1.0 km south eastern of Grootvlei Power Station.
- b) The proposed site in Grootvlei has total area available for PV installation is approximately 17 ha. Not all of area is suitable for PV installation.
- c) The site boundary is surrounded by a fence on western, southern and eastern side of the site.

CONTROLLED DISCLOSURE

- d) The site is divided into two sections: Grass land (GL) section and Ash disposal (AD) section. The elevation difference between these two sections is in the range between 2 to 5 meters. The terrain in both sections is almost flat (with slope less than 2%).
- e) Grass land section is covered by grass and small bushes. Ash disposal section is mostly concrete-sandy soil.
- f) North-west section of grass land has a wetland area and is not suitable for PV installation.
- g) The area between the site boundaries in south, east and north side and ash disposal section are not preferred for installation of PV.
- h) The preferred area for PV installation is indicated in Figure 3-2.



Figure 3-2: Area Suitable for PV Installation

3.1.3.2 Site Access

- a) The site is located approximately 3 kilometres north of Grootvlei and 5.3 kilometres north-east from the intersection of the N3 road in Mpumalanga Province.
- b) The site is easily accessible from N3 highway coming from Johannesburg and the distance between the site and N3 (exit 28) is nearly 7 km. The one-line road connecting N3 to Grootvlei site is paved and it is not sloppy.
- c) The entire access road until the site is paved and all turning radius appear to be suitable for heavy trucks.
- d) An existing entrance gate to the site is located on north-west side corner of the grass land section. Two existing ramps (width in a range between 3 – 5 meters) on south-eastern and on western part of the site can be used for access to ash disposal section from grass land section.

CONTROLLED DISCLOSURE



Figure 3-3: Road Connection N3 Highway to Site

3.1.3.3 Soil Condition - Geotechnical Study

- a) A preliminary geotechnical study was performed by the *Employer* as a part of Environmental Impact Assessment (EIA). Based on the study, the site has three different founding conditions. This includes; ash fill, residual sandstone and alluvial soil material.
- b) The *Contractor* reviews the existing geotechnical study report and performs a detailed geotechnical study in order to verify the geotechnical study present at the selected site. The existing geotechnical study is presented in **Appendix A-02**.

3.1.3.4 Possible Area for Utilities and Temporary Construction Yard

- a) O&M and PV Plant Substation buildings are to be constructed near to existing gate (north-west section) in order to reduce the MV AC cable line and for easy access.
- b) Temporary construction yard can be used in the areas between the site boundaries in the south, east and north side and ash disposal section which are not the preferred areas for PV installation.

3.1.3.5 Point of Connection

- a) The Point of Connection (PoC) for PV Plant is at +01BCA 6.6kV Station Board 1 Maintenance Board and +02BCA 6.6kV Station Board 2 Maintenance Isolator Board located within the Grootvlei Power Station. The site is located approximately 2.5km (in regard to estimated evacuation lone) from the PoC. The *Contractor* verifies according to proposed design.

CONTROLLED DISCLOSURE

- b) The generated power from the Solar PV Plant is to be evacuated to the PoC through a combination of 6.6kV cables and 6.6 kV overhead lines. The transmission lines will cross existing 400 kV and 5 x 88 kV overhead lines.
- c) The *Contractor* designs the transmission line according to requirements detailed in this document and according to requirements from Water Use License permit and Environmental permit.

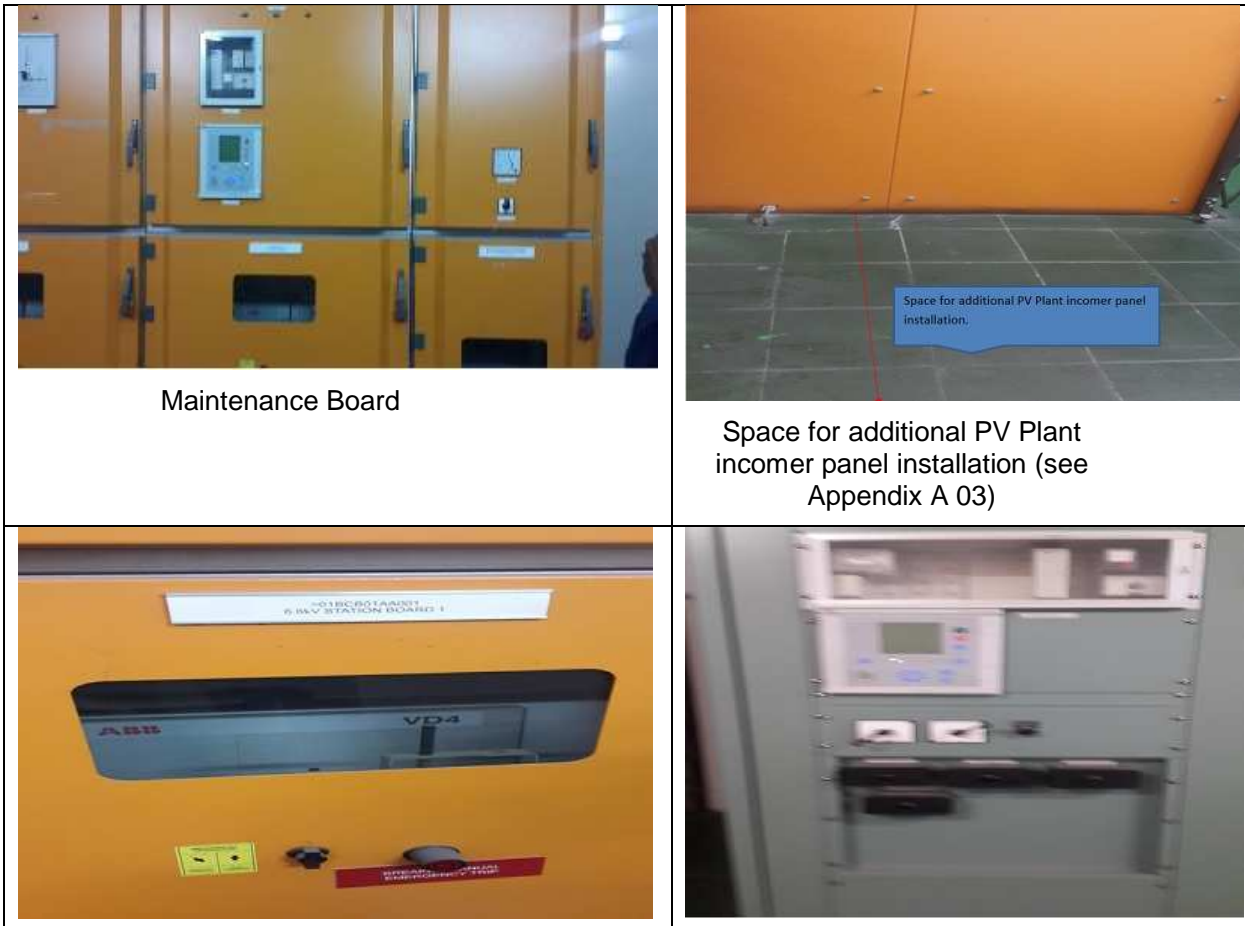


CONTROLLED DISCLOSURE



Figure 3-4: Transmission Line Option

- d) There is currently no spare circuit breaker in the existing boards, hence requirement for installation of additional circuit breakers. Space for installation of additional ABB CB for the PV Plant incomer is available.
- e) At PoC, the existing maintenance board CB panels are approximately 2500mm x 800mm x 2000mm and the Voltage Transformer (VT) isolator panel is approximately 2500mm x 400mm x 2000m. The panels are equipped with ABB vacuum CBs. The panels consists of incomer panel, feeder panel and VT isolator panel with a busbar rating of 2500A at a voltage rating of 6.6kV



CONTROLLED DISCLOSURE



Figure 3-5: MV Cable Routing and PoC

CONTROLLED DISCLOSURE

3.1.3.6 Meteorological Situation (Solar Resource and Temperature)

- The long term annual average solar irradiation on horizontal plane (GHI) is expected to be around 2,039 kWh/m².
- The annual average temperature at the site is estimated to be around 16.2°C.
- The *Contractor* designs the plant operation for minimum and maximum ambient temperature of -10°C and +45°C respectively, unless specified other wise.

Table 3-1: Monthly Average of Solar Resource, Ambient Temperature and Wind Speed

Month	Average GHI [kWh/m ²]	Average Ambient Temperature [°C]	Wind Speed [m/s]
January	205	21.7	2.8
February	174	21.2	2.2
March	170	19.6	2.3
April	150	16.5	2.7
May	136	11.5	2.1
June	119	6.9	3.2
July	131	9.5	2.8
August	156	11.7	3.1
September	182	17.0	4.3
October	197	18.4	3.3
November	202	19.9	3.5
December	214	20.3	2.7
Annual	2038	16.2	2.9

- The TMY (Typical Meteorological Year) generated for the project site is presented in **Appendix B** (for guidance purpose only) which the *Tenderer* can use to evaluate the plant performance and provide the estimated plant performance accordingly as defined in Table 3-5. However, the *Tenderer* is free to choose his own TMY dataset to guarantee the performance ratio as defined in Section 3.13.

3.1.4 Design Definition

- The *Contractor* develops the detailed design in full compliance with the general requirements and performance specifications as set out in this document and takes *liability* for the design.
- The *Contractor* ensures that all designs are signed off by a respective ECSA (Engineering Council of South Africa) registered Professional Engineer.
- The *Contractor* submits his detailed designs to the *Project Manager* for review and comment prior to procurement and construction of the PV Plant. Each document review turnaround time is 5

CONTROLLED DISCLOSURE

working days. The detailed design is to be completed and frozen not more than 60 calendar days after Contract Signature Date.

- d) The *Contractor* labels the PV Plant and documents using coding provide by the *Employer*. KKS coding to be used for this Project
- e) The *Contractor* designs the PV Plant with consideration of approved Environmental Permit and Water Use License Permit (**Appendix A-01**).
- f) The *Contractor* designs the PV Plant with due consideration to the site environmental conditions, particularly in relation to wetland, wind, temperature, lightning, hail and dust.
- g) The design data specified in this document and those dimensions shown on the tender drawings are intended for tendering purposes only. The *Contractor* is required to take the actual measurements onsite before proceeding with design & manufacture of the complete *works* as dimension accuracy remains the responsibility of the Contractor.
- h) The *Contractor* defines the PV Plant performance and provides the guaranteed performance ratio and plant availability calculation along with detail calculation and losses assumptions. The *Contractor* uses industry standard methods for carrying out yield and performance ratio calculations and demonstrates the basis of the calculations.
- i) The *Contractor*, as part of the design, takes into account all requirements as stipulated in the South African Grid Code for renewables. The *Contractor* ensures that design and construction of the PV Plant complies with current standards and statutory obligations arising from current legislation and regulations, including statutory legislation and codes of practice, and relevant South African and international standards.
- j) The *Contractor* ensures compliance with all applicable health and safety regulations at all times during design, construction and operation of the PV Plant in accordance with OHSAS 18000 and in accordance with the Eskom Health and Safety Specification provided in the Contract
- k) 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.
- l) The *Contractor* designs the PV Plant with due consideration to the minimisation of lifecycle costs (achieving an optimal balance between delivered kW, kWh, reliability, life cycle cost, maintainability, and overall cost effectiveness).
- m) The *Contractor* designs the PV Plant with due consideration to offering a network configuration that maintains adequate resilience at acceptable cost.
- n) The Systems is designed for ease of future deconstruction and recycling and be designed for disassembly with an associated end of life waste management plan.
- o) 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.
- p) The *Contractor* reviews, validates and subsequently assumes responsibility for the scope and accuracy of any such data relevant to completion of the *works* provided by the *Employer* and to be relied upon by the *Contractor* and be responsible for planning, specifying and executing any additional site investigations required in order to satisfy itself that the required level of scope and accuracy of data and analysis has been obtained, so as to not in any way affect the performance of its obligations.

CONTROLLED DISCLOSURE

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.
- 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 PV Plant and maintenance of the PV Plant throughout the 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) Ensures that, where possible, all materials used are recyclable.
- i) 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.
- j) Does not use any materials or substances that support mould, bacterial growth or vermin or cause objectionable odours under service conditions.
- k) 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.
- l) Ensures materials and products are appropriately CE/UL marked or SABS approved.
- m) Follows manufacturers' instructions on the use of materials and products.
- n) Selects materials & products with regard to standardisation and availability of spare parts and for ease of maintenance.
- o) Ensures the same manufacturer is used for materials or products of a similar type and that identical parts of similar products are interchangeable.
- p) Ensures that materials and components are transported and stored in accordance with manufacturer's guidelines.
- q) Does not use plant and equipment prior to Handover other than for testing, commissioning and demonstration.
- r) Provides suitable packaging for the protection of all materials and equipment during delivery, storage, and where exposed to damage on site. The *Contractor* returns re-usable packaging to the supplier. The *Contractor* takes particular care to protect and maintain plant and equipment delivered early.
- s) Examines materials and products supplied when delivered to site and immediately prior to installation. The *Contractor* replaces any damaged or faulty materials or products.
- t) Stores all materials on raised boarded platforms under weatherproof covers and/or according to manufacturers' specifications.

CONTROLLED DISCLOSURE

- u) Protects all materials and equipment which may be exposed to damage, inclement weather, or ultra violet light.
- v) Ensures that sensitive plant and equipment items are not exposed to dirt or dust at any time to maintain manufacturers' warranties and long term reliability.
- w) Repairs any damage to finished materials and equipment prior to handover of the PV Plant.
- x) Maintains the minimum level of spare parts (defined in **Appendix E**) throughout the maintenance period and provides to the *Project Manager* prior to the handover of the PV Plant.

CONTROLLED DISCLOSURE

3.2 CIVIL WORKS

3.2.1 Introduction

- a) This section describes the following:
 - 1) The building and civil *works* activities which are within the scope of the *Contractor*.
 - 2) Civil Works Information and designs and all necessary interface requirements that are provided by the *Contractor*.
- b) The *Contractor* ensures that all buildings, structures, cable trenches/routings, internal roads, fencings and service routes which are incorporated in this contract are functionally and efficiently located and that each building/component is sized for optimum space usage.
- c) The *Contractor* submits the design calculations/drawings of the building/civil items which are within this scope of work for review, acceptance and comments by the *Project Manager*.
- d) No construction is started prior to acceptance by the *Project Manager*. The *Project Manager* provides comments within 5 working days after the design is submitted by the *Contractor* to the *Project Manager*.

3.2.2 Scope of Work

3.2.2.1 General

- a) This specification describes the following:
 - 1) The detailed geotechnical investigation performed by the *Contractor*.
 - 2) The detail design, procurement and construction of all civil *works* which includes the foundation, mounting structure, drainage, MV Cabin, O&M Building, PV Plant substation, Power evacuation line, Ring roads, Internal roads, borehole system, Fencing and security systems.
 - 3) The supply of detailed design, construction drawings, method statement, design report and construction specification for the construction of the PV Plant, civil structures, foundations, buildings, roads and all other associated supporting structures.
 - 4) Corrosion protection and design of the finishes of the plant and equipment in accordance with the relevant norms and standards.
 - 5) All necessary interface requirements and liaison provided by the *Contractor*.
- b) 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 included by the *Contractor* and submitted to the *Project Manager* for acceptance. The *Contractor* clearly indicates the proposed scope regarding these additional items.
- c) The design, procurement and execution of all civil *works* is performed by the *Contractor* according to the applicable norms and standards and approval on any permits but not limited to Environmental Permit and Water Use License Permit.

3.2.2.2 Preparation and Site Establishment Phase

- a) The *Contractor* is responsible for all site preparation and site established required for the construction of facilities.

CONTROLLED DISCLOSURE

- b) The *Contractor* liaises with third parties that have access to Site.
- c) The *Contractor* is responsible for site preparation, e.g. Clearing and grubbing, dust control, excavation and backfilling, grading, levelling, earth moving, soil improvement, dredging, relocation of any cables, pipes present on site etc.;
- d) The *Contractor* is responsible for providing site drainage and sewage drainage systems;
- e) The *Contractor* is responsible for providing construction facilities including to, but not limited to, provisions for temporary *Contractor's* office, warehouse, toilets, workshop for site construction purpose, vehicles, mobile equipment, temporary power generators, electricity, water and any other provisions required for site preparation and construction
- f) The *Contractor* performs surface grading (if required) for site establishment and construction of facilities.
- g) The *Contractor* demolishes and removes all temporary facilities upon the Substantial Completion date including restoration of areas.

3.2.2.3 Design Phase

- a) Services provided by the *Contractor* in the design phase include:
 - 1) Complete design in accordance with the requirements of this specification.
 - 2) Design of PV modules mounting structures, foundations, O&M building, PV Plant substation, Ring roads, internal roads, MV Cabins, Power Evacuation structures and all other associated supporting structures.
 - 3) Geotechnical investigation in order to determine the foundations and mounting structure solution. The solution on foundation is according to approved permits (Environmental and Water Use License).
 - 4) Method statements for the installation of the foundations and mounting structures.
 - 5) Sizing and optimizing of the different components.
- b) All calculations relating to the civil work and all drawings are prepared and submitted to the *Project Manager* for review and acceptance. Calculations are arranged in a logical sequence and include such sketches and annotations as may be required to make them self-explanatory.
- c) Calculations clearly identify the subject of the calculations and include, but are not be limited to the following information:
 - 1) Project name
 - 2) *Contractor's* name
 - 3) Contract No.
 - 4) Date of calculation
 - 5) Revision No.
 - 6) Name of the item
 - 7) Page No.
 - 8) Assumptions used for design purposes
 - 9) Codes and standards used
 - 10) Computer programmes used
 - 11) Loading imposed by structures, plant and equipment during the erection, commissioning, operation and maintenance

CONTROLLED DISCLOSURE

-
- 12) Safety factors and combinations of loads used
 - 13) Calculations of all components
 - 14) Settlement of plant and equipment foundations
 - 15) Reference sources (including text books and design manuals used)
 - 16) Reference to the appropriate drawing
 - 17) Selected materials and finishes
 - 18) Manufacturer's technical specifications
- d) The foundation and PV mounting structures are designed for the worst combination of dead loads, construction live loads, plant loads, impact and dynamic effects due to operation of plant, maintenance loads, wind loads and temperature effects.
 - e) Drawings prepared by the *Contractor* include complete construction details including:
 - 1) General arrangement layouts
 - 2) Foundation layouts
 - 3) Layouts and sections of the different components
 - 4) Reinforcements drawings and schedules
 - 5) Construction joint schedules
 - 6) Details of embedded parts
 - 7) Details of the PV mounting structure and fixing
 - 8) Structural steel detailing and corrosion protection
 - 9) Details of all plinths, openings, box-outs, holding down arrangements, grouting, connections etc. required for plant and equipment.
 - 10) As built drawings
 - f) The *Contractor* is responsible for the detail design of the *works* and is responsible for ensuring that the design satisfies the structural, dynamic, seismic, acoustic, hydraulic, safety and environmental requirements of all permits and statutory obligations, as applicable in South African laws.
 - g) The *Contractor* submits design calculations, specifications and drawings of the civil items which are within his scope of work for comments to the *Employer and the Employer's representatives*.
 - h) All calculations are submitted in electronic format.
 - i) The *Contractor* supplies details of the computer programs used and any certification of approval by independent authorities are given for the programs used.
 - j) Drawings are submitted in Bentley Microstation compatible software and in acrobat pdf format.

3.2.2.4 Prior to Fabrication and Construction

- a) Electronic copies of all design calculations and electronic copies of all drawings are submitted for acceptance to the *Project Manager*, before the relevant fabrication or construction work is carried out. In addition one set of hardcopies of all drawings and calculations are provided. The *Contractor's* programme allows 5 working days for the *Project Manager's* acceptance and at least one revision following the *Employer's* initial comments.

CONTROLLED DISCLOSURE

- b) 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.
- c) A detailed Construction Work Programme, broken down to specific tasks and time allocated for completion of each task be submitted.

3.2.2.5 Fabrication and Construction

- a) The *works* provided by the *Contractor* include:
 - 1) Provision of all scaffolding, site crane, lifting equipment, etc. which are required by the *Contractor*.
 - 2) Supply, fabrication and erection of the foundations, O&M buildings, PV Plant substation.
 - 3) Construction of the PV modules mounting structures.
 - 4) Construction of security systems (fences, gates), ring roads, internal roads.
 - 5) Grouting of all structural steelwork. The *Contractor* provides details of materials and method of grouting including epoxy type non-shrink materials for acceptance by the *Employer*.
 - 6) Testing of the welding work to be done in accordance with SANS 1200H Section 7.3.
 - 7) Corrosion protection of the steel supporting structures, roofing material, bolts, nuts and embedded parts in accordance with SANS 121 and SANS 1200HC.
 - 8) Building Services—lighting, power supply and fire protection.
- b) All concrete are tested as follows: slump test and compressive strength test in accordance to SANS 3001. After placing and compaction, concrete is finished to a smooth, even surface by means of steel floats or other suitable equipment. Concrete is cured by protection against loss of moisture and rapid temperature changes.
- c) Steel framed structures are designed in accordance with SANS 10162, South African Steel Construction Handbook (latest edition). The structural design is carried out in accordance with structural design code of practices.
- d) Road design component criteria are to accommodate the construction and operation of the power station. The design of roads, storm water management and pavement design to conform to SANS 1200, TRH series for roads, THM series for roads, UTG series for roads, COLTO specification.

3.2.3 Civil Design Requirements

3.2.3.1 General

- a) The *Contractor* engages a competent qualified Professional Engineer experienced (minimum 5 years' experience) in the design of similar work to be fully responsible for the design.
- b) The *Contractor* complies with the South African codes for buildings and structures within his scope of *works* as well as the standards listed in section 3.2.4 and section 3.2.6 of this document.

CONTROLLED DISCLOSURE

3.2.3.2 Geotechnical Investigations

- a) The *Contractor* reviews the existing geotechnical investigations (**Appendix A02**), performed by the *Employer* as a part of Environment Impact Assessment (EIA) for the Project.
- b) The *Contractor* performs the detail geotechnical investigations which is the basis for foundation design for the Project. Such geotechnical report is provided to the *Project Manager* for review and acceptance.

3.2.3.3 Foundations

- a) The *Contractor* designs, procures and construct the foundation for PV module mounting structure and for all buildings and civil works according to the results based on detailed geotechnical investigation.

3.2.3.4 Mounting Structures

- a) The *Contractor* designs, procures and construct the suitable mounting structure according to geotechnical study and according to Environmental permit and Water Use License Permit.
- b) The mounting structure is of ground mounted, fixed type and facing perfect North. The structure withstands all possible static, dynamic and seasonal load at site condition.
- c) All PV mounting structures are off-the-shelf products as much as possible. Engineered solutions are only allowed for specific circumstances only after consultation with the *Project Manager*.
- d) The proposed mounting structures (product) have proven track record and the product has been installed in PV projects for more than 1 MW capacity.
- e) The mounting structures are designed for optimum PV module orientations. The tilt angle is between 20°– 30° and azimuth at perfect north.
- f) The row to row distance is selected to minimize the shading losses. The row – row shading losses are not more than 2.5%. The *Tenderer* provides supportive calculation to verify row to row shading loss.
- g) The mounting structure is designed for minimum 25 years of operation and the *Contractor* provides minimum 10 years as warranty on material/product.
- h) The *Contractor* provides the mounting structure solutions which is efficient, cost effective and reliable. The design reduces installation time and material waste.

3.2.3.5 MV Cabin

- a) The *Contractor* designs, procures and construct the suitable MV cabin for the Project, according to recommendation from inverter manufacturer (if applicable).
- b) The MV cabin includes proper fire protection, lighting and ventilation system.

3.2.3.6 O&M Building

- a) The *Contractor* designs, procures and constructs the O&M building, according to indicative layout presented in **Appendix C03**.
- b) The O&M Building houses minimum of control room with office space, server room, spare parts room, kitchen for O&M staff, toilets (ladies and gents separately).
- c) The *Contractor* ensures that space for each section (room or partition) in O&M building is sufficient enough for its purpose.

CONTROLLED DISCLOSURE

- d) The *Contractor* designs O&M building according to ergonomic principles (Eskom standard 240-56355808 Ergonomic Design of Power Station Control Suite Guideline) and sound solar PV Plant practice
- e) The O&M building include proper fire protection and ventilation systems according to requirement set in section 3.4, 3.7 and 3.8 of this document.
- f) The O&M building is equipped with normal florescent lighting, as well as essential lighting with battery pack backup in case normal lighting fails. The minimum lux level is as per OHS Act.
- g) The *Contractor* considers Eskom Architectural technical specification 240-56364535 to select the appropriate material for O&M building.

3.2.3.7 Access Roads, Ring Road and Internal Roads

- a) The *Contractor* designs, procures and constructs suitable the ring road (perimeter road) and internal roads for providing access and security during construction and operation.
- b) The *Contractor* uses the existing road for access to the site and maintains (if required) during the construction and operation of the Project.
- c) The design must be according to approved Environmental permit and Water Use License permit.
- d) The *Contractor* considers the top soil to be removed during construction process as low as possible and uses the existing roads inside the site area as much as possible.
- e) The road design provides sufficient slope (camber 2%) for drainage of rain water and must include the proper drainage system.
- f) The ring road (perimeter road) is wide enough to provide sufficient access to heavy trucks during construction and maintenance of the Project. The width of the ring road is around 4.5 m width. The internal roads provide sufficient access to Inverter, MV cabin, O&M building, PV Plant Substation, Meteorological stations, and any civil infrastructure built for the Project. The indicative site layout is in **Appendix C01**.
- g) The design of roads, storm-water management and pavement design to conform to SANS 1200, TRH series for roads, THM series for roads, UTG series for roads, COLTO specification

3.2.3.8 PV Plant Substation

- a) The *Contractor* designs, procures and constructs PV Plant Substation according to indicative layout presented in **Appendix C04**.
- b) The PV Plant substation houses MV Switchgear, 2 × Auxiliary Transformer and 2× Battery Tripping Units.
- c) The *Contractor* considers the suitable cable trenches inside the PV Plant substation.
- d) The *Contractor* designs PV Plant substation according to ergonomic principles (Eskom standard 240-56355808 Ergonomic Design of Power Station Control Suite Guideline) and sound solar PV Plant practice.
- e) The *Contractor* ensures that PV Plant substation has adequate fire protection and ventilation systems according to requirements defined in this document.
- f) Equipment door is a standard substation double door with minimum height of 3000mm, including a detachable panel to cater for equipment entry, 1600mm width while the personnel door is a single door with minimum dimensions of 2032mm height and 800mm width. All doors are fire doors with, at least, a two hour fire rating and are equipped with automatic closer and locks which

CONTROLLED DISCLOSURE

a master key is made available to all doors switchgear room. The doors are equipped with a "quick release mechanism" for quick emergency evacuation.

- g) The inside surface of the wall are plastered and painted with a fire retardant paint.
- h) Switchgear room floor is of reinforced concrete, finished, smooth and level. Self-leveling epoxy or granolithic screed is used as the final coat on the substation floor. The floor colour sequence is finalized with the *Employer*.
- i) The substation room is equipped with normal florescent lighting, as well as essential lighting with battery pack backup in case normal lighting fails. The minimum lux level is as per OHS Act.
- j) The *Contractor* considers Eskom Architectural technical specification 240-56364535 to select the appropriate material for Substation building.

3.2.3.9 Drainage

- a) The *Contractor* designs, procures and constructs suitable drainage system for the site according to approved Environmental permit and Water Use License permit.

3.2.4 Construction Specifications

- a) All civil engineering construction work complies with the requirements of SANS 1200: Standard Specification for Civil Engineering Construction.
- b) All steel materials supplied and erection of the steelwork comply with the requirements of SANS 2001 – CS1:2012 Ed.1.01 – Construction works Part CS1 – Structural steel works.
- c) SANS 2001 – Construction Works – Part CC1 – Concrete Works (Structural)
- d) For surface treatment of steelwork provided under this contract see SANS 121: 2011 - Hot dip galvanized coatings on fabricated iron and steel articles - Specifications and test methods and SANS 1200HC: 1988 - Standardized specification for civil engineering construction Section HC: Corrosion protection of structural steelwork.
- e) All buildings comply with the requirements of SANS 10400: National Building Regulations.
- f) All buildings *works* comply with the requirement of the Model Preamble for Trades (1997) as issued by the Association of South African Quantity Surveyors.

3.2.5 Project Co-Operation

- a) The *Contractor's* attention is drawn to the work done by others, working on the project, prior to and simultaneously. Close co-operation, exchange of information, careful scheduling and planning on a continuous basis is required to minimise interference and to ensure co-ordination between designs and good working practices are maintained at all times.
- b) In addition the *Contractor* is required to work continuously with the *Employer*, *Employer's representative* and power station in identifying, assessing, monitoring and managing interface issues. Where change is required these items are to be included in the risk register, such changes are only implemented by means of notification to the *Employer and the Employer's representatives*.

3.2.6 Codes and Standards

All civil engineering design work complies with the following standards:

CONTROLLED DISCLOSURE

- a) SANS 10400 - Code of Practice – The Application of the National Building Regulations
- b) SANS 10100 – The structural use of concrete.
- c) SANS 10160 – Basis of structural design and actions for buildings and industrial standards.
- d) SANS 10162-1 – The structural use of steel Part 1: Limit states design of hot-rolled steelwork
- e) SANS 10162-2 – The structural use of steel Part 2: Limit states design of cold-formed steelwork
- f) SANS 10162-4 – The structural use of steel Part 4: The design of cold-formed stainless steel structural members
- g) SANS 10021 Ed4.0 – The water-proofing of buildings (including damp-proofing and vapour barrier installation
- h) SANS121:2011 Ed2 – Hot dip galvanized coatings on fabricated iron and steel articles - Specifications and test methods
- i) SANS 2001 – CS1:2012 Ed.1.01 – Construction works Part CS1 – Structural steel works.
- j) SANS 1921-3:2004 Ed.1 – Construction and Management requirements for works contracts – Part 3 Structural steel works
- k) SANS 1200H: 1990 Ed3 – Standard specification for Civil Engineering construction - Structural steel work installation
- l) SANS 1200HC: 1988 - Standardized specification for civil engineering construction Section HC: Corrosion protection of structural steelwork
- m) SANS 2001 – Construction
- n) 240-56364535 – Architectural Technical Specification for structures and other building
- o) 240-56364545 – Structural design and engineering standard
- p) 240-56364542 – Standard for Reinforced concrete foundations and structures

CONTROLLED DISCLOSURE

3.3 ELECTRICAL WORKS

This section defines the electrical *works* for the Grootvlei PV Plant.

3.3.1 PV Capacity

- a) The *Contractor* designs the PV capacity as much as possible to cover the preferred area of installation as shown in Figure 3-2 and indicative site layout in **Appendix C01**.
- b) The *Contractor* uses the area for design and installation of PV Plant according to Environmental permit and Water use license permit.
- c) The DC capacity to AC capacity of PV Plant is sized according to industry practice and considering local site condition.
- d) The DC capacity is the sum of nominal power of all modules (defined at STC) to be installed for the Project. The AC capacity is the sum of nominal power of all inverters (without derating) to be installed for the Project.
- e) The PV array sizing not to overload and overheat its corresponding inverter (than manufacturer's recommendation) at any time during the year. The ratio of DC to AC capacity is between 1.0 and 1.12.
- f) The *Contractor* designs the string size in such a way that inverter always operates within its MPP range throughout anytime in a year and throughout the project lifetime.
- g) The *Contractor* provides the PV capacity information according to requirements set in Tender technical schedules in **Appendix M**.

3.3.2 PV Modules

- a) The *Contractor* supplies and installs the PV Modules to achieve the specified levels of performance for the required design life of 25 years under the prevailing site environmental conditions, which be determined by the *Contractor*.
- b) PV Modules technology is either of crystalline silicon (c-Si) type or thin-film (TF) type. All PV modules supplied for the Plant are of the same type, size and from a single manufacturer.
- c) Modules to be reliable with a proven track record in performance, operation and obtaining long term debt (project finance). The *Contractor* ensures that PV modules are sourced from a Tier 1 manufacturer or complying with equivalent the track record. (Tier 1 in this context refers to the Tier 1 list of Bloomberg New Energy Finance in the version as of the date of publishing of the tender documents. Locally assembled modules are considered Tier 1 if there is a clear train to one of the manufacturers of the BNEF Tier 1 lists). The *Contractor* provides the proof of offered module under Tier 1 List.
- d) The PV module type to have been deployed and in operation in field for similar ambient temperature ($\geq 35^{\circ}\text{C}$) for at least 12 months in commercial financed non-recourse projects.
- e) 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 respectively for 10 years and 25 years operational period.
 - 2) Workmanship guarantee: Product guarantee against manufacturing defects for a minimum of 10 years.

CONTROLLED DISCLOSURE

-
- f) The module rated peak power (defined at STC condition) is used to determine the peak power of the Plant. The peak power is the sum of the manufacturer's name plate data sheets for each individual module.
 - g) 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.
 - h) All modules to have valid certifications, according to requirements set in Tender technical schedules in **Appendix M**, issued by reputable testing institutions according to IEC and other standards.
 - i) The *Contractor* is responsible to decide the module arrangements to minimize the losses due to mismatching. The *Contractor* uses proper sorting method and only modules from the same set is used in in the same string.
 - j) The quality of equipment supplied is controlled by the *Contractor* to meet the guidelines for engineering design included in the standards and codes listed.
 - k) All transportation, storage, handling and installation of the modules to be in accordance with the specifications from the manufacturer, as to not to void the module manufacturer's warranty.
 - l) The *Contractor* verifies the quality of PV modules according to the requirements set in inspection, test and commissioning section of this document.
 - m) The *Contractor* provides PV modules complying with the minimum specific technical requirement set in Tender technical schedules in **Appendix M**.

3.3.3 DC Combiner box

- a) The DC combiner boxes are designed for use for external condition with a design lifetime of minimum 25 years.
- b) The combiner box includes string fuse for each string. The fuse rating is sized according to the requirement from module and inverter manufacturer.
- c) The DC combiner box includes lightning current and overvoltage surge arrester.
- d) The DC combiner box is includes array on-load disconnect switch, which is accessible without opening the combiner box. This switch allows for isolating array connected to box for maintenance and emergency purpose and is lockable.
- e) The combiner boxes are equipped with sun shields where exposed to direct sunlight. To prevent overheating inside the boxes, reduced terminal occupancy is considered. The place of installation location must be easily accessible and offer a secure base for working on the device.
- f) The cable labelling and single line diagram of connections inside the combiner box is kept on each combiner box.
- g) The combiner boxes (only primary combiner boxes if the design considers the secondary combiner boxes) include the string monitoring system which communicates to CMS server.
- h) The combiner boxes comply with the minimum specific technical requirement set in Tender technical schedules in **Appendix M**.

CONTROLLED DISCLOSURE

3.3.4 DC Fuse Box

- a) In between combiner box and inverter, fuse boxes serve as combiner of several primary/secondary combiner box outputs to an (sub-) array cable (connection in parallel).
- b) The fuse box includes fuse for each input from combiner box.
- c) The fuse boxes are equipped with sun shields where exposed to direct sunlight. To prevent overheating inside the boxes, reduced terminal occupancy is considered. The place of installation location must be easily accessible and offer a secure base for working on the device.
- d) The DC Fuse boxes comply with the minimum specific technical requirement set in Tender technical schedules in **Appendix M**.

3.3.5 Inverters

- a) The *Contractor* selects Inverters with proven track records in terms of performance and operation.
- b) The *Contractor* provides an inverter arrangement that gives overall optimal energy yield over the life of the Project, taking into account the site conditions and the proposed module layouts and shading.
- c) All inverters installed are of same type, size and from a single manufacturer. The inverter manufacturer complies with followings
 - 1) Has been producing inverters for last five years,
 - 2) Has minimum annual production capacity of 50 MW,
 - 3) Has experience in minimum one utility scale PV project capacity more than 5 MW with proposed inverter type or series.
- d) Inverters selected for the Project conform to the following specifications
 - 1) Each inverter has a minimum nominal capacity (without deration) of 250 kVA,
 - 2) Inverter is selected with respect to local climatic and environmental condition and is equipped to operate in high temperature regions,
 - 3) The inverter type or series offered for the Project has been deployed and in operation on field (with ambient temperature up to $\geq 35^{\circ}\text{C}$) in past 12 months,
 - 4) The inverter power is not derated for the temperature range between -10°C and $+45^{\circ}\text{C}$.
- e) Inverters selected for the Project has a minimum of 10 years product guarantee against manufacturing defects.
- f) The *Contractor* confirms the inverter manufacturer's warranties for the site specific environment and installation type. The *Contractor* also mentions if the inverter warranties can be extended. Possibility on extension of warranties is preferred.
- g) The *Contractor* provides the list of spare parts required for the operation of inverter over 25 years period, recommended by the inverter manufacturer.
- h) The inverters complies with all relevant national and international certificate labels, according to requirements set in Tender technical schedules in Appendix M.
- i) Inverters meets the following general requirements:
 - 1) Due to maintenance reasons and a conservative spare part approach, inverter of the same type and size from the same manufacturer is deployed over the whole project.

CONTROLLED DISCLOSURE

- 2) Inverters are equipped with communication capabilities as required by the Control and monitoring system (CMS); all inverters are able to be controlled / supervised by the same software or CMS system presented in this document.
- 3) Inverters comply with South Africa Grid Code requirements for renewables, and include Anti-islanding, Surge protection (AC and DC) and other protections.
- 4) Inverters are provided with lockable DC disconnect switch and AC disconnect switch for isolations.
- j) 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.
- k) The quality of equipment supplied is controlled by the *Contractor* to meet the guidelines for engineering design included in the standards and codes listed. All transportation, storage, handling and installation of the inverters are in accordance with the specifications from the manufacturer, as to not to void the inverter manufacturer's warranty.
- l) The quality of Inverters is verified according to the requirements set in inspection, test and commissioning section of this document.
- m) The inverters comply with the minimum specific technical requirement set in Tender technical schedules in **Appendix M**.

3.3.6 MV Cabin (Inverter Transformer Shelter)

- a) The MV Cabin is a shelter which houses inverters, LV to MV (6.6 kV) step up transformer, cabin switchgear and MV circuit breakers.
- b) Each MV Cabin composes of at least one or more inverters, a step-up transformer and its corresponding switching and protection equipment (Ring Main Unit – RMU). The minimum capacity of each block is 1 MVA.
- c) Inverter(s) are connected to the step up transformer via AC disconnect switch for isolation and protection purpose. LV auxiliary supply to the cabin is provided by LV/MV transformer inside the cabin.
- d) The MV cabin is approved by the inverter manufacturer and does not violate any warranties and guarantees for inverter.
- e) The inverter cabin includes the proper cooling/ventilation system allows inverter to operation always within manufacturer's recommended operating range without deration of output (power, efficiency).
- f) The proposed MV cabin for the Project has already been deployed with utility scale PV projects with capacity minimum of 10 MW.
- g) MV Cabins selected for the Project have a minimum of 10 years product guarantee against manufacturing defects.
- h) The MV cabin is designed and protected to withstand in outdoor conditions for 25 years period and the cabin includes fire protection system.
- i) Due to the POC configuration, which requires two separate interconnection points at 6.6kV Station Boards 1 and 2 Maintenance isolator boards, the MV Cabins are arranged into two sets of 4MVA which are further connected to the PV Plant substation (switchgear room). Indicative layout for MV cabin configuration is presented in **Appendix C02**.

CONTROLLED DISCLOSURE

- j) The MV cabin selected for the Project complies with the minimum specific technical requirement set in Tender technical schedules in **Appendix M**.

3.3.6.1 LV/MV Step Up Transformer

- a) The *Contractor* designs, manufacturer, supplies and installs all indoor MV Step –Up Transformer for the required design life under the prevailing site environmental conditions, which is to be determined by the *Contractor*.
- b) The transformer has an assigned rated power for each winding which is marked on the rating plate. The transformer is fully rated when supplied in an enclosure. The rated power refers to continuous loading. This is a reference value for guarantees and tests concerning load losses, temperature rises and short-circuit impedance.
- c) The LV/MV Step up transformer step up the LV inverter output voltage to 6.6kV medium voltage
- d) The transformer has three phases and operates at 50Hz.
- e) The LV/MV transformer design is the dry core type suitable for indoor use with AN cooling
- f) The transformer design and testing conforms to SANS 60076-11.
- g) The LV/MV transformer is designed to deliver full rated power continuously on any tapping within the specified tapping range under the following conditions:
- 1) With the voltage of the untapped winding at normal, without the need to derate the transformer at the extreme tap positions and without exceeding IEC temperature limits
 - 2) With voltage applied up to 10% in excess of the rated tapping voltages and without injurious overheating
- h) Transformer tap change is provided with a ganged off-load tap changer operated by means of an external handle which can be pad-locked in each operating position. This switch has a rotary motion of operation. The tap changer is indelibly marked to indicate the tapping position corresponding to the diagram plate.
- i) The tapping range is $\pm 5\%$ in steps of 2.5% (5 tap positions).
- j) The standard product warranty against any manufacturing defects has a minimum of 5 years.
- k) The transformer is designed with adequate transformer protection with the following as minimum: restricted earth fault protection, over current protection, thermal overload protection, over voltage protection.
- l) The rating plate fitted to the transformer is provided with a rating plate of weatherproof material fitted in a visible position. The information on the plate is as per 9.1 of SANS 60076-11.
- m) The *Contractor* provides a full set of type test reports along with operation and maintenance manual for the transformer. The O&M manuals are in addition to any instructions or parts lists packed with or attached to the equipment when delivered.
- n) The LV/MV transformer selected for the Project complies with the minimum specific technical requirement set in Tender technical schedules in **Appendix M**.

3.3.7 Ring Main Unit (RMU 6.6 kV) - MV Switchgear in MV Cabin

- a) The RMU is used to connect to other adjacent MV cabins and is used for MV cabin isolation and protection, as presented in indicative layout in **Appendix C02**.

CONTROLLED DISCLOSURE

-
- b) The *Contractor* designs, manufactures, supplies and installs all RMU switchgear in the MV Cabins for the required design life under the prevailing site environmental conditions, which is determined by the *Contractor*. The RMU is designed according to SANS 1874 and consists of the following switchgear:
- 1) MV CB for transformer protection
 - 2) Cable disconnect switches
 - 3) Earth Switches
- c) Adequate interlocking is designed for the CBs, disconnect switch and the earth switch,
- d) The CBs, disconnect switch and earth switch have provision to be locked in the ON/OFF position.
- e) The CBs, disconnect switches and earth switches are capable of being operated local and on remote.
- f) The control voltages for opening and closing commands and for the operating mechanism motor(s) are sufficiently designed by the *Contractor*.
- g) The RMU is internal arc classified to be AFLR in accordance with SANS 62271-200.
- h) The RMU complies with the minimum specific technical requirement set in Tender technical schedules in Appendix M

3.3.8 PV Plant Substation

- a) The *Contractor* designs the PV Plant substation according to indicative layout presented in **Appendix C02** and **Appendix C04** and the PV Plant substation houses the following electrical components
- 1) PV Plant switchgear,
 - 2) 2 x step down (6.6/0.4 kV) auxiliary transformers,
 - 3) auxiliary supplies distribution boards (DB)
 - 4) 2 x Energy Meters,
 - 5) 2 x Battery Tripping Units (BTU).

3.3.8.1 PV Plant MV Switchgear

- a) The following MV switchgear are housed at the PV Plant substation:
- 1) 2 x 6.6kV incomer circuits from the PV Plant MV cabins,
 - 2) 2 x auxiliary supply feeders to the 6.6/0.4kV auxiliary transformers,
 - 3) 1 x buscoupler,
 - 4) 2 x outgoing feeders to the POC at the 6.6kV station board 1 and 2 maintenance isolator boards.
- b) The indicative MV switchgear is presented in **Appendix C02** and **Appendix C04**. MV switchgear configuration is made in following manner
- 1) The switchgear is split into two busbars using the bus coupler
 - 2) The PV Plant incomer 1 feeds busbar 1 of the switchgear and PV incomer 2 feeds busbar 2 of the switchgear. The bus coupler is used to connect the two switchgear busbars under certain operating condition of the plant,

CONTROLLED DISCLOSURE

- 3) During normal day operation, busbar 1 outgoing feeder (PUC1) sends power to the POC Station board 1 maintenance isolator board and busbar 2 outgoing feeder (PUC2) sends power to the POC Station board 2 maintenance isolator board independently. When the inverters are off (e.g. at night), the power is fed back from the POC to the PV Plant via the same interconnection lines.
- c) The PV Plant protection is provided as per section 3.6. of the Eskom standard of interconnection of embedded generation (240 – 61268576). Anti-islanding protection is provided at PUC1 and PUC2 outgoing feeders. The whole PV Plant complies with minimum protection requirements stated in the standard. Switchgear and auxiliaries is properly rated, protected and earthed according to SANS 1874.
- d) Adequate interlocking is designed for the CB, disconnect switch and the earth switch
- e) The CB, disconnect and earth switch have provision to be locked in the ON/OFF position.
- f) The CB, disconnect and earth switch is capable of being operated local and on remote.
- g) The control voltages for opening and closing commands and for the operating mechanism motor(s) are sufficiently designed by the *Contractor*.
- h) The MV Switchgear is internal arc classified to be AFLR in accordance with SANS 62271-200.
- i) The MV Switchgear installed in PV Plant substation for the Project complies with the minimum specific technical requirement set in Tender technical schedules in **Appendix M**.

3.3.8.2 Auxiliary Transformer (MV/LV Step-Down 6.6/0.4 kV)

- a) The auxiliary transformer for the Project is Dry type transformer. The *Contractor* is responsible for complete design, supply, manufacture, factory testing, delivery, offloading, installation, testing and commissioning of the transformers.
- b) The transformer assigned rated power for each winding is marked on the rating plate. The transformer is fully rated when supplied in an enclosure. The rated power refers to continuous loading. This is a reference value for guarantees and tests concerning load losses, temperature rises and short-circuit impedance.
- c) The transformer is designed in accordance with SANS 60076-11, Power Transformers: Dry Type transformers.
- d) The auxiliary transformer is designed to deliver full rated power continuously on any tapping within the specified tapping range under the following conditions:
 - 1) With the voltage of the untapped winding at normal, without the need to derate the transformer at the extreme tap positions and without exceeding SANS 60076 temperature limits
 - 2) With voltage applied up to 10% in excess of the rated tapping voltages and without injurious overheating
- e) Transformer tap change is provided with a ganged off-load tap changer operated by means of an external handle which can be pad-locked in each operating position. This switch has a rotary motion of operation. The tap changer is indelibly marked to indicate the tapping position corresponding to the diagram plate.
- f) The tapping range is $\pm 5\%$ in steps of 2.5% (5 tap positions) as specified in technical bid form.

CONTROLLED DISCLOSURE

- g) Two 6.6/0.4kV auxiliary transformers, one on each busbar of the PV Plant MV switchgear is installed to supply power to the PV Plant auxiliaries according to indicative layout presented in **Appendix C-02**. Each transformer is able to supply 100% of the auxiliary loads.
- h) The auxiliary transformers are provided with the following as minimum: restricted earth fault protection, over current protection, thermal overload protection, over voltage protection adequate protection on both the MV and LV sides. The LV DB incomer circuit breakers have electrical and mechanical interlock changeover switch. The auxiliary supply wiring and circuit protection comply with all applicable standards including but not limited to SANS 10142-1 and SANS 556-1.
- i) The transformer has three phases and operates at 50Hz.
- j) Loading capabilities follows all applicable codes and standards.
- k) The rating plate fitted to the transformer is provided with a rating plate of weatherproof material fitted in a visible position. The information on the plate is as per 9.1 of SANS 60076-11
- l) The standard product warranty against any manufacturing defects has a minimum of 5 years.
- m) The *Contractor* provides a full set of type test reports along with operation and maintenance manual for the transformer. The O&M manuals will be in addition to any instructions or parts lists packed with or attached to the equipment when delivered.
- n) The auxiliary transformer complies with the minimum specific technical requirement set in Tender technical schedules in **Appendix M**.

3.3.8.3 Auxiliary Supplies Distribution Board (DB)

- a) The auxiliary supply distribution board supplies PV Plant auxiliary loads and is fed from the two auxiliary transformers 1 and 2. The auxiliary DB bus bar is split into two incomer supplies from the two auxiliary transformers and interconnected via an electrical/mechanical changer over switch.
- b) The auxiliary transformers operate independent of each other and the changer over switch will only be closed when one of the incomer supply is out of service. The DB contains the following minimum equipment
 - 1) Two incomer main switches,
 - 2) Overvoltage protection and
 - 3) Electrical/mechanical change over switch
- c) The DB is installed in the switchgear room, as shown in indicative layout in **Appendix C-04**. The installation location must be easily accessible.
- d) Auxiliary loads include; HVAC, lighting, socket outlets, CMS, security systems (perimeter lighting, cameras, gate motors, etc.), battery tripping units (BTU), UPS, telephones, fire detection, meteorological stations etc.
- e) The auxiliary supplied distribution board complies with the minimum specific technical requirement set in Tender technical schedules in **Appendix M**.

3.3.8.4 PV Plant Energy Meters

- a) Two energy meters (one per switchgear section) are required for energy measurements at the PV Plant substation as shown in **Appendix C-02**.

CONTROLLED DISCLOSURE

- b) The metering and measurement requirements are as per Eskom Standard; 240-56359083; Metering and Measurement Systems for Power Stations in Generation Rev 02. Specifically, the accuracy class requirements are as per Table 02 of the same standard.
- c) Metering complies with section 3.7 of the Eskom standard of interconnection of embedded generators (240 – 61268576).
- d) The meters procured must be listed in the Eskom standard 240-56227589; List of electronic devices to be used on Eskom Power stations Rev 2.

3.3.8.5 Battery Tripping Units

- a) The *Contractor* designs, manufacturers, supplies and installs two (2) Battery Tripping Units for the required design life under the prevailing site environmental conditions at the switchgear room to power DC circuits for all the switchgear, which is determined by the *Contractor*.
- b) The battery tripping unit comprises of the battery and charger.
- c) The battery is of the sealed type.
- d) The battery has a minimum standby time of 4hrs.
- e) The charger output voltage is 220V DC.
- f) The BTU provides DC power to main 1 and main 2 protection circuits. All protection requirements are designed by the *Contractor*.
- g) The *Contractor* calculates and determines the battery capacities, the power rating for the chargers to suit the requirements of the equipment to be installed.
- h) The battery tripping units comply with the minimum specific technical requirement set in Tender technical schedules in **Appendix M**.

3.3.9 Cabling

- a) The design and installation of power and control cables and execution of associated work is in accordance with Eskom standard 240-56227443, Requirements for control and Power Cables for Power Stations. All AC cables comply with norm and standards, SANS 1507 and SANS 10142-1.
- b) All 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, weathering and UV radiation.
- c) All cables are uniquely numbered (permanent labelling) to facilitate later traceability & fault location. Circuits and cables are planned and installed to ensure accessibility and ease of maintenance.
- d) Electrical conductors are selected with an insulation level applicable to the system voltage for which they are used and ampacities suitable for the load being served. The type of cable used is determined by individual circuit requirements and individual equipment manufacturer's recommendations. Current carrying conductors are either copper or aluminium.
- e) To minimize the damage that can be caused by a cable fire, cables have insulations and jackets with non-propagating and self-extinguishing characteristics. These cables meet the flame test requirements.
- f) All exposed (to sun) wiring are clearly indicated as sunlight, or UV resistant

CONTROLLED DISCLOSURE

3.3.9.1 DC Cabling

- a) The *Contractor* designs for cable losses of under 1.5% on DC cable circuits except where other agreed with the *Employer*. Evidence of a detailed wiring loss analysis is submitted as part of the design submission.
- b) DC string, array and main cabling are selected and installed in such a way to prevent the risk of leakage currents. Single-core conductors are used for the enforcement of cable protection against outer impact.
- c) 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.
- d) Insulation and resistance measurements are carried out after every cable installation in order to locate any possible faults and records kept so that faults can be identified in future.
- e) DC cables may be directly buried and must have a minimum insulation that meets the code requirement for “wet locations.” Conduit will be used for transitions “entering” and “exiting” the cable trench to meet local code requirements for underground installations. Cable insulation levels are rated according to the maximum system voltage. Insulation and jacket materials on all DC conductors, regardless of location, are made from thermoset materials such as XLPE. No thermoplastic insulation or jacket materials are permitted for DC conductors. DC conductors installed in PVC conduit are acceptable.
- f) DC string cables are sized in accordance with the solar photovoltaic code requirements for “solar photovoltaic systems” and are rated according to the maximum system voltage. Cable insulation type is sunlight resistant, rated for wet locations, and have a temperature rating of 90° C or better. DC cables are sized accordingly taking into account any ambient temperature or conduit de-rating factors and voltage drop considerations.
- g) The minimum specific technical requirement for DC cabling is presented in Tender technical schedules in **Appendix M**.

3.3.9.2 DC Connectors

- a) Modules connectors and DC cables connectors will be compatible and from the same manufacturer throughout the whole PV Plant.
- b) The *Contractor* use cables with connectors which are contact-proof and designed to avoid corrosion.
- c) The minimum specific technical requirements for DC cabling is presented in Tender technical schedules in **Appendix M**.

3.3.9.3 AC Cabling

- g) The design and installation of power and control cables and execution of associated work are in accordance with Eskom standard 240-56227443, Requirements for control and Power Cables for Power Stations. All AC cables comply with norm and standards, SANS 1507 and SANS 10142-1 and 2.
- a) MV Cable defined in this section represents the cable connecting from MV cabin to the PV Plant Substation and from PV Plant Substation to the Point of Connection (POC).
- b) LV cabling connects the AC terminals of the inverters with Cabin transformers and also auxiliary loads.

CONTROLLED DISCLOSURE

- c) The *Contractor* designs, manufacturers, supplies and installs all cables for the required design life under the prevailing site environmental conditions, which is determined by the *Contractor*. Cable works is designed and installed in accordance with the latest edition of all applicable codes, standards and recommendations.
- d) Underground MV cables are protected against damage were they cross vehicle roads and are fastened adequately where they run in cable racks to avoid swinging and tension and durable mounted in such a way as to protect them from mechanical damage rodent attack, weathering and UV radiation.
- e) The cables are uniquely numbered to facilitate later traceability & fault location. Circuits and cables are planned and installed to ensure accessibility and ease of maintenance.
- f) The minimum specific technical requirement for MV and LV AC cabling is presented in Tender technical schedules in **Appendix M**.

3.3.10 Earthing

- a) The *Contractor* provides an earthing system for the PV Plant 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.
- b) The *Contractor* designs the earthing system in accordance with Solar PV industry best practice and in compliance with SANS 10200:1985 and SANS 10292:2001.
- c) Conductors utilized for earthing are appropriate for the site's soil conditions.
- d) The *Contractor* designs the station earthing grid for adequate capacity to dissipate heat from earth current under the most severe conditions in areas of high earth fault current concentrations, and in such a way that it is possible to maintain grid spacing to achieve safe voltage gradients.
- e) Major items of equipment, such as switchgear, transformers, inverters, relay panels, and control panels, have integral earthing buses connected to the station earthing grid.
- f) The perimeter fence is earthed at 10m intervals whenever it is less than 45m from the centre line of a transmission line
- g) The *Contractor* provides an earthing proposal during tender including but not limited to:
 - 1) A project specific earthing system diagram
 - 2) Data sheets of main products used
 - 3) Proposed test procedure
- h) The *Contractor* performs earthing calculations in accordance with applicable standards and submits to *Project Manager* for verification that step and touch potentials are within the acceptable limits. The *Contractor* determines the values used in the calculations through testing and not use typical values or estimates. The *Contractor* conducts tests on the earthing system to fully verify the safety of the site.
- i) The minimum specific technical requirements for Earthing are presented in Tender technical schedules in **Appendix M**.

CONTROLLED DISCLOSURE

3.3.11 Surge and Lightning Protection

- a) The *Contractor* carries out a risk assessment for lightning and installs an adequate lightning protection system.
- b) The *Contractor* designs the Lightning Protection system in accordance with the latest edition of the SANS 62305 standards.
- c) The *Contractor* provides a lightning protection system installation safety report is in accordance to SANS10313.
- d) The lightning protection system protects the whole PV plant including buildings, MV cabins, modules, structures, control and monitoring systems and any other electrical and mechanical equipment against damage caused by lightning strikes.
- e) The *Tenderer* submits proposals to the *Employer* for ensuring adequate design against lightning induced overvoltage risk.
- f) Overvoltage protection is installed at DC side as well as AC side of the inverter, DBs and within the PV arrays.
- g) The design of the DC system ensures that cables are kept in parallel and as short as possible, while cable loops are also avoided or restricted. Protection against direct strikes (direct strike lightning protection) is installed and coupling as a result of strikes elsewhere in the grid (indirect strike lightning protection) is taken into consideration and designed out of the system.
- h) The minimum specific technical requirement for surge and lightning protection is presented in Tender technical schedules in **Appendix M**.

3.3.12 6.6kV Overhead Line

- a) Two 6.6kV interconnection lines are constructed to evacuate power from the PV Plant substation to +01BCA 6.6kV Station Board 1 Maintenance Board and +02BCA 6.6kV Station Board 2 Maintenance Isolator Board respectively. The distance from the PV Plant to POC is approximately 2.5 km. The exact distance is verified by the *Contractor*.
- b) The interconnection line is combination of MV cables and MV overhead line. Underground cables are run for a shortspan from the PV Plant substation to tie into the overhead line.
- c) The 6.6kV MV cables are of adequate size and current carrying capacity and run from the overhead line termination point to the POC station board 1 and 2 maintenance isolator boards in existing cable trenches, cable racks and cable trays.
- d) The interconnection lines have differential protection and over voltage protection as per Eskom distribution requirements at both the PV Plant and at the point of interconnection.
- e) The *Contractor* designs and constructs the MV interconnection line according to the indicative layout of interconnection line is presented in **Appendix C-02**.
- f) The design of the overhead line follows all Eskom standards and the *Contractor* ensures that all requirements and standards are met.
- g) The design and execution of the overhead line is in accordance to SANS 10280; Overhead Power Lines for Conditions Prevailing in South Africa.
- h) The *Contractor* ensures compliance with all requirements and standards. The *Contractor* consults with the *Employer* for the design and construction of the overhead line, where the overhead line crosses High Voltage Lines minimum safety clearances and safe installation procedures are put in place before and are observed during stringing.

CONTROLLED DISCLOSURE

- i) Where indicated, shield wire protection against direct lightning strikes are installed and coupling as a result of strikes elsewhere in the grid (indirect strike lightning protection) is taken into consideration and designed out of the system.
- j) Insulators and wood path are to be utilized to increase the BIL so as to reduce the structure footing earthing requirement, furthermore, bonding is applied to control inter phase leakage currents
- k) The following is taken into consideration during design and construction
 - 1) The leveling of the holes and correct backfilling is very important – *Contractor* leaves bottom of holes level and compacted. Furthermore, correction for cross slope has been allowed in the design, however, detailed site interventions are required to ensure correct installations. Where these are identified, the *Contractor* is notified the project engineer and surveyor.
 - 2) Paint is applied to any cut surface of eyebolt or threaded rod.
 - 3) No Vibration dampers is fitted on shield wire
 - 4) Tensioning is performed with aid of a dynamometer. (The sag & tension sheets are supplied at the appropriate time in the project)
- l) **Special Note to the *Tenderer*:** The affected line section crosses under 400 kV and 88 kV lines and runs parallel to a 22 kV line. The appropriate care and safety precautions are to be exercised at all times.
- m) The additional minimum specific technical requirements for MV transmission line are presented in Tender technical schedules in **Appendix M**.

3.3.13 Overhead Line (OHL) Protection and Interlocking

- a) The Overhead Line (OHL) protection is designed for distance protection between the PV Plant overhead line feeders and the POC incomer PV Plant feeders.
- b) Optic fibre cable per feeder is used for the signal communication between the PV Plant substation and the POC.
- c) Zoning of the line is used to allow the CB closest to the fault to trip and inter trip with the CB furthest to the fault.
- d) Inter tripping is used as interlocking between the PV Plant and the POC
- e) Apart from distance protection local interlocking is provided for at the PV Plant feeder CB and POC CB

3.3.14 MV Switchgear at POC

- a) The Contractor designs, manufacturers, supplies and installs all indoor ABB MV switchgear for the required design life under the prevailing site environmental conditions at the Power Station +01BCA 6.6kV Station Board 1 Maintenance Board and +02BCA 6.6kV Station Board 2 Maintenance Isolator Board, which is determined by the Contractor.
- b) The panel extension design is according to SANS 62271-200-AC Metal enclosed switchgear and control gear for rated voltage above 1kV and up to and including 52kV
- c) Adequate interlocking is provided for the CB, disconnect switch and the earth switch
- d) The CB, disconnect switch and earth switch have provision to be locked in the ON/OFF position.
- e) The CBs, disconnect switches and earth switch are capable of being operated local and on remote.

CONTROLLED DISCLOSURE

- f) The control voltages for opening and closing commands and for the operating mechanism motor(s) are 220V DC from Power Station existing auxiliary supplies
- g) The new switchgear panels at the POC is rated the same as the existing switchgear with fault rating of 31.5kA.

3.3.15 Metering and Measurements at POC

- a) Three energy meters (2xmain and check) per board are required for energy measurements at the PoC as shown in **Appendix C-02**.
- b) One Quality of Supply (QoS) power quality meter per board is required as shown in **Appendix C-02**.
- c) The *Contractor* provides a complete metering solution including but not limited to CTs, VTs and CT and VT test Blocks. A separate metering panel is provided to house the energy and power meters.
- d) The metering and measurement requirements are as per Eskom Standard; 240-56359083; Metering and Measurement Systems for Power Stations in Generation Rev 02. Specifically, the Metering and Measurement arrangement is according to Table 01 of the standard and the accuracy class requirements is as per Table 02 of the same standard.
- e) The meter provides tariff metering, bi-directional energy measurements and power quality measurements.
- f) The meters procured must be listed in the Eskom standard 240-56227589: List of electronic devices to be used on Eskom Power stations Rev 2.
- g) The Energy meter and Power Quality meter communicates with the respective control and instrumentation devices. The minimum communication protocol is RS485.
- h) The energy meters must have bus interface capabilities using open published communication protocols, such as Modbus, DLMS COSEM or DP.
- i) For standardization, same type energy meters should be used at POC and at the PV Plant.

3.3.16 Grid Code Compliance

- a) It is the *Contractor's* obligation to ensure compliance to the Grid Connection Code for Renewable Power Plants (RPPs) Connected to the Electricity Transmission system (TS) or the Distribution System (DS) in South Africa Standard v2.8.
- b) Grid code compliance testing is done by the *Contractor* and witnessed and by a third party provided by the *Employer*.
- c) The *Contractor* performs fault level studies to ensure proper sizing of PV Plant equipment (e.g. PV Switchgear, Cabling, DBs, eathmats, etc.). The calculated steady state fault contribution per board at PoC is approximately 14kA.
- d) The *Contractor* performs dynamic and transient studies of the PV Plant coupled to the Grootvlei power station reticulation using Digsilent powerfactory model.

3.3.17 Codes and Standards

All equipment and services supplied comply with the standards listed below.

CONTROLLED DISCLOSURE

a) Electrical - General

- 1) SANS 10142-1 – The wiring of Premises – Part 1: Low voltage installation.
- 2) SANS 10142-2 – The wiring of Premises – Part 2: Medium voltage installation.
- 3) Grid Connection Code for Renewable Power Plants (RPPs) Connected to the Electricity Transmission system (TS) or the Distribution System (DS) in South Africa
- 4) 240-61268576: Standard for the Interconnection of Embedded Generation
- 5) NRS 048 – Electricity Supply - Quality of Supply

b) PV Modules

- 1) IEC 61215 Ed.2 - Crystalline silicon terrestrial photovoltaic (PV) module - Design qualification and type approval
- 2) IEC 61646, Ed.2 - Thin-film terrestrial photovoltaic (PV) modules - Design qualification and type approval
- 3) IEC 61730-1 Ed.1.2 - Photovoltaic (PV) module safety qualification - Part 1: Requirements for construction
- 4) IEC 61730 -2 Ed.1.0: Photovoltaic (PV) module safety qualification - Part 2: Requirements for testing
- 5) IEC 61701 Ed. 2 - Salt mist corrosion testing of photovoltaic (PV) modules
- 6) IEC 62716 Ed. 1 - Photovoltaic (PV) modules - Ammonia corrosion testing
- 7) IEC 60891 Photovoltaic devices - Procedures for Temperature and Irradiance Corrections to Measured I-V Characteristics
- 8) IEC 60904-1 Photovoltaic devices. Part 1: Measurement of PV I-V Characteristics
- 9) IEC 60904-2 Photovoltaic devices. Part 2: Requirements for Reference Solar Devices
- 10) IEC 60904-3 Photovoltaic devices. Part 3: Measurement Principles for Terrestrial PV Solar Devices with Reference Spectral Irradiance Data
- 11) IEC 60904-6 Photovoltaic devices – Part 6: Requirements for reference solar modules
- 12) IEC 60904-7 Computation of Spectral mismatch correction for Measurement of a PV Device
- 13) IEC 60904-8 Measurement of a Spectral response of a PV Device
- 14) IEC 60904-9 Solar Simulator Performance Requirements
- 15) IEC 60904-10, Photovoltaic devices - Part 10: Methods of linearity measurement
- 16) IEC 61829 Crystalline Silicon PV Array - On-Site Measurement of I-V Characteristics
- 17) IEC 61853: Performance testing and energy rating of terrestrial photovoltaic (PV) modules
- 18) IEC 60068-2-78, Environmental testing – Part 2-78: Tests – Test Cab: Damp heat steady state
- 19) IEC 60068-2-21, Environmental testing – Part 2-21: Tests – Test U: Robustness of terminations and integral mounting devices
- 20) IEC 61345, UV test for photovoltaic (PV) modules
- 21) IEC 62093, Balance-of-system components for photovoltaic systems - Design qualification natural environments
- 22) IEC 62548, Photovoltaic (PV) Arrays – Design Requirement

CONTROLLED DISCLOSURE

c) Inverters

- 1) IEC 62093 Ed. 1.0: Balance-of-system components for photovoltaic systems - Design qualification natural environments
- 2) SANS 62109-1 Ed 1.0: Safety of power converters for use in photovoltaic power systems - Part 1: General requirements
- 3) IEC 62109-2 Ed 2.0: Safety of power converters for use in photovoltaic power systems - Part 2: Particular requirements for inverters
- 4) IEC 62116 Ed 2.0: Utility-interconnected photovoltaic inverters - Test procedure of islanding prevention measures.
- 5) SANS 60730-1: Automatic electrical controls - Part 1: General requirements.
- 6) IEC 61683: Photovoltaic systems - Power conditioners - Procedure for measuring efficiency
- 7) SANS 61000 – 6 – 2, 3 and 4: Electromagnetic compatibility (EMC)
- 8) IEC 61727 Ed.2: Photovoltaic (PV) systems - Characteristics of the utility interface
- 9) Grid connection code for Renewable Power Plants (RPPs) connected to the electricity Transmission system (TS) or the Distribution system (DS) in South Africa Version 2.8.
- 10) IEC 60364-7-712 Electrical Installations of Buildings: Requirements for Special Installations or Locations – Solar Photovoltaic power supply systems
- 11) IEC 62103 Electronic equipment for use in power installations

d) Electrical Cabling

- 1) IEC 62053 Requirements for cables for use in photovoltaic systems 2Pfg1169” by TÜV
- 2) SANS 1507 Part 1: General - Electric cables with extruded solid dielectric insulation for fixed installations (300/500 V to 1900/3300 V)
- 3) SANS 1507 Part 2: Wiring Cables - Electric cables with extruded solid dielectric insulation for fixed installations (300/500 V to 1900/3300 V)
- 4) SANS 1507 Part 3: PVC Distribution cables - Electric cables with extruded solid dielectric insulation for fixed installations (300/500 V to 1900/3300 V)
- 5) SANS 1507 Part 4: XLPE Distribution cables – Electric cables with extruded solid dielectric insulation for fixed installations (300/500 V to 1 900/3300 V)
- 6) SANS 1507 Part 5: Halogen-free Distribution Cables - Electric cables with extruded solid dielectric insulation for fixed installations (300/500 V to 1900/3300 V)
- 7) SANS 1507 Part 6: Service cables - Electric cables with extruded solid dielectric insulation for fixed installations (300/500 V to 1900/3300 V)
- 8) SANS 10198 Parts 1-14 The selection, handling and installation of electric power cables of rating not exceeding 33 kV Part 1 to 14
- 9) SANS 1213 Mechanical Cable Glands
- 10) NRS 074- Part1 and Part 2 Low Voltage cables systems
- 11) 240-56227443: Requirements for control and power cables for power stations standard

e) Earthing, Lighting and Surge Protection**CONTROLLED DISCLOSURE**

- 1) IEC 60364-4-41 Low-voltage plants installation. Part 4-41 - Protection for safety – protection against shock
- 2) SANS 10313 – Protection against lightning
- 3) SANS 62305 – Earthing and Lightning Protection
- 4) SANS 10292 - Earthing of low-voltage (LV) distribution systems
- 5) SANS 1063 - Earth rods and coupling
- 6) SANS 10199 The design and installation of earth electrodes
- 7) IEEE 80 Earthing – Ground System Design
- 8) IEEE 665 - Guide for Generating Station Grounding
- 9) SANS 61312-3 - Protection against lightning electromagnetic impulse Part 3: Requirements of surge protective devices (SPDs)
- 10) SANS 62305-1 to 4 - Protection against lightning - Parts 1 to 4
- 11) SANS 10313 - Protection against lightning - Physical damage to structures and life hazard
- 12) SANS 10200 – Neutral earthing medium voltage industrial power systems
- 13) NRS 039 Part 1 and Part 2 - Surge arresters for use in distribution systems
- 14) IEC 61009 Residual current operated circuit-breakers with integral overcurrent protection for household and similar uses (RCBO's)
- 15) SANS 61024 – Protection of structures against lightning

f) **Metering and Measurements**

- 1) 240-62581162: Generation energy management and data acquisition System (EMDAS) standard
- 2) 240-56227589: List of electronic devices to be used on Eskom Power station standard
- 3) IEC 62053 Electricity metering equipment (A.C.) – particular requirements
- 4) IEC 61036 Alternating current static watt-hour meters for active energy
- 5) NRS 057/ SANS 474 Code of practice for electricity metering
- 6) 240-56359083: Metering and Measurement Systems for Power Stations in Generation Rev 02

g) **Performance Monitoring**

- 1) IEC 61724, Photovoltaic system performance monitoring - Guidelines for measurement, data exchange and analysis
- 2) IEC 61683, Photovoltaic systems - Power conditioners - Procedure for measuring efficiency
- 3) IEC 60364-6 Ed. 1: Low Voltage Electrical installations.
- 4) IEC 62446 "Grid connected photovoltaic systems – Minimum requirements for System documentation, commissioning tests & Inspections"
- 5) ISO 9845-1, Solar energy - Reference solar spectral irradiance at the ground at different receiving conditions, Part 1: Direct normal and hemispherical solar irradiance for air mass 1.5.

CONTROLLED DISCLOSURE

- 6) ISO 9847, Solar energy - Calibration of field pyranometers by comparison to a reference pyranometer. / BS 7621:1993 Method for calibrating field pyranometers by comparison to a reference pyranometer
- 7) ISO 9060, Solar energy - Specification and classification of instruments for measuring hemispherical solar and direct solar radiation.
- 8) ISO/TR 9901, Solar energy - Field pyranometers – Recommended practice for use.
- 9) IEC 61725, Analytical expression for daily solar profiles

h) Transformer

- 1) IEC 61724, SANS 60076 -1 to12: Power transformers
- 2) SANS 780 – Distribution transformers

i) Switchgear

- 1) 240-56227516–LV switchgear and control gear assemblies and associated equipment for voltages up to and including 1000 V AC and 1500 V DC Standard
- 2) SANS 1973-1 to 4 Low-voltage switchgear and controlgear Assemblies Parts 1 to 4
- 3) IEC 60898 Electrical accessories - circuit breakers for overcurrent protection for household and similar installations
- 4) IEC 61009 Residual current operated circuit-breakers with integral overcurrent protection for household and similar uses (RCBO's)
- 5) SANS 60269 Low-Voltage fuses Part 1 and Part 2
- 6) SANS 1765 Low-voltage switchgear and controlgear assemblies (distribution boards) with a rated short-circuit withstand strength up to and including 10 kA
- 7) SANS 60439-1 to 5 Low-voltage switchgear and controlgear assemblies parts 1 to 5
- 8) SANS 60947 Low-voltage switchgear and controlgear
- 9) IEC 60265-1 High-voltage switches Part 1: switches for rated voltage above 1kV and less than 52kV
- 10) SANS 62271- 100 High-voltage switchgear and controlgear – Alternating Current Breakers
- 11) SANS 62271- 1 High-voltage switchgear and controlgear – Common specifications.
- 12) SANS 62271- 102 High-voltage switchgear and controlgear – Alternating Current Disconnections and earthing switches
- 13) SANS 62271- 200 High-voltage switchgear and controlgear – AC Metal-enclosed switchgear and controlgear for rated voltages above 1kV and up to and including 52kV
- 14) SANS 62271- 202 High-voltage switchgear and controlgear – High-voltage/low-voltage prefabricated substation
- 15) SANS 60694 Common specifications for high-voltage switchgear and controlgear standards
- 16) SANS 60529 Specification for degrees of protection provided by enclosures (IP code)
- 17) SANS1874: Switchgear- Metal-enclosed ring main units for rate AC voltage above 1kV and up to and including 36kV
- 18) IEC 60255-1 Measuring relays and protection equipment part 1: common requirements

CONTROLLED DISCLOSURE

19) IEC 61958 High-voltage prefabricated switchgear and controlgear assemblies- Voltage presence indicating systems

20) 240-53114248: Thyristor and Switch mode chargers, AC/DC and DC/AC and UPS standard

j) **Safety Act**

- 1) Occupational Health and Safety Act 85 of 1993
- 2) ISO 18001 – Occupational Health and Safety Management Systems

k) **Environmental Protection**

- 1) IEC 60721-3-1 - Classification of groups of environmental parameters and their severities; Storage.
- 2) IEC 60721-3-2 - Classification of groups of environmental parameters and their severities; Transportation.
- 3) IEC 60721 -3-3 - Classification of groups of environmental parameters and their severities; Stationary use at weather protected locations.
- 4) SANS 12944 – Corrosion Protection of Steel Structures
- 5) SANS 14713 - Protection against corrosion of iron and steel structures – Zinc and aluminium coatings – Guidelines.
- 6) ISO 14000 – Environmental Management Systems

CONTROLLED DISCLOSURE

3.4 CONTROL, MONITORING AND COMMUNICATION WORKS

3.4.1 General

- a) The *Contractor* provides an onsite supervisory control and monitoring system (CMS) for the PV Plant that responsible for data acquisition and monitoring of instruments and electronic sub-systems, including, but not limited to:
- 1) PV Inverter systems,
 - 2) PV meteorological systems (Weather stations),
 - 3) PV string combiner boxes,
 - 4) Electrical Medium voltage (MV) switchgear,
 - 5) Electrical MV and LV transformers,
 - 6) Electrical Protection relay,
 - 7) Electrical Energy measurement and metering,
 - 8) Electrical Battery tripping units (BTU),
 - 9) Uninterruptable power supplies (UPS),
- b) As part of the CMS, the *Contractor* provides an on-site building management system (BMS) to control and monitor the following sub-systems of the PV plant, in accordance with the network diagram in Appendix I:
- 1) Internal environmental sensors of equipment panels, network cabinets, MV Cabins,
 - 2) Balance of plant (BoP) potable water and sewage tank levels,
 - 3) BoP Fire detection system (FDS),
 - 4) BoP Heating, ventilation and air-conditioning (HVAC) system
- c) The *Contractor* reviews the conceptual CMS network drawing in **Appendix I** of this specification as a guide to produce the detailed designs. The *Contractor* does not reproduce the same drawings in **Appendix I** as a submittal to the *Employer* for evaluation or review.
- d) The *Contractor* designs, procures, installs, tests and commissions the entire CMS scope as specified in this *Works*.
- e) The *Contractor* provides a CMS that achieves 98% availability in accordance with the plant availability.
- f) The *Contractor* provides dual redundantly configured set of CMS servers (i.e. 2 server machines).
- g) The *Contractor* provides dual redundant plant information servers to store and retrieve plant data for the lifespan of the PV Plant.
- h) The *Contractor* provides (2) operator systems for two (2) permanent plant operators per shift.
- i) The *Contractor* provides an operator system in the PV plant control room that is dedicated for monitoring and control of the building management systems. The *Contractor* designs the BMS network in accordance with **Appendix I**,
- j) The *Contractor* provides monitoring of the plant security system, at the PV plant control room. The required number of monitors is specified in **Appendix I**. The *Contractor* provides a dedicated optical fibre interface to from the PV plant security system to the Grootvlei Power station security centre for monitoring.

CONTROLLED DISCLOSURE

-
- k) The *Contractor* provides a control room and server room within the O&M building to install the CMS network cabinets and 3rd party network cabinets. The *Contractor's* designs the control and server room in accordance to Eskom specifications, standards and best practices as stipulated under the codes and standards section.
- l) The *Contractor* provides an HVAC system to control the operating temperature and humidity levels within the control and server room in accordance to Eskom standards. The *Contractor* provides positive pressurisation of the control and server rooms to prevent dust content from entering the control and server rooms. The *Contractor* provides monitoring and alarms of the HVAC system at the control room HMI.
- m) The *Contractor* ensures that all CMS equipment installed in uncontrolled environmental conditions is rated to operate safely within the ambient environmental conditions it will be exposed to during the life of the plant. The *Contractor* provides equipment that is designed to operate under a wide temperature range (i.e. -40°C to +75°C).
- n) The *Contractor* designs the CMS with lightning protection, surge protection, earthing, grounding and shielding in accordance to Eskom standards, international standards and best industry practices.
- o) The *Contractor* provides a CMS network that operates using full duplex data communication.
- p) The *Contractor* provides a CMS that is single fault tolerant. In an event of a single fault, be it physical or functional, at a power supply or at a networking level, there is no loss of data communication, plant operations and monitoring of the remaining areas of the plant via the Human Machine interface (HMI) located in the control room.
- q) The *Contractor* provides a web-server as part of the CMS network. The web server securely communicates real time and historical plant data to remote web-clients. The web-clients are remotely based users (off-site) with authorised access to monitor the plant in near real time via a web browser such as Mozilla Firefox, Google Chrome or Internet Explorer.
- r) The *Contractor* provides a colour laser printer for the CMS network. The printer prints A4 and A3 size documents. The *Contractor* installs the printer onto a printer desk inside the control room, preferably nearby the operator desks.
- s) The *Contractor* provides a fire detection system (FDS) for the plant in accordance with Eskom standards as indicated under the codes and standards section of this specification. The *Contractor* conducts a detailed fire risk assessment and provides a fire management and evacuation plan. The fire detection system is monitored on a dedicated HMI at the PV Plant control room. The *Contractor* provides a functional interface between the PV plant fire detection system and the fire detection system at Grootvlei Power station for monitoring at the Power station Electrical operator's desk (EOD) The *Contractor* provides the FDS that includes the following equipment as a minimum:
- a. At least three (3) sensors per MV cabin, switchgear room, control room, server room, spare parts room.
 - b. Fire indication sirens and lights per inverter cabin, switchgear room, and O&M building
 - c. Fire panels are installed inside the MV Cabins, switchgear rooms, and control room as required by the design.
- t) The *Contractor* provides continuous level monitoring of the potable water tank levels and sewage tank levels in real time at the operator HMI in the control room. Alarms and warnings are indicated immediately to the control room operator if the tank levels are reaching its lower or upper limits. (I.e. 'low = 30%', 'low-low = 15%', 'high = 70%' and 'high-high = 85%').

CONTROLLED DISCLOSURE

- u) The *Contractor* provides monitoring of all HVAC panels on the plant in real time at the operator HMI in the control room. Alarms and warnings are indicated immediately to the control room operators if the HVAC system is operating abnormally.
- v) The *Contractor* installs an interface PLC (Honeywell) to interface signals between the PV plant CMS and the Honeywell control system at Grootvlei Power station via the Modbus protocol over optical fibre.
- w) The *Contractor* provides interface communication between the CMS network and 3rd part *Employer's* networks. Furthermore, the *Contractor* provides interface communication between the CMS network and other systems not listed in this specification report that the *Employer* sees necessary during the detailed designs, construction and commissioning phases.
- x) The *Contractor* ensures that all data of the PV plant subsystems is stored at 1 min intervals, and where required, an average of the values over the period is stored.
- y) The *Contractor* ensures that the refresh rate of the values on the CMS operator HMI (monitors) is within 5 seconds from change of value at the instrument or sensor on the field.
- z) The *Contractor* provides an audible public address (PA) system for the *Project* that is used to alert the staff on site. The PA system is installed in the PV plant control room. The PA system is designed for use in a power plant environment in accordance with Eskom standards.

3.4.2 Control and Monitoring System (CMS) Servers

- a) The *Contractor* provides one pair of redundantly configured CMS servers (i.e. 2 server machines). The servers operate as a primary-standby configuration and rated for continuous operation. Switchover from the primary server to the standby server, and vice versa, is seamless and instant upon detecting failure, without interrupting data acquisition, processing of data, and operations and monitoring functions of the CMS. The standby server continues full operations if the primary server fails to operate.
- b) The *Contractor* provides the following hardware for each server machine of the redundant pair:
 - 1) redundant central processing units (CPU),
 - 2) redundant array of independent disks (RAID) configuration,
 - 3) redundant power supplies with dual power input ports,
 - 4) redundant case fans,
 - 5) 19" (inch.) rack-mountable type enclosure for the servers and power supplies installed in the plant server room,
 - 6) on-board database to continuously process and store all real time plant data for the lifespan of the plant,
 - 7) removal media such as a digital versatile disk (DVD) writer and front accessible universal serial bus (USB) ports.
- c) The *Contractor* provides the CMS servers that accomplish multiple functions, including:
 - 1) hosting the Microsofts Windows operating system suitable for industrial process plant applications,
 - 2) hosting the CMS application software for operating and monitoring of all equipment.
 - 3) hosting the anti-virus software,
 - 4) performing comprehensive operating and monitoring functionality of the plant in real time via the thin clients,

CONTROLLED DISCLOSURE

- 5) performing network configuration, logic development, mimic development, antivirus and software updates,
- 6) storing and processing of plant data via the redundant information servers database,
- 7) storing of all engineering logic and CMS network configuration settings,
- 8) performing of online engineering and diagnostics of the plant via the thin clients,
- 9) hosting a web application that makes available, multiple pages or mimics of real time plant data for monitoring and alarming to authorised remote clients connected to the Eskom network.
- 10) running the OPC protocol software to communicate between multi-vendor systems on the plant and to remotely transmit data to the PDS in MWP via the PDS network at Grootvlei power station,
- 11) running the back-up and recovery application in an event of a disaster to the CMS network
- 12) copying of data automatically from the information servers onto the removable media at pre-configured intervals, and
- 13) automatic shut down the CMS servers and thin clients in a safe sequence after detecting the loss of the input power to the UPS system. The sequence includes automatic saving of plant and system data, closing of all running applications, and providing the plant operator with adequate warning of the shutdown.

3.4.3 Operator System Thin Clients

- a) The *Contractor* provides two (2) thin client machines that comprise of the Human machine interface (HMI) between the plant operator and the CMS servers.
- b) The *Contractor* provides 100% plant operational and monitoring availability of each thin client. Therefore, each thin client offers its operator, the complete operating and monitoring functionality of the entire plant.
- c) The *Contractor* provides the following peripherals to thin clients 1 and 2:
 - 1) 3 x 19" liquid crystal display monitors (LCD)
 - 2) 1 x 40" LCD monitor,
 - 3) Built-in DVD writer,
 - 4) 1 x USB type keyboard and mouse
- d) The *Contractor* installs the thin clients inside the CMS network cabinets of the server room.
- e) The *Contractor* provides the keyboard, video, mouse (KVM) extenders to interface the HMI peripherals in the control room, to the thin clients in the server room. The KVM extenders not degrade the video quality as displayed on the monitors. The KVM extender not introduce any operating delay or lower refresh rate as required. The KVM extenders are installed securely at the each operator's desk to prevent physical interference.

Thin Client Operational and Graphical Display Requirements

The *Contractor* provides the functional requirements described in sections (a) and (b) below:

a) Graphical display requirements:-

1) Alphanumeric characters:

- Text, with the exception of labels, is presented using upper and lower case characters.

CONTROLLED DISCLOSURE

- Capitalization is used to start sentences, and to indicate proper nouns and acronyms.
- Labels are displayed in upper case.
- A sans-serif font is used. An example of a sans-serif font is Arial. Sans-serif fonts are more legible on electronic displays than serif fonts.
- For the selected font, it must be possible to clearly distinguish between X and K, T and Y, I and L, l and 1, O and Q, O and 0, S and 5, and U and V.
- Text, numbers and symbols are readable from the normal operating position be it seated or standing at the plant operator's desk or remote client's desk.

2) Numeric data:

- Numeric values are displayed using the decimal number system.
- Leading zeros for whole numbers are not displayed. For example, the number fifty two must be displayed as 52, rather than 0052. A leading zero is only provided if the number is a decimal with no preceding integer. For example, the decimal number of a half should be displayed as 0.5, rather than .5.
- Numbers are displayed at the number of significant digits required by the users to perform their tasks. The number of significant digits must be supported by the accuracy of the underlying instruments and CMS hardware.
- Each numeric display must be able to accommodate all the values in the range of its variable.
- All numeric data is oriented upright.

3) Abbreviations and acronyms:

- Abbreviations are avoided, except when terms are commonly referred to by their initials or abbreviations.
- Abbreviations and acronyms not include punctuations. For example, CMS is preferred over C.M.S.
- The use of the letters O and I in arbitrary codes is avoided, since they are easily confused with the numbers 0 (zero) and 1(one), respectively.
- When arbitrary codes use both letters and numbers, the letters are grouped together and numbers grouped together rather than interspersing letters with numbers.

4) Labels:

- Label formats are consistent across and within displays.
- Labels are worded consistently, so that the same item is given the same label wherever it appears.
- Labels are separated from one another by at least two standard character spaces.
- Labels are oriented horizontally.

5) Icons and symbols:

CONTROLLED DISCLOSURE

- Icons in graphic displays are primarily used to represent actual objects or actions.
- Icons and symbols are used consistently throughout the displays for all plant areas
- Icons are designed to look like the objects, processes, or operations they represent, by use of literal, functional, or operational representations.
- Icons must be closed i.e. they must have a continuous outside border.
- The symbols used on displays are consistent with those of other information sources used in the work area, such as SLDs and logic diagrams, or based on the outline or physical structure of the plant device if ergonomically appropriate.
- Each icon and symbol represents a single object or action, and are easily distinguished by their external geometric configuration from all other icons and symbols.
- Icons and symbols are oriented upright.
- Icons and symbols are large enough for the user to perceive the representation and discriminate it from other icons and symbols.
- An icon or symbol is highlighted when it is selected by a user.
- Icons are accompanied by a text label, except when the icon has an unambiguous meaning to the user, e.g., standard SLD or Logic symbology. The text label is incorporated into the icon itself, provided it does not clutter or cause distortion of the icon.

6) Colour:

- The colours used for coding is readily distinguishable from each other.
- The number of colours used for coding is kept to the minimum needed for providing sufficient information. Once colours are assigned a specific use or meaning, no other colour is used for the same purpose.

7) Highlighting:

- Highlighting methods (e.g., flashing, and brightness) associated with emergency conditions is not used in association with normal conditions.

8) Flashing:

- Flashing is used only for the highlighting of information that requires immediate attention (e.g., warning messages, hazardous conditions). The only exception to this is the convention of blinking the cursor as an aid in locating it quickly.
- When a single flash rate is used, the rate is at least 2Hz and not more than 3Hz. The percentage of time that an item is 'on' must be equal to the time that it is 'off' i.e. a 50% duty cycle is used.
- Flash suppression or event acknowledgement keys are provided.

9) Pointing cursors:

- The pointing cursor is visible to the user at all times.
- The pointing cursor does not blink.

CONTROLLED DISCLOSURE

- The position of the pointing cursor is clearly visible during movement from one screen position to another.
- The pointing cursor maintains its size across all screen and display locations.
- The pointing cursor does not move in the absence of any input from the user.

10) Display pages:

- Displays are configured in a clear and unambiguous manner to provide the operator with information relevant to the task.
- Every display contains a title positioned suitably at the top, which briefly describes the contents or purpose of the display.
- Displayed information, which temporarily overlays and obscures other display data, must not erase the overlaid data.
- In a multi-page display, each page must be labelled to show its relation to the others.
- A comprehensive method of display access across all types of display is provided, while at all times providing the operator with an overview of high-level plant status.
- Selection of any display should not require more than two keystrokes. In alarm or abnormal conditions only one keystroke is required to access the relevant display.

11) Menus:

- Navigation is clear, simple and unambiguous.
- All menu items are visible to the user without scrolling.
- Menu options is ordered and grouped logically. If no logical structure is apparent, the menu options must be ordered alphabetically.
- The order of the menu options is fixed.
- Menus clearly indicate which options are selectable.
- When the same options appear on several different menus, consistency of wording and ordering on all of the menus is maintained.
- When menu selection is to be made from a long list, and not all options can be displayed at once, a hierarchic sequence of menu selections is provided rather than one long multi-page menu.
- When hierarchic menus are used, the user must have some indication of current position in the menu structure.
- Users are able to return to the highest level menu in the hierarchic menu structure by a single key action.

12) Windows:

- Windows are identifiable by a label consistently located at the top of the window's border.
- Users are able to select separate windows that share a single display screen.
- When multiple windows are opened simultaneously, the user has the capability to tile, layer, or sequentially view the windows. Tiling refers to a configuration in which windows

CONTROLLED DISCLOSURE

are positioned beside one another. Layering refers to moving one window so it appears to be positioned on top of another one.

- The system keeps track of the windows that are open and provide a means of displaying the list of open windows to the user.
- Caution and warning windows are positioned front most on the display.
- User control of windows is consistent from one display to another for each type of window.
- Users must be able to close windows with a single action.
- The users must be able to move windows to different areas of the display.
- It is not possible to position windows such that they obscure menu bars, access to the command area, or caution and warning messages.
- The action that opens a window automatically makes that window active.
- Windows have a default location on the display screen.
- Users must be able to change the horizontal and vertical dimensions of a window independently and together.
- The user must be able to scroll through the contents of a window both horizontally and vertically.
- Display data that is temporarily obscured by a window object reappears when the object is removed.
- There is a maximum limit to the number of windows allowed to be open at one time.

13) Display efficiency:

- Response time for acknowledgement of any display control command is no longer than 2 seconds.
- Any display selected or requested by the operator, including trend displays and dynamic data, is completed within 2 seconds.
- Feedback that any command issued by the operator to change the status of a plant device, such as closing a breaker has been received by the switchgear, is displayed within 2 seconds and feedback that the breaker has reached its desired position is displayed within 2 seconds of the event.
- The response time for the update of variables in displays (i.e. running time of signal from signal change on the binary or analogue device up to the change of the appropriate dynamic value on the plant mimic) do not exceed 5 seconds.

b) Operational requirements:-

1) General:

- The operator control interface presents an integrated and standardised set of displays and facilities which is designed to conform to ergonomic principles and modern power plant practice.
- The design approach of the operating interfaces, and the underlying functionality of the CMS behind the interfaces, is consistent across all sub-systems and functional areas covered by the CMS.

CONTROLLED DISCLOSURE

- Uniformed signal descriptions and abbreviations are used though-out the entire CMS and physical plant interface.

2) Errors:

- No set or sequence of key strokes causes the operator systems and CMS servers to fail or freeze.
- Any incorrect operation is indicated to the operator by audible signal or suitable text message.
- In all cases a standardised back track facility is available so that the operator can escape from a display. True system errors are fully indicated as to type, cause and remedial action.

3) Alarms:

- A comprehensive and integrated alarm handing system is employed, which clearly distinguishes between different alarm types.
- Alarm information is not lost or inaccessible whilst navigating through displays, and dynamic alarm presentation is provided the operator with information matched to the current situation and its criticality.
- Faults or operational failure detected on each individual string or the network raises an alarm to the control room operator.
- Alarm handling and management system is designed in accordance to Eskom's standards and guidelines.

3.4.4 CMS Plant Information Server Requirements

The *Contractor* provides the following requirements:

a) General:

- 1) The on-site, redundant plant information servers is a central database repository built into the redundant CMS servers for the long term storage of all plant data produced at the solar PV Plant. This includes all plant information generated by the sub systems of the plant as well as calculated or processed data.
- 2) The CMS servers contains a software application and database that stores all plant data and include tools for the analysis of all the plant data including:
 - Alarm data,
 - Sequence of Events (SoE),
 - Field and other system's readings (inputs and outputs),
 - calculated variables,
 - control variables,
 - CMS system settings, and
 - Operator inputs (key logging).
- 3) The software application stores all analogue tags and events at a resolution of one (1) second or better. All data is time stamped using the GPS time server.

CONTROLLED DISCLOSURE

-
- 4) The software application stores each analogue tag according to the amount of change in the tag value, where the amount of change is specified by the user.
 - 5) Data on these servers is accessible by an OPC client and all applications are OPC compliant for external interfacing. Web server application is available on the CMS web server to be able to serve web pages containing real time data and historical data to remote clients via the Eskom network.
 - 6) The software application stores historical plant information on-line for the lifespan of the plant at maximum resolution.
 - 7) The software application automatically copies the historical plant information stored on the historian to an external hot-swappable hard disk drive, while on-line and without any loss of availability and functionality of the software application. The external hot-swappable hard disk drives serve as a backup of the historical plant information. Furthermore, the software application automatically copies the data onto the DVD in the CMS servers at pre-defined intervals. The intervals are set on the software application. Data is stored on .CSV files then copied onto the DVD. Each file contains data for a pre-defined period.
 - 8) The CMS thin clients (full functionality) and remote client Users (limited functions), with the appropriate user rights, are able to select and view all the near real-time and historical plant data from plant information servers, in the form of:
 - Trends,
 - Chronological lists,
 - Reports,
 - Process graphics,
 - Performance calculations and analysis,
 - Event history and analysis, and
 - Importing/exporting of information from/to Microsoft Excel®, and via SQL and OPC.
 - 9) Data stored in the Historian database are appropriately time stamped.
 - 10) Comprehensive prioritising, grouping, filtering and database sorting is provided from the CMS servers.
 - 11) The historian databases are open to queries from OPC Clients.
 - 12) Any changes made to the database is made in real-time and on-line via the CMS servers, and all changes come into effect without restarting any part of the CMS server or thin clients.
- b) Trends:
- 1) From the CMS thin clients, trends are configurable. Remote users have access to specific (not all) trending parameters over a web browser. The user, as a minimum, is able to configure the following:
 - select the tags to view,
 - specify the start and stop date of each trend, and
 - specify the start and stop time of each trend.
 - 2) From the CMS thin clients, the user views a minimum of 6 trends in the same display window. Remote user views 2 trends per window.

CONTROLLED DISCLOSURE

c) Chronological Lists:-1) Binary Events:

- From the CMS thin clients, the user views binary events in the form of a chronological list. The chronological list includes:
 - event date,
 - event time,
 - tag name,
 - tag description, and
 - tag value.
- The user filters the binary events, as a minimum, according to:
 - unit,
 - tag name,
 - tag description, and
 - time period.
- The user saves the binary event history as a .CSV or .xls file type.

2) Alarm Events:

- From the CMS thin clients and remote clients, the users views alarm events in the form of a chronological list. The chronological list includes:
 - event date,
 - event time,
 - tag name,
 - tag description, and
 - tag value.
- The users filters the alarm events, as a minimum, according to:
 - unit,
 - tag name,
 - tag description,
 - priority, and
 - entry/exit.
- The users save the binary event history as a .CSV or .xls file type.

3) Operator Events:

- From the CMS thin clients, the user views all operator event history in the form of a chronological list. The user filters the operator events, as a minimum, according to:
 - unit,

CONTROLLED DISCLOSURE

- operator system,
- time period,
- event type,
- The user saves it as a CSV or .xls file type.

d) Reports:

- 1) A report generator that builds and schedules reports is provided at the CMS thin clients and for remote clients.
- 2) From the CMS thin clients, the users, as a minimum, are able to configure the following:
 - create, edit and store reports,
 - create, edit and store report formats, and
 - schedule the automatic creation of reports at periodic intervals, elapsed times or on the occurrence of an event (e.g. alarm or event message).
- 3) Remote client users creates and save a report of selectable parameters via a standard web browser in .CSV or .xls file formats
- 4) The users create reports and report formats without any software programming. The report generator provides total control over report format similar to spreadsheet packages.
- 5) The users include both near real-time and historical plant information.
- 6) Users produce lists of totals and averages and apply arithmetic functions to plant information.
- 7) The types/classes of data used by the report generator includes the following:
 - analogue variables
 - status of multi-state variables
 - alarm and event messages
 - calculated variables
 - batch-end information for sequence control
 - historical data values and status
 - any other retrievable tagged items
- 8) Users are provided data in the form of:
 - current values
 - batch values
 - database query value
 - operator entry values
- 9) Users save reports CSV, .XLS and HTML files.
- 10) The report generated includes one parameter per column. Time stamp intervals are displayed on the rows. Under default setting, all parameters are generated onto a single file for selectable period of time period. Reports containing user selectable parameters are produced. Daily, weekly and monthly report templates are producible.

CONTROLLED DISCLOSURE

e) Process Graphics:

- 1) The process graphics are configurable by a user at the CMS thin clients. The user, as a minimum, configures the following:
 - create, edit and store graphical displays
 - select the tags to be displayed in the process graphic displays
- 2) The user is able to include both near real-time and historical plant information in the displays.
- 3) The user is able to save the process graphic as .JPEG file HTML file.

3.4.5 Network Switch

- a) The *Contractor* provides industrial Ethernet network switches with the following requirements:-
 - 1) managed type with online management and configuration via the thin clients using a network management software installed on the CMS servers,
 - 2) compatibility with Simple network management protocol version 3 (SNMP v3) and Internet protocol version 6 (IPv6),
 - 3) online monitoring of the port connections, communication link status, bandwidth, and device health status indicating alarms and faults to the server and remote users,
 - 4) power supply from dual redundant power sources (230 Vac or 24 Vdc),
 - 5) dual power input ports
 - 6) mounted on a Deutsche Industrie Norm (DIN) rail in field equipment panels, or, mounted on a 19" network cabinet for redundant master switches located in the server room,
 - 7) optical fibre and Ethernet ports,
 - 8) 10% unused ports (rounded up),
 - 9) wide operating temperature range (typically between -40C to +75C),
 - 10) auto negotiation capability, and
 - 11) auto crossover (MDIX) capability.
 - 12) full duplex communication capability
- b) The *Contractor* provides the following information regarding the network switches to be monitored and alarmed on the CMS thin clients and remote users:
 - 1) device state
 - 2) link and connection state of each connection
 - 3) bandwidth utilization of each connection
 - 4) network performance and traffic statistics (latency, throughput, errors, dropped packets)
 - 5) network loads, malfunctions and failures of the network components are detected and alarmed promptly and countermeasures are initiated automatically in due time through the use of the network management software.

3.4.6 Network Time Synchronisation

- a) The *Contractor* provides a clock synchronisation system to synchronise the time of the system clock of each network device on the CMS network, to a common time source. Common clock synchronisation assures consistent stamping of data onto the CMS servers which simplifies data analysis and troubleshooting during an investigation.

CONTROLLED DISCLOSURE

- b) The *Contractor* provides a clock synchronisation system that includes the following requirements:
- 1) a global positioning system (GPS) antenna and a time server;
 - 2) implement the network time protocol (NTP) via an Ethernet connection to the CMS network switch;
 - 3) time stamping with an accuracy of 10 milliseconds (UTC+2);
 - 4) on loss of the GPS signal, the accuracy of the GPS clock, i.e.: deviation from UTC is less than 1 minute per day;
 - 5) determine its installation position automatically by self-calibrating;
 - 6) retains critical data (by means of non-volatile memory or battery back-up) in the event of power supply failure;
 - 7) automatic time synchronisation to the plant, after recovery from any GPS time sync system failure or power supply failure;
 - 8) the GPS antenna and receiver system provided are highly resistant to electrical surges from sources such as lightning;
 - 9) an on-board display and function keys;
 - 10) monitoring and alarming of the time server at the CMS thin clients;
 - 11) 19" rack or DIN rail enclosure;
 - 12) powered from a 230 Vac or 24 Vdc source.

3.4.7 Miscellaneous Network Equipment

- a) The *Contractor* provides the following equipment as required by the design:
- 1) network protocol convertors,
 - 2) network medium convertors,
 - 3) digital or analogue input and output (IO) modules;
 - 4) programmable logic controllers (PLC) with on-board IO cards, communication processors and protocol convertors;
 - 5) dc power supplies (12V or 24V); and
 - 6) splice trays and path panels for fibre optic cables.
- b) The equipment described in (a) is installed in the CMS field equipment panels or 19" network cabinets. If installed in an uncontrolled environment, the equipment is rated to operate between a wide temperature range (i.e. -40°C to +75°C).

3.4.8 CMS Field Equipment Panels

- a) The *Contractor* provides CMS equipment panels inside MV Cabins and switchgear rooms. The equipment panels contain CMS network equipment as required by each area of the plant. This includes the network switch and associated equipment listed in section 3.4.7 above. The CMS equipment panels are IP54 for indoor installation. It is preferred that the panels be wall mounted with front accessible doors.
- b) The *Contractor* designs the CMS equipment panels to include physical separation of the power supply equipment, networking devices and splice tray and patch panels into their own compartments within the panel. Cable channels are installed to route the cabling between compartments or section within the panel.

CONTROLLED DISCLOSURE

- a) The *Contractor* provides field equipment panels for string combiner boxes (SCB) and weather stations (WS) that is rated IP65 for outdoor installation.

3.4.9 Server Room Network Cabinets

- a) The *Contractor* provides nineteen inch type (19") network cabinets to install CMS servers, thin clients, redundant network switches and UPSs. All connectors on rack mounted components are rear facing in the cabinet for easier cable management. Network and power cabling are bottom entry with cable entry from raised false flooring in the server room.
- b) The *Contractor* provides network cabinets that include the following characteristics:
- 1) grommets are installed where panels are cut for communication and power cable entry,
 - 2) Internal cable channels or traces to neatly route cables inside the cabinet,
 - 3) Removable blanking panels on all unused slots or sections,
 - 4) Adequate depth (> 200mm free space) to allow air circulation around cables in the rear,
 - 5) Perforated front and rear door and side panels to allow circulation of air,
 - 6) Flexible brushes to be used to prevent air leakage via cable entries or cut-out,
 - 7) Include 19" racks and DIN rails to mount equipment,
 - 8) Removable perforated front and rear door panels,
 - 9) Doors with manual locking mechanism and automatic open/close detection,
 - 10) Internal lights for illumination,
 - 11) 10% uninstalled space on the racks and DIN slots to install spare equipment,
 - 12) blanking panels on un-used slots, and
 - 13) internal air temperature and relative humidity sensors monitored on the network cabinet (local) and the CMS (operator HMI). Internal temperature to be controlled at $22^{\circ}\text{C} \pm 2^{\circ}\text{C}$.

3.4.10 Building management system (BMS)

- a) The *Contractor* provides a fully functional BMS network that monitors the potable and sewage tank levels, the fire detection system, the HVAC system and the environmental sensors in the inside the server room network cabinets. The BMS network is conceptually shown in Appendix I.
- b) The *Contractor* provides a dedicated network switch to communicate with the BMS equipment. The network switch complies with the specifications in section 3.4.5.
- c) The *Contractor* provides the BMS server to host the application software and the information database to monitor the equipment as stated in (a). The BMS server complies with the specifications as stated in section 3.4.2.
- d) The *Contractor* provides a local thin client for the BMS network. The thin client complies with the specifications as stated in section 3.4.3.
- e) The *Contractor* provides two (2) 19" LCD monitors, 1 keyboard and 1 mouse to form the HMI for the BMS at the PV plant control room. The peripherals connect to the think client PC in the server room.
- f) The *Contractor* provides a dedicated 19" floor standing network cabinet for the BMS equipment as shown in the server room on Appendix I.

CONTROLLED DISCLOSURE

3.4.11 Fire detection System

- a) The *Contractor* provides a fully functional fire detection and monitoring system for the PV Plant in accordance with the fire detection and protection standards referenced in this specification.
- b) The *Contractor* provides fire panels with on-board display for local monitoring and testing. The fire panels interface to the building management system (BMS) at the PV plant. The FDS is monitored at the PV plant control room via the dedicated BMS communication network as shown in Appendix I.
- c) The *Contractor* provides all fire sensors, alarms, panels, cabling, and supporting equipment in accordance with the fire detection and protection standards referenced in this specification.
- d) The *Contractor* provides power to the fire detection system from an uninterruptable power source (i.e. the battery tripping units or UPSs with battery back-up).
- e) The *Contractor* designs the fire detection system to ensure that any failure to the FDS network, failure to the FDS power supply or failure to monitor the FDS at the control room HMI not prevent each fire panel from operating normally on its own.
- f) The *Contractor* provides a direct optical fibre interface between the PV plant FDS and the FDS at Grootvlei Power station. This interface allows the EOD at the Power station to monitor the status of the PV plant FDS for early indication in an event of a fire.

3.4.12 Third Party Network Access into the CMS Network

3.4.12.1 Eskom Corporate IT Network

- a) The *Contractor* provides the network interface to Eskom's corporate IT network. Eskom IT equipment will be installed inside a network cabinet in the server room of the PV Plant to enable the interface between the CMS network and the Eskom IT network.
- b) The *Contractor* provides OPC DA (tunneling method) and OPC-XML protocols. Real time data is required to be stored on Eskom's plant data system (PDS) at Grootvlei power station where it can be accessible from Megawatt (MWP).
- c) The *Contractor* provides support to the *Employer* (Eskom IT) throughout the installation, testing, commissioning and configuration of the interface for the duration of the *Contract* (incl. O&M period).

3.4.12.2 Remote Access to the CMS Network

- a) The *Contractor* is required to remotely monitor the plant data in real time and provide remote support. The *Contractor* provides a medium to acquire this data. Either one of the following services are established by the *Contractor* for internet connectivity:
 - a. A wireless GSM modulator-demodulator (MODEM), or
 - b. A fixed line with broadband ADSL.
- b) The *Contractor's* remote access into the CMS network is allowed for monitoring of data. No operations, control or system configuration of equipment on the plant is allowed via the remote link, unless authorised by both the *Contractor* and *Employer*. It is preferred that all configurations take place at the plant, when both parties are present.
- c) By using the network interface mentioned in (a), the *Contractor* installs a webserver on the CMS network to serve web pages to *Employer's* remote clients. The authorised clients make use of a standard web browser such as Mozilla Firefox or Google chrome to login to the CMS server and visualise the operation and alarms of the entire plant in near real time.

CONTROLLED DISCLOSURE

-
- d) The *Contractor* provides a web-based CMS application for the remote monitoring. The web pages are similar to the pages displayed on the HMI at the control room. Thin client software that is required to be installed onto the remote client PCs are downloaded from the onsite CMS web server via the secured remote interface. Daily, weekly, monthly and yearly graphical trends and reports of specific parameters are generated from the web page. Comprehensive reports of all plant data are saved on .CSV or .xls file formats for further analysis. A log activity schedule of each remote user is saved on the CMS web server for the lifespan of the plant.
- e) The *Contractor* provides sufficient bandwidth for use over the remote link mentioned in (a) to ensure that near real time visualisation is achievable to the remote users.
- f) The *Contractor* provides a gateway firewall for the remote interface mentioned in (a). The firewall complies with Eskom specifications. The *Contractor* implements the IPsec protocol over a secured VPN tunnel. The relevant Eskom network security specifications are adhered to.
- g) The *Contractor* provides the following minimum security requirements for firewalls:
- 1) deep packet inspection,
 - 2) network antivirus protection,
 - 3) network intrusion detection system (NIDS) for detecting attacks, rogue systems and unauthorized traffic in the network,
 - 4) intrusion prevention system,
 - 5) VPN (Virtual private network) gateway for secured remote access,
 - 6) Firewall management software
- h) By using the network interface mentioned in (a), the *Contractor* provides the short message service (SMS) notification system to the *Employer*. The *Contractor* designs the CMS that automatically generates and submits a short message service (SMS) notification to the *Employer's* maintenance staff in the event a breaker at the PoC is automatically disconnected from the power grid under a fault condition experienced during normal operation. The SMS notifies the user of the fault condition causing automatic disconnection.
- i) By using the network interface mentioned in (a), the *Contractor* provides an e-mail notification service to the *Employer*. A daily report of the previous day's production is generated automatically and sent via email notification to authorised users of the *Employer*.

3.4.12.3 CMS Interface to Grootvlei EOD Control System

- a) *The Contractor* provides a fully functional interface between the PV plant CMS network and the EOD control system network at Grootvlei PS
- b) The *Contractor* provides an interface PLC for signal exchange between the PV plant CMS and the Honeywell Experion PKS DCS at Grootvlei Power station. The PLC is installed inside the PV server room and communicates via the Modbus protocol to Grootvlei control system.
- c) The *Employer* specifies the signals to be exchanged between the CMS and the EOD control system which the *Contractor* makes available via the Modbus interface.
- d) The *Contractor* supports the *Employer* (Engineers) to assist with configuring the interface signals to the EOD control system HMI.
- e) The *Contractor* provides an Eskom gateway as specified in the Eskom Standard for Interconnection of Embedded generators. The gateway is an interface between the CMS network and Eskom Distribution NSP, for future connectivity. The gateway communicates using the DNP3 protocol.

CONTROLLED DISCLOSURE

3.4.13 CMS Power Supply and Power Distribution

- a) The *Contractor* provides dual redundantly configured, 230 Vac uninterruptable power supply (UPS) system with a battery bank to provide uninterruptable source of power to the CMS equipment in the server and control rooms of the PV Plant.
- b) The *Contractor* provides sealed-type, deep cycle battery banks to support the redundant UPSs. The batteries are free from hydrogen discharge. Sealed type Nickel Cadmium, Lithium Ion or Valve regulated lead acid batteries are preferred. It is preferred that the *Contractor* install the UPS system inside 19" floor standing cabinets inside the PV Plant server room. Alternatively, the *Contractor* installs the UPS and batteries in a dedicated battery room with ventilation if the batteries are of the type that will discharge hydrogen.
- c) The *Contractor* designs the UPS and battery bank system to provide a standby time of one (1) hour under full load immediately after the main 230 Vac supply to the UPS system is isolated. The UPS provides a regulated power source for sensitive CMS equipment and ensures a safe shutdown sequence of the CMS servers and thin clients when the UPS battery source reaches a reserve capacity of 25 percent (%).
- d) The *Contractor* provides 230 Vac distribution boards (DB) containing miniature circuit breakers (MCBs) for the CMS power distribution. The DBs are installed to distribute the power from UPSs to the loads. The *Contractor* provides earth leakage protection system for CMS loads.
- e) The *Contractor* designs the CMS network and its power supply distribution to ensure that loss of power to a single CMS equipment panel in a specific inverter cabin or switchgear room does not result in the failure of operation of the remaining CMS equipment panels. The remaining CMS panels continue communicating over the CMS network to the CMS servers and operator HMI.
- f) The *Contractor* provides suitably rated DC power source for all CMS equipment requiring dc power.
- g) The *Contractor* provides a detailed CMS load schedule by using the high level load list shown in the table below as a guide to size the CMS power supplies.

Table 2 Power source to CMS equipment

Control system equipment	Equipment room / location	Power source per device
CMS network panels	MV Cabins and switchgear room	Uninterruptable power source (AC or DC)
String combiner boxes	PV field array	230 Vac from Aux. DB per cabin
Weather stations	Grassland area 2, field	230 Vac from Aux. DB per cabin
Fire panels (FDS)	MV Cabins and switchgear room	DC power from BTU per inverter cabin or switchgear room
1 x 19" UPS cabinet	PV Plant server room	230 Vac from PV Aux DBs located in switchgear room (Aux 1 and Aux 2)
1 x 19" network/server cabinet	PV Plant server room	230 Vac (redundant UPSs)

CONTROLLED DISCLOSURE

Control system equipment	Equipment room / location	Power source per device
- Redundant CMS and plant information servers - Redundant master switches - Common switch - GPS clock - Web server - Firewall & internet modem - Honeywell interface PLC		
1 x 19" BMS cabinet - BMS server - BMS switch - BMS thin client	PV plant server room	230 Vac (redundant UPSs)
2 x CMS thin clients	PV Plant control room / server room	230 Vac (redundant UPSs)
4 x KVM extenders	PV Plant server room and control room	230 Vac (redundant UPSs)
6 x 24" and 2x 40" monitors	PV Plant control room	230 Vac (redundant UPSs)
3rd party equipment		
Local security system cabinet	PV Plant server room	230 Vac (redundant UPSs)
IT/IM cabinet	PV Plant server room	230 Vac (redundant UPSs)
EOD gateway cabinet	PV Plant server room	230 Vac (redundant UPSs)

3.4.14 Field Equipment, Cabling and Installation Requirements

- a) *Contractor* provides all CMS field equipment enclosures and structures, instruments, field power and communication cabling and cable infrastructure (conduit and racks) in accordance to the relevant standards and guidelines as specified under the codes and standards section of this specification.
- b) The *Contractor* provides CMS enclosures that is rated IP65 for outdoor installation.
- c) The *Contractor* provides adequate earthing, lightning protection, grounding, bonding, shielding and surge protection on all CMS equipment and cabling.
- d) The *Contractor* installs data communication and control cables into a separate cable trench (raceway or rack) from power cables to prevent noise interference.

CONTROLLED DISCLOSURE

3.4.15 CMS Control Room, Server Room, Equipment Rooms

- a) The *Contractor* provides the PV Plant control and server room in accordance with the Eskom standards for process control and ergonomic control suite design, as specified under codes and standards section of this specification.
- b) The *Contractor* provides a suitable operating environment (controlled or uncontrolled) for all CMS equipment in accordance to the relevant standards and guidelines as specified under codes and standards section of this specification
- c) The *Contractor* installs the CMS equipment panels and fire panels inside the MV Cabins and switchgear rooms as required.
- d) The *Contractor* provides sufficient lighting inside the server and control room
- e) The *Contractor* designs the server room with sufficient walking space of at least 1 meter between the cabinets for operations and maintenance staff. The dimensions and layout inside the server room are ergonomically friendly such that removal of a network cabinet or piece of equipment at the far end of the room does not require switching off and removal of any other equipment inside the server room and control room.
- f) The *Contractor* installs raised floors (0.3 meter) inside the server room to allow for adequate cable access into the network cabinets.
- g) The *Contractor* designs the server room to house the following network cabinets, as a minimum:
 - a. CMS network cabinet/s (servers, thin clients, switches, splice trays, etc.),
 - b. Building management system (BMS) network cabinet Redundantly configured CMS UPS system cabinet/s,
 - c. PV Plant security system network cabinet/s,
 - d. 1 x 19" IT network cabinet, and
 - e. 1 x Network cabinet for Eskom gateway/RTU (Grid code).

3.4.16 Plant Parameters

- a) The *Contractor* provides a CMS that stores and displays all parameters from plant instruments and equipment onto the CMS servers, thin clients and remote clients. Furthermore, network communication faults and statuses are monitored and logged onto the CMS servers.
- a) The *Contractor* populates the signal list attached in **Appendix J** of this specification. The attached spreadsheet is a template document and the *Contractor* adds to the list, any number of system parameters, signals or calculated parameters that the *Employer* requires during the detailed design and commissioning phase of the project.

3.4.17 Software Management

- a) The *Contractor* provides all application and antivirus software used on the CMS network.
- b) The *Contractor* provides all software to the *Employer* by means of DVDs which remains the property of the *Employer*. The *Employer's* O&M representative is in position of all plant software.
- c) The *Contractor* provides software that requires minimal or no updates over the lifespan of 25 years. If the software expires, a warning is displayed on the CMS server and the CMS continue operating normally (for the life of the plant) without shutting down the CMS system or any plant sub-system.

CONTROLLED DISCLOSURE

- d) During the O&M period, if software version updates are required, 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. One copy of the maintenance manual remains the property of the *Employer* while the other copy remains with the *Contractor*.
- e) The *Contractor* provides a list of all CMS software.
- f) All passwords of the CMS servers and thin clients remain the property of the *Employer*. In this way, both the *Employer* and *Contractor* are required in order conduct modifications to the CMS.

3.4.18 Labelling and Codification

- a) The *Contractor* provides a suitable labelling and codification system for the entire CMS works. This helps identify all instruments, cables, cable cores, equipment enclosures, network hardware, power supply systems, signals, OPC tags, etc.
- a) The *Contractor* provides warning labels on all equipment that pose a risk of electric shock.

3.4.19 Vendor Document Submittal Schedule (VDSS)

- a) The *Contractor* provides the following list of CMS documents to the *Employer*. Refer to the **Appendix G** for a schedule of documentation requirements. During handover, the as-built design documents are handed over as softcopy (2 x DVDs) and hardcopy (2 x files). All file formats are compatible with Microsoft office and Adobe reader software.
 - 1) List of deviations from the scope and recommendations or proposals to meet the scope requirements with reasons, advantages and disadvantages. The *Contractor* provides this list as part of the tender submission.
 - 2) Detailed CMS network single line diagram of the complete CMS works
 - 3) Detailed field wiring schematics
 - 4) Site specific equipment locations and cable route diagrams
 - 5) Instrument and equipment list
 - 6) Cable schedule and cable specifications (power and communication)
 - 7) Comprehensive CMS design report (Operating and engineering description, logic diagrams and formulas used to calculate data, HMI mimics, graphical user interface screen dumps, data analysis and information storage description, operations and troubleshooting, etc.)
 - 8) CMS signal list
 - 9) All instrument and equipment datasheets, manuals, specifications
 - 10) CMS load list (Power supply and distribution SLD including design calculations, battery sizing, etc.)
 - 11) Server room network cabinet and CMS equipment panel specifications and general arrangement diagrams (2D and 3D)
 - 12) Control and server room specifications and general arrangement diagrams (2D and 3D)
 - 13) Calibration and Factoring acceptance test (FAT) certificates

CONTROLLED DISCLOSURE

- 14) Site acceptance test (SAT) procedure and check sheet
- 15) Site integration test (SIT) procedure and check sheet
- 16) Commissioning procedure and check sheet
- 17) Operations and maintenance manual for the CMS during the O&M period. CMS fault finding and troubleshooting guide to be included in comprehensive O&M manual

3.4.20 Codes, Standards and Guidelines

The *Contractor* complies with the latest revisions of the following standards:

- 1) IEC 61724 Photovoltaic system performance monitoring - Guidelines for measurement, data exchange and analysis
- 2) IEC 61850-7 Communication networks and systems for power utility automation - Part 7-420: Basic communication structure – Distributed energy resources logical nodes
- 3) IEC 60870 Telecontrol equipment and systems. Remote control of photovoltaic power plants.
- 4) IEC 62381 – Factory acceptance test (FAT), site acceptance test (SAT), and site integration test (SIT)
- 5) IEC 62382 Electrical and Instrumentation loop check activities
- 6) IEC 62337 – Commissioning of electrical, instrumentation & control systems
- 7) EIA/TIA 568 – Standard for structured cabling
- 8) EIA/TIA 569 – Standard for communication pathways and spaces
- 9) EIA/TIA 607 – Standard for grounding and bonding of communication cabling
- 10) TIA/EIA 485: Electrical Characteristics of Generators and Receivers for Use in Balanced Digital Multipoint Systems
- 11) SANS 10142-1-2012 – The Wiring of Premises Part 1: Low-voltage installations
- 12) SANS 10340-1 Installation of telecommunication cables part 1: Fibre optic cables in buildings
- 13) SANS 10340-2 Installation of telecommunication cables part 2: Outdoor fibre optic cables
- 14) SANS 60794-1-1 – Optical fibre cables - Part 1-1: Generic specification – General
- 15) SANS 60794-1-2 – Optical fibre cables - Part 1-2: Generic specification - Basic optical cable test procedures
- 16) SANS 61312 – Protection against lightning electromagnetic impulse
- 17) SABS 1411: Parts 2-6 – Materials of Insulated Electric Cables and Flexible Cords
- 18) SANS 60947-7-1 and 60947-7-2 – The terminal blocks for the junction box terminations
- 19) SANS 60429 – Degree of protections provided by enclosures (IP)
- 20) 240-56227443 Requirements for Control and Power Cables for Power Stations Standard, sections 3.2.7, 3.6, 3.7, 3.8.7, 8, tables 16, 17, 18 & 19;
- 21) 240-56355754 Field Instrument Installation Standard, section 3
- 22) 240-56355815 - Field Instrument Installation Standard Junction Boxes and Cable Termination
- 23) 240-56355731 Environmental Conditions for Process Control Equipment Used at Power Stations Standard
- 24) 24056355728 Human Machine Interface Design Requirements Standard

CONTROLLED DISCLOSURE

- 25) 24056737448 Fire detection and Life Safety Design Standard
- 26) 24056355466 Alarm Management System Guideline
- 27) 240-56355808 Ergonomic Design of Power Station Control Suite Guideline
- 28) 240-56355541 Control System Computer Equipment Habitat Requirements Guideline

3.5 INFORMATION MANAGEMENT WORKS

- a) The *Contractor* supports the Eskom IM (Information Management) team and provides access to all parts in the Plant for installation, communication and information management as per required by the IM team.

3.6 METEOROLOGICAL SYSTEM WORKS

- a) The *Contractor* installs three weather stations: weather station 1, weather station 2 and weather station 3. The installation of any weather station does not provide shading to the PV array.
- b) Weather Station 1 is installed in central area of Grassland section and contains the following primary sensors,
 - a. Two (2) high-accuracy calibrated solar reference cells installed on the module POA with the same technology and type as in-installed PV modules. The calibration of the reference cell is performed according to IEC 60904-2: Photovoltaic device – Part 2: Requirements for reference solar devices, and
 - b. Two (2) thermal sensors (Pt 100 class B according to IEC 60751) to measure module surface temperature with a measurement resolution up to $\pm 1^{\circ}\text{C}$ at the back sheet
- c) Weather Station 2 is installed in the center of Ash disposal area and contains following primary sensors:
 - a. Two (2) high-accuracy calibrated solar reference cells installed on the module POA with the same technology and type as in-installed PV modules. The calibration of the reference cell is performed according to IEC 60904-2: Photovoltaic device – Part 2: Requirements for reference solar devices, and
 - b. Two (2) thermal sensors (Pt 100 class B according to IEC 60751) to measure module surface temperature with a measurement resolution up to $\pm 1^{\circ}\text{C}$ at the back sheet
- d) Weather Station 3 is installed at the center of the plant or in an location for maximum PV area coverage and contains the following secondary sensors,
 - a. Two (2) high-accuracy calibrated solar reference cells installed on the module POA with the same technology and type as in-installed PV modules. The calibration of the reference cell is performed according to IEC 60904-2: Photovoltaic device – Part 2: Requirements for reference solar devices
 - b. Two (2) horizontally mounted and completely unshaded calibrated pyranometers to measure the global horizontal irradiation according to Secondary Standard as stipulated in ISO 9060.
 - c. One (1) shielded ventilated thermocouple to measure the ambient temperature with a measurement accuracy of $\pm 1^{\circ}\text{C}$ (Pt 100 class B according to IEC 60751),
 - d. One (1) wind speed and wind direction sensor,

CONTROLLED DISCLOSURE

- e. One (1) relative humidity sensor, and
 - f. One (1) rain gauge
- e) The *Contractor* provides the technical data sheet and calibration certificates of all meteorological sensors to be supplied for the Project.

CONTROLLED DISCLOSURE

When downloaded from the EDMS database, this document is uncontrolled and the responsibility rests with the user to ensure it

is in line with the authorized version in the database.

3.7 HEATING VETILATION AND AIR CONDITIONING (HVAC) WORKS

- a) The *Contractor* performs the design, drawings, procurement, manufacture, quality control & assurance, supply, delivery, installation, commissioning, testing, training, and maintenance and handing over of HVAC works based on the *Employer's* outlined functional specification. The HVAC Works include the following:
- 1) Direct expansions air conditioning units air handling units, ductwork, pipework, condensers, evaporators and its associated subsystems with new energy efficient systems.
 - 2) Mechanical ventilation system, complete with fans, grilles, louvres and ducting.
 - 3) Associated electrical works and related controls & monitoring of complete Heating Ventilation and Air Conditioning (HVAC) system.
 - 4) Complete HVAC related building and civil works.
 - 5) Interfacing with CMS for monitoring of complete HVAC system.
 - 6) Provision of painting and corrosion protection for complete Works.
 - 7) Provision training, operation & maintenance manuals.
 - 8) Plant codification & labelling for the complete works.
 - 9) The *Contractor* makes provision for spares and maintenance support for a period of 24 months during the guarantee stage.
- b) The complete HVAC system is to be designed to accommodate 10% future growth under Grootvlei Power Station site conditions.
- c) The complete HVAC performance figures obtained during testing and commissioning must be within a range of $\pm 5\%$ of the specified figures given during *Contractors* design, plant and material selection phase.

3.7.1 Design Conditions

- a) The indoor conditions and areas to be provided with HVAC system include the following:

Table 3: Indoor conditions and areas to be provided with HVAC system

Area/Building	Indoor Temperatures	Relative Humidity
1. O&M Control room	22°C \pm 2°C	Not Controlled
2. O&M Server Room	21°C \pm 2°C	50% \pm 10%
3. O&M Spare Parts-Workshop	6°C above ambient	Not Controlled
4. O&M Ablutions	6°C above ambient	Not Controlled
5. Switchgear room	25°C Max.	Not Controlled

- b) The outdoor design conditions are as follows:
- Summer: 32°C DB, 20°C WB
 - Winter: 2°C DB
 - Altitude: 1651 m
- c) The following assumptions were made for heat load calculations:

CONTROLLED DISCLOSURE

- Server room heat load is equivalent to 200 W/m²
- MV_LV room heat load is equivalent to 150 W/m²
- Control room heat load is equivalent to 100 W/m²
- Lighting load is equivalent to 20 W/m²

d) The heat loads are envisaged to be as follows, however it remains the responsibility of the Contractor to recalculate and verify the heat loads during the detailed design stage:

Table 4: Admin building Space loads and airflows

Space Name	Total Cooling Load (kW)	Heating Load (kW)	Floor Area (m ²)	Design Air Flow (L/s)	Outdoor Air Quantity (L/s)	Total Supply air quantity (L/s)	Total Supply air quantity (L/s/m ²)
1. O&M Control room	11.2	6.0	52	685	100	765	14.7
2. O&M Server Room	6.9	-	24	526	50	576	21.9
3. O&M Spare Parts- Workshop	-	-	29.3	-	100	100	5.0
4. O&M Ablutions	-	-	16	-	60	60	7.5
5. Switchgear room	21.8	-	80	1475	295	1770	22.1

3.7.2 HVAC System Description

- The O&M Control room is to be serviced by one (1)-off dedicated direct expansion split unit complete with an evaporator and matching air cooled condensing units. The cooling and heating plant is to be based on air cooled outdoor units which are connected to indoor unit via a single refrigerant circuit, comprising suction and liquid refrigerant pipework. Both the indoor and outdoor units are to be inverter type units which provide space cooling or heating depending on the individual space requirements.
- The O&M Server Room is to be equipped with running and standby under ceiling type indoor units together with air cooled outdoor units. The HVAC equipment is to be configured to operate on running and standby mode for redundancy, including automatic change over between the units in case of failure of any one unit and at pre-set intervals to allow equal running time between the units.
- The switchgear room is to be serviced by two (2)-off ducted direct expansion air handling units together with matching air cooled condensing units. The air handling units are to be supplied complete with cooling & pressurisation functions. The filtration system is to be supplied complete with a fresh air primary filter of 92% average gravimetric efficiency and return air filtration of 85% dust spot efficiency.
- The switchgear room and O&M Server Room HVAC system is to be configured to operate on running and standby mode for redundancy, including automatic change over between the units in case of failure of any one unit and will be set at pre-set intervals to allow equal running time between the units. The units must have a cooling only mode of operation and will provide cooling 24 hours a day, seven day a week throughout the year.

CONTROLLED DISCLOSURE

- e) The HVAC units are to be controlled by wall mounted controllers which allow the occupants to set the room temperature, fan speed, and turn the units on and off. The room temperatures are to be sensed at wall mounted thermostat which will automatically adjust its cooling or heating in order to maintain the room set point. The switchgear room and O&M Server Room HVAC system are to be programmed such that should the temperatures within the respective rooms rise above 26°C or should a fault occur on the running unit, the controller will automatically start the standby unit.
- f) Outdoor filtered air is to be provided by means of fresh units which are connected to an external insulated galvanized sheet metal duct-work. Air is to be introduced into the space by means of constant air volume (CAV) diffusers/grilles.
- g) Ablution and O&M Spare Parts-Workshop ventilation is provided by a ducted extraction system and window extractor fans discharging contaminated air to outside with make-up air supplied from the surrounding areas via door grilles and ducted fresh air supply.

3.7.3 HVAC System Commissioning

- a) The complete HVAC system is to be commissioned in accordance with the following SANS and Chartered Institution of Building Services Engineers (CIBSE) codes or such other recognized commissioning procedure or code accepted by the Employer:
 - 1) Air distribution systems
 - SANS 10173: Code of Practice for the Installation, Testing and Balancing of Air Conditioning Ductwork, or
 - CIBS Commissioning Code A: 1996 or latest revision
 - 2) Automatic controls: CIBS Commissioning Code C: 2001 or latest revision
 - 3) Refrigerating Systems: CIBS Commissioning Code R: 2002 or latest revision

3.7.4 HVAC applicable Codes, Standards and Guidelines

The following are applicable standards, specifications and guidelines to HVAC *works*:

- 1) SANS 10400: The Application of the National Building Regulations
- 2) SANS 10103: The measurement and rating of environmental noise with respect to annoyance and to speech communication
- 3) SANS 10140-3: Identification color marking Part 3: Contents of pipelines
- 4) SANS 10142-1: The wiring of premises Part 1: Low-voltage installations
- 5) SANS 10147: Refrigerating systems including plants associated with air-conditioning systems
- 6) SANS 10173: The installation, testing, and balancing of air-conditioning duct work
- 7) SANS 193: Fire dampers
- 8) SANS 1238: Air-conditioning ductwork
- 9) SANS 1287-1: Ventilation brattices and ducting Part 1: Flexible ducting
- 10) SANS 1287-2: Ventilation brattices and ducting Part 2: Brattices, unsupported
- 11) SANS 1424: Filters for use in air-conditioning and general ventilation
- 12) ASHRAE 15: Safety Codes for mechanical refrigeration

CONTROLLED DISCLOSURE

- 13) ASHRAE 62: American Society of Heating Refrigeration and Air Conditioning Engineers. Ventilation for acceptable indoor air quality
- 14) ASHRAE 55: Thermal environmental condition for human occupancy
- 15) ASHRAE 52/76: Standard test method for filters
- 16) ASHRAE G1: Guideline for commissioning of air conditioning system

CONTROLLED DISCLOSURE

When downloaded from the EDMS database, this document is uncontrolled and the responsibility rests with the user to ensure it

is in line with the authorized version in the database.

3.8 FIRE PROTECTION SYSTEM WORKS

- a) The *Contractor* performs the design, drawings, procurement, manufacture, quality control & assurance, supply, delivery, installation, commissioning, testing, training, and maintenance and handing over of Fire Protection System *works* based on the *Employer's* outlined functional specification. The Fire Protection System *works* include the following:
- 1) Portable fire extinguishing equipment to service the MV cabins, O&M and Switchgear rooms in accordance with SANS 10400-T-2011, SANS 10105, and and the Eskom Fire and Life Safety Design Standard (240-54937450, revision 2)
 - 2) SABS symbolic signs are to be installed to clearly indicate all firefighting equipment, fire escape routes and exit doors in accordance with SANS 1186.
 - 3) The required fire protection system for the PV Solar plant, which is to be determined through a fire risk assessment by checking all possible failure modes in of the PV Solar system.
 - 4) Provision training, operation & maintenance manuals.
 - 5) Plant codification & labelling for the complete *works*.
 - 6) The *Contractor* makes provision for spares and maintenance support for a period of 24 months during the guarantee stage.
- b) The complete fire protection system is to be designed, constructed and equipped to satisfy the requirements of SANS 10400 and Eskom Fire Protection & Life Safety Design Standard (240-54937450) in order to ensure the following requirements are met:
- 1) Ensure protection of occupants (life safety);
 - 2) Minimize the spread and intensity of fire;
 - 3) Minimize and control the generation of fire and spread of smoke;
 - 4) Ensure sufficient building stability is retained in a fire; and to
 - 5) Provide adequate fire detection and fire extinguishing equipment, and access for fire brigade services

3.8.1 Fire Protection System applicable Codes, Standards and Guidelines

- 1) SANS 246: Code of Practice for Fire Protection for Electrical Equipment Installations
- 2) SANS 10400: The Application of the National Building Regulations
- 3) SANS 1186: Symbolic safety signs
- 4) SANS 1910: Portable refillable fire extinguishers
- 5) SANS 1464: Safety of luminaires Part 22: Luminaires for emergency lighting
- 6) SANS 10105: The use and control of fire-fighting equipment
- 7) SANS 10139: Fire detection and alarm systems for buildings - System design, installation and servicing
- 8) SANS 10177: Fire testing of materials, components and elements used in building
- 9) 240-54937450: Fire Protection & Life Safety Design Standard
- 10) 240-56737448: Fire Detection and Life Safety Design Standard

CONTROLLED DISCLOSURE

3.9 WET SERVICES WORKS

- a) The *Contractor* performs the design, drawings, procurement, manufacture, quality control & assurance, supply, delivery, installation, commissioning, testing, training, and maintenance and handing over of Fire Protection System *works* based on the *Employer's* outlined functional specification. The Wet Services *works* include the following:
- 1) Potable water supply and its reticulation system consisting of a closed potable water tank with at least 6000 litres capacity, sized for a least one week supply to 6 staff permanently on site.
 - 2) Contractor to provide an option to install borehole system for potable water supply (these are not to be included in tender price but will be ordered at the discretion of the *Employer*)
 - 3) Sewage reticulation system from O&M ablutions to sewage conservancy tank.
 - 4) Interfacing with PV CMS for monitoring of potable water tank level and sewage conservancy tank level.
 - 5) Provision of painting and corrosion protection for complete *works*.
 - 6) Provision training, operation & maintenance manuals.
 - 7) Plant codification & labelling for the complete *works*.
 - 8) The *Contractor* makes provision for spares and maintenance support for a period of 24 months during the guarantee stage.

3.9.1 Wet Services System Description

- a) Potable water supply and its reticulation system is to consist of a closed potable water tank with at least 6000 litres capacity, sized for a least one week supply to 6 staff permanently on site. The size of the potable tank is based on the recommendation of table 1 of SANS 10252-1.
- b) The potable water tank is to have inlet valve for filling, drain nozzle and outlet valve for supplying potable water to the O&M building. The tank must have an overflow protection, low level and high level indicators. The potable water meeting SANS 241 is to be trucked from Grootvlei Power Station for filling the tank.
- c) Pressure is to be maintained by means of boosting pumps (running and standby domestic water pump). The system pressure is not exceeding 600kPa and the pressure at the furthest point is not less than 300 kPa. This pressure is to be made available to all plumbing fixtures. The potable water reticulation pipes are to be designed in accordance with SANS 10252 and the manufacturer's technical information. Pipes are to be sized to suit the operational requirements of the chosen brassware and sanitary ware fixtures. No flow velocity shall exceed 1.5m/s inside buildings.
- d) Sewage disposal and its reticulation system are to consist of a sewage conservancy tank that is imbedded in the ground. The sewage conservancy tank is to be linked with pipes from the kitchen and toilets O&M building. The sewage conservancy tank is to have an overflow detection and protection to avoid environment contamination.
- e) The *Contractor* makes provision for the supply of PV Solar Plant panel washing for a period of 24 months during the Defects Period. The water required for panel washing and dust suppression is to be trucked from Grootvlei Power Station. If the Employer accepts the provisions for borehole system then the water for PV cleaning to be sourced through a borehole system.
- f) The Contractor designs, procures, and installs the tank for storage of water for PV module cleaning. The minimum tank capacity to be 20,000 litres.

CONTROLLED DISCLOSURE

3.9.1.1 Borehole System

- a) The *Contractor* is to provide a borehole system (this will be ordered at the discretion of the Employer) as means of providing potable water supply for human consumption as well PV Solar plant panel washing. The borehole system is to consist of the following:
 - 1) Siting of the borehole system
 - 2) Drilling of borehole
 - 3) Aquifer testing of borehole system
 - 4) Pumping system, piping to connect portable and PV module cleaning tank, and ancillaries
 - 5) Maintenance and operation of borehole system for Defects Period.
- b) The contractor's quotation is to be accompanied by a design, construction, maintenance, and operation and decommissioning approach of borehole system.
- c) The borehole system is to be designed and constructed in accordance with the following applicable codes, standards and guidelines:
 - 1) SANS 10299: Development, maintenance and management of groundwater resources-Part 0- Glossary of terms
 - 1) SANS 10299: Development, maintenance and management of groundwater resources-Part 1-The location and siting of water boreholes
 - 2) SANS 10299: Development, maintenance and management of groundwater resources-Part 2- The design, construction and drilling of boreholes
 - 3) SANS 10299: Development, maintenance and management of groundwater resources-Part 4- Test-pumping of water boreholes
 - 4) SANS 10299: Development, maintenance and management of groundwater resources-Part 5- The design, selection and performance of pumping equipment for production boreholes
 - 5) SANS 10299: Development, maintenance and management of groundwater resources-Part 6- The installation and commissioning of pumping equipment for production boreholes
 - 6) SANS 10299: Development, maintenance and management of groundwater resources-Part 7- The rehabilitation of water boreholes
 - 7) SANS 10299: Development, maintenance and management of groundwater resources-Part 8- The management of water boreholes
 - 8) SANS 10299: Development, maintenance and management of groundwater resources-Part 9- The decommissioning of water boreholes

3.9.2 Wet Services applicable Codes, Standards and Guidelines

- 9) SANS 62: Pipes suitable for threading and of nominal size not exceeding 150mm
- 10) SANS 719: Electric welded low carbon steel pipes for aqueous fluids (large bore)
- 11) SANS 776: Copper alloy gate valves
- 12) SANS 1056-3: Ball Valves
- 13) SANS 1123: Pipe Flanges
- 14) SANS 241: Drinking water

CONTROLLED DISCLOSURE

- 15) SANS 10400-A: The application of the National Building Regulations Part A: General principles and requirements
- 16) SANS 10400-P: The application of the National Building Regulations Part P: Drainage
- 17) SANS 10400-S: The application of the National Building Regulations Part S: Facilities for persons with disabilities
- 18) SANS 10400-XA: The application of the National Building Regulations Part X: Environmental sustainability Part XA: Energy usage in buildings
- 19) SANS 10252: Water supply and drainage for buildings

CONTROLLED DISCLOSURE

3.10 CHEMICAL WORKS

- a) This section describes the following:
 - 1) The sewage disposal and its reticulation system which are within the scope of the *Contractor*.
 - 2) Chemical Works Information and designs and all necessary interface requirements that are provided by the *Contractor*.
- b) The *Contractor* ensures the sewage conservancy tank is functionally and efficiently located and it is sized for optimum space usage.
- c) The *Contractor* submits the design calculations/drawings of the sewage conservancy tank which is within this scope of work for review, acceptance and comments by the *Project Manager*.

3.10.1 Scope of Work

3.10.1.1 General

- a) This specification describes the following:
 - 1) Sewage disposal and its reticulation system consist of a sewage conservancy tank of at least 16,740 litres capacity that is imbedded in the ground.
 - 2) A warning system with an audible alarm is installed in order to protect public health, prevent the discharge of raw sewage to the environment and protect the public health by preventing backup of sewage and subsequent discharge. This alarm is triggered at 80% capacity in order to give sufficient warning to the onsite personnel. This gives sufficient time to arrange for removal by the *Contractor*.
 - 3) The sewage conservancy tank is linked with pipes from the kitchen and toilets in the O&M building. The kitchen waste passes through a grease trap before entering the drain. This grease trap requires regular cleaning and maintenance that should not be neglected.
 - 4) The sewage conservancy tank is situated where it is accessible to vacuum tankers, for sludge and scum removal, noting that no erection of building is permitted over the tank.

3.10.1.2 Design Phase

- a) The *Contractor* engages a competent qualified Professional Engineer experienced (minimum 5 years' experience) in the design of similar work to be fully responsible for the design.
- b) The Services performed by the *Contractor* in the design phase include
 - 1) Complete design in accordance with the requirements of this specification.
 - 2) Design of the sewage conservancy tank and all other associated supporting structures.
 - 3) Sizing and optimizing of the different components.
- c) The *Contractor* ensures the sewage conservancy tank which is incorporated in this contract is functionally and efficiently located and that it is sized for optimum space usage.

3.10.1.3 Construction Specifications

- a) As a minimum, the sewage conservancy tank's design meets the following requirements.

CONTROLLED DISCLOSURE

- 1) The tank is constructed and designed in accordance to the information contained within SANS 10400-P: The Application of the National Building Regulations.
- 2) The tank is designed such that all requirements of the Occupational Health and Safety Act (Act No. 85 of 1993) and its regulations are adhered to.
- 3) The inlet is designed such that blockage by the scum layer is prevented.
- 4) The tank is designed with two compartments to allow for periodic desludging. The tank is easily accessible.
- 5) The tank is watertight at all times and does not allow for any storm water inflow. The tank is constructed of materials which are not susceptible to excessive corrosion. The interior is plastered with a waterproof material.
- 6) Water supply for cleaning is always available within the vicinity of the conservancy tank. The design includes a water connection point.

3.10.1.4 Codes and Standards

- a) All chemical engineering design *works* comply with the following standards.
 - 1) SANS 10400-P: The Application of the National Building Regulations Part P: Drainage
 - 2) Occupational Health and Safety Act (Act No. 85 of 1993)

CONTROLLED DISCLOSURE

3.11 SECURITY SYSTEM WORKS

3.11.1 General

- a) The site perimeter serves as an enclosure for all key areas of the site comprising of PV modules, copper cables, MV cabins with step up transformers, O&M building and PV Plant Substation.
- b) Physical protection is integral for areas that can be attacked to compromise or reduce system effectiveness and reliability; and to prevent forceful intrusion or attack against the facility.
- c) Facility characterization takes into account site planning and landscaping, building and facility design and comprises of the establishment of a core security area.

3.11.2 Perimeter Fencing

3.11.2.1 Inner and Outer Fence

- a) The security fence comprises of inner and outer perimeter fence.
- b) The *Contractor* designs the inner and outer perimeter fence using the applicable Eskom standard 240-76368574, SANS 23-4, SAN121 and SANS1700-5-8 Standards.
- c) The *Contractor* designs, manufacturer, supply and install the inner and outer perimeter fence for the required design life under the prevailing site environmental conditions which will be determined by the *Contractor*.
- d) The perimeter fence consists of meshed steel grade wire.
- e) The minimum requirements of the steel grade wire are as follows:
 - 1) Ultimate tensile strength : 500 MPa (prior to welding)
 - 2) Wire diameter : 4 mm (\pm 0.06 mm)
- f) The chemical composition of the wire is not specified because it might influence the welding process as preferred by the manufacturer. The end product meets the performance requirements stipulated in **Appendix N**.
- g) The mesh is produced by electrical resistance welding at every line wire/cross wire intersection.
- h) The welded mesh panel have the following dimensions and aperture:

Dimensions

- 1) Panel Height: Mesh Height above ground level: 2.4m (+/- 1%)
- 2) Panel width: 3.0 to 3.5m (Standard panels)
- 3) Shorter lengths are allowed for stepping purposes.

Aperture

- 1) Category 1: 762mm (+/- 2mm) x 12.7mm (+/- 1mm)
 - 2) Category 2: Any combinations or alternative designs that will make bridging of the system more difficult than category 1 products.
- i) For detailed technical specification of perimeter fence refer to **Appendix N**.

CONTROLLED DISCLOSURE

3.11.2.2 Energised Fence

- a) The PV plant is protected against unauthorised access by a Non-Lethal Energised Perimeter Detection System (NLEPDS).
- b) At all installations, the NLEPDS is self-supported, installed between electrically inert (inner and outer), double barrier perimeter fence systems.
- c) The height of the NLEPDS and spacing of supports is as specified in **Appendix N**.
- d) The energised fence is earth at regular intervals of 10 to 20m for dry soils, 20 to 50m for semi-moist soils and 50 to 100m for moist soils, for detailed technical specification refer to Earthing section of Energized fence in **Appendix N**.
- e) Lightning protection equipment is installed where there are voltage surges due to lightning, variety of line faults, power interruptions, high voltage switching conditions, and is able to operate without failure under all of the above mentioned conditions. Therefore, it is imperative that the system be adequately earthed. For detailed technical specification refers to lightning protection section of Energised fence in **Appendix N**.
- f) Protection against high voltage transients is provided on both signal and power circuitry, without impairing the system's electrical parameters, sensitivity, or performance.
- g) The *Contractor* designs, manufactures, supplies and installs the energised fence for the required design life under the prevailing site environmental conditions which will be determined by the *Contractor*.
- h) The *Contractor* designs the non-lethal energised fence in accordance to the applicable SANS standards 23-4, 121, 1700-5-8, 10222-3 and 4628
- i) The NLEPDS, in all aspects, conforms to the Occupational Health and Safety Act Regulations (OHS Act No. 85 of 1993 dated April 2003) or latest revision - Electrical Machinery Regulation – item 11 Electric Fences.
- j) UV resistant warning signs of minimum size (200mm x 100mm) are displayed conspicuously, warning people that the site is protected by a NLEPDS and securely fixed along the entire length of the perimeter, at each gate and access point, placed at eye level on the conductor / trace wire and spaced at intervals not exceeding 10m.
- k) Background colour of each warning sign is yellow with black inscription.
- l) The energizer is in accordance with IEC 60335 -2-7 Standard and have the following:
 - 1) Peak value of voltage is above 8kV, but not exceeding 10kV
 - 2) Maximum energy delivered to a load of 500Ω is not less than 7.5 Joules at the energizer when connected to the NLEPD structure.
 - 3) The required energy on each live conductor / trace wire on the NLEPD structure is not to be less than 6 Joules, with a minimum Differential of Potential of 7.5 kV.
 - 4) Minimum interval between two consecutive impulses is not be less than 1.0 second
 - 5) Maximum impulse duration is 50 milliseconds.

3.11.2.3 Non-Lethal Energized Perimeter Detection structure

- a) A free standing NLEPD structure is erected on the inner side, and at a minimum of two (2) meters away from the outer perimeter barrier.
- b) SANS 10222-3:2003 is used as a general guideline for installation of the NLEPD structure.

CONTROLLED DISCLOSURE

For detailed technical specification on the Non-Lethal Energised Perimeter Detection structure refer to **Appendix N**.

3.11.3 Closed Circuit Television (CCTV)

- a) The PV plant is monitored via closed circuit television (CCTV) surveillance system.
- b) The scope of this IP surveillance and pre-detection system provides proactive surveillance coverage and alarm monitoring of all areas around PV plant perimeter, entrances to the PV plant, all gates, guard rooms, control rooms, PV plant substation, and strategic spares storerooms.
- c) The intelligent robust digital IP video surveillance and pre-detection system is considered as part of Eskom security systems integrated solution. Intelligent robust IP video surveillance and pre-detection system is integratable with current and future access control systems.
- d) All cameras are IP and power over Ethernet (POE) enabled. Pre-detection sensors are infrared sensors, microwave beams and fibre optic based sensors on outer barrier fence/wall and on electric fence where applicable.
- e) As IP infrastructure is dedicated to security systems purposes only, it is not be integrated with Eskom IT system network.
- f) Operators in a Control Centre are able to monitor live video over the network and to retrieve and replay recorded video from the PV plant site.
- g) Video images are displayed on a video-wall, workstations etc. wireless IP cameras are utilized on the site and offices where applicable.
- h) The *Contractor* designs, manufacturers, supplies and installs the CCTV for the required design life under the prevailing site environmental conditions is determined by the *Contractor*.
- i) The digital IP video surveillance system enables intrusion detection in the following areas:
 - 1) Energised fence
 - 2) O&M Building
 - 3) MV cabins
 - 4) PV Plant Substation
- j) For effective alarm monitoring, all cameras are equipped with the following:
 - 1) Built in video motion analytic detection system
 - 2) Audio detection alarm
 - 3) I/O connections
 - 4) Alarm and event management
- k) Each access control area have a camera with an associated intelligent digital IP camera with sensor where necessary
- l) Access control areas are as follows:-
 - 1) Main gate
 - 2) O&M Building
 - 3) MV Cabins
 - 4) PV Plant Substation
- m) During the alarm situation(s) the following take place:-
 - 1) Lights are immediately switched on in that particular zone(s)

CONTROLLED DISCLOSURE

-
- 2) PTZ camera(s) are immediately zoom into that zone(s)
 - 3) Siren(s) sound in the control room(s)
 - 4) Alarm zone(s) are immediately displayed in all the working station(s), PCs, video wall(s)
 - 5) Two way inbuilt audio system are immediately activated for operator(s) to speak to the intruder(s)
 - 6) Send videos via emails and cell phones
- n) IP video surveillance and pre-detection system and associated equipment are able to adapt and function without being affected by its immediate electrical environment where high voltage switching occurs often and as such, subject to high levels of radiated electrical interference due to its physical placement or its direct connection to electrical plant.
 - o) The functioning of the IP video surveillance and pre-detection system are affected by other device frequencies such as cell phones, portable radio, telephones, communication transmitters/satellites; dc relays operations, switching ac supplies, cable-borne interference and many others.
 - p) The IP Video surveillance system are connected to an electrical supply and battery back up
 - q) The supply is 220V (+/-10%), 47-51Hz single phase AC source and total harmonic distortion of 5%.
 - r) A battery backup facility of at least 8 hours is provided.
 - s) The IP surveillance system are connected to the Video Management System (VMS) which accepts videos from the cameras, stores the videos and manage the distribution of the videos to viewers.
 - t) Fixed and remote panic buttons are installed at strategic places inside the PV Plant as determined by the *Employer*. These places are:
 - 1) MV yard strategic places etc.
 - 2) Control room
 - 3) MV Cabins
 - 4) PV plant substation
 - u) During an alarm situation, camera(s) in the panic button vicinity are immediately turned to that direction and provide video footage.
 - v) Alarm is immediately sent to the control room.
 - w) For detailed technical specification on the CCTV refer to **Appendix N**.

3.11.4 Lighting

- a) The Contractor designs the PV plant to consist of perimeter Lighting divided into zones.
- b) The Contractor designs the perimeter security lighting in all aspects to conform to the requirements of SANS 10389-2
- c) Perimeter security lighting defines boundaries and establishes territory. Light directed horizontally away from spaces provides visual security and prevent unwanted observation into facilities / installations.
- d) The Contractor designs the perimeter security lighting divided into zones, in accordance with the non-lethal energized perimeter fence system's zones. These lighting zones are switched on by a signal from the non-lethal energized perimeter fence alarm system, transmitted via fibre optic

CONTROLLED DISCLOSURE

cables. Individual zones are able to be switched on manually for testing and security purposes from the main gate security control room located in the Access Control Building (ACB).

- e) An even horizontal illumination level with a minimum of 5 lux and a maximum uniformity (E_{max} / E_{min}) of not more than 5 to 1 is provided. Submission, proofing the above compliance, is accompanied by a lighting calculation, which is based on the following criteria:
 - 1) Illuminance level is calculated at ground level.
 - 2) Maintenance factor of 0.75 is applied for HPS luminaires with an IP 66 rating certified by SABS test report.
 - 3) Luminaire data are supported by a report / certificate issued following tests conducted by a national or international accredited laboratory
- f) Luminaires complying with SANS 60598-2-3 and 475 standards are offered.
- g) For detailed technical specification on the lighting refer to **Appendix N**.

3.11.5 Security Alarms

- a) The alarm system forms an integral part of the IP surveillance system to provide proactive surveillance coverage and alarm monitoring of all areas around site perimeters, entrances, all gates, guard rooms, control rooms, battery rooms, MV yard strategic places, strategic spares rooms etc. as determined by *Employer*.
- b) The system facilitates for local and remote control rooms IP surveillance signals monitoring, effective crime pre-detection, live event monitoring, investigations, provision of management information, reviewing, profiling, data storage (digital), data retrieval, and the provision of evidence admissible in legal and disciplinary proceedings.
- c) The alarm system is integratable with all Employer's electronic security systems.

3.11.5.1 Operating conditions

- a) All the elements of the alarm system are able to function in all climatic conditions prevailing in South Africa with the minimum environmental conditions below, without the performance being out of limits or the life cycle being shortened:
 - 1) Altitude 0 – 2500 meters
 - 2) Ambient temperature -10 to + 55 °C
 - 3) Relative humidity Up to 100 % outdoors, 5 to 95% indoors in the specified temperature range.
 - 4) The components of the system are inherently corrosion resistant.
- b) Environmental tests on the alarm system detector are conducted in accordance with 5.4 of SANS2220-1-1, during and after the test the detector is not adversely affected, it is not damaged and it does not generate an alarm.

3.11.5.2 Detection Alarms

- a) Alarm is activated to enable intrusion pre-detection in the following areas:
 - 1) MV yard strategic places,
 - 2) Tunnelling underneath the electric fence,

CONTROLLED DISCLOSURE

- 3) Separation of electric fences,
 - 4) Cutting and climbing over perimeter outer barrier fences,
 - 5) Digging underneath, breaking through and climbing over the outer barrier walls
 - 6) Unauthorized access
- b) The system is designed to ensure a clear and unambiguous indication of the origin of the alarm signal. The site and sensor (zone number and description) triggered is clear e.g. Simmerpan Substation, Zone 5 – MV yard.
- c) Alarm triggers on the integrated alarm system occur as follows:
- 1) Due to Camera video analytics alarm detection on the zone(s);
 - 2) Noise in the guarded zones;
 - 3) Alarm inputs from electric fence;
 - 4) Alarm inputs from infrared sensors;
 - 5) Alarm inputs from microwave beams;
 - 6) Alarm inputs from panic buttons;
 - 7) Alarm input from fiber optic sensors(s);
 - 8) Alarm inputs from access control points.

3.11.5.3 Door Alarms

- a) The alarm system is able to receive alarming instruction from security controller and sensors properly installed on each door. Reference to **Appendix N** of System and technology (table of components)

3.11.5.4 Local Monitoring

- a) The alarm system is able to receive alarming instruction from security controller and sensors such as security lights, PA systems, Doors, CCTV, panic buttons or any other electronic security system.
- b) The security control centre is able to remotely issue alarming instructions to the alarming system. It is possible for the security control centre to monitor and control the system both locally and remotely.
- c) The local and remote controllers are able to schedule equipment operation.
- d) The alarm system have a signalling interface (modem, fibre, microwave etc.) to enable
- e) Operators to easily monitor sites remotely.

3.11.6 Integrated Access Control

- a) The Integrated Access Control (IAC) Project aims to collaborate and align efforts across the logical and physical security domains in an effort to standardise access control within Eskom.
- b) The project defines and implements a strategy for the integration of physical and logical security domains within the context of access control.
- c) For detailed specification of IAC, **Appendix N**.

CONTROLLED DISCLOSURE

3.11.7 Interface to Power Station

3.11.7.1 CCTV and Alarm

3.11.7.1.1 Integration with CCTV cameras

- a) For effective alarm monitoring and proactive accurate response, all cameras are equipped with the following features which enable the network cameras to be constantly on guard in analysing alarm inputs and activating sirens in the control rooms while zooming into the alarm(s) spot(s):
- 1) Built-in video motion analytic detection system,
 - 2) Audio detection alarm,
 - 3) Active tampering alarm,
 - 4) I/O connections. Some inputs are used for the purposes of electric fence alarm relay outputs, sensors alarm triggers etc.,
 - 5) Alarm and event management.
 - 6) Integration with PA (Public Address) system
- b) Audio detection facilitates for the following activities:
- 1) Operators to listen for sounds in the guarded areas and react accordingly.
 - 2) Operators to speak to intruders.
 - 3) Communication at the access points (entrances to the protected sites) etc.
 - 4) Integration with pre-detection sensors
 - 5) Pre-detection sensing will occur as follows:
 - 6) Infrared along the perimeter and in the strategic places of the protected site.
 - 7) Microwave beams in the selected strategic place of the protected site.
- c) Fibre optic sensors are installed as follows:
- 1) Beneath, inside middle and top of the outer barrier wall to sense digging, intrusion through the wall and climbing over the wall.
 - 2) On the outer barrier fence.
 - 3) Underneath electric fence and in-between conductors in order to sense digging as well as separation of the conductors.

3.11.7.1.2 Integration with panic buttons

- a) A panic button is installed to alert the security control room operators with a distress signal should an incident occur at a protected site.
- b) There is an option for both portable wireless panic buttons and fixed panic buttons installed at strategic areas.
- c) The alarm condition or status continues until the panic button is manually reset.
- d) The panic button function is operational over the entire area of the protected site.

CONTROLLED DISCLOSURE

3.11.7.1.3 Integrated Alarm management

- a) During the alarm situation(s) the following take(s) place:
- 1) Lights are immediately switched on, in that particular alarmed zone(s).
 - 2) PTZ camera(s) are immediately zoomed into that zone(s).
 - 3) Siren(s) sound in the control room(s).
 - 4) Video recording commences immediately.
 - 5) Alarm zone(s) are immediately displayed in all the working station(s), PCs, video wall(s).
 - 6) Two way inbuilt audio system is immediately activated for operator(s) to speak to the intruder(s) using the PA system.
 - 7) Each violation is reported to the control centre and notified to the security controller.
 - 8) The operator is able to use information available, as well as the site history to decide on a response.

3.11.7.1.4 Arming and Disarming system

- b) System is able to be armed via a remote control. The remote have a minimum of four buttons / key combinations below:
- 1) Alarm system activation / deactivation;
 - 2) Open electric gate (When installed);
 - 3) Open the maglock to the relay house door (Where implemented);
 - 4) Panic Button to alert the security control room operators with a distress signal when an incident occurs.
- c) It is possible to arm and disarm the intruder detection system from inside a vehicle outside the gate of the protected site.
- d) There is a high brightness LEDs to indicate alarm status (armed or disarmed). LEDs are mounted at each entry point in such a way that it is clearly visible even in bright sunlight.
- e) It is possible to detect the following scenarios when the system is armed:
- 1) Unauthorised access to protected site;
 - 2) A panic button (if installed) is pressed;
 - 3) Authorised access;
 - 4) AC fail;
 - 5) Periodic test signals to confirm system is operational.

3.11.7.1.5 Integrating system / controller

The integrating system/controller is designed to:

- a) Collect information from intrusion detection systems, access control and video surveillance devices.

CONTROLLED DISCLOSURE

- b) Contain circuitry that provides interface with the peripheral devices by means of industry standard communications protocol in both directions.
- c) Maintain a real-time sequential record (on the hard disk) of reader events, alarm events and all operator programming events and date and time stamped to the nearest second. These events are stored in such a format that it is possible for other operators to sort and analyse them.
- d) Have a transaction memory and be able to store information over a one month period or 1000 transactions.
- e) Have a transaction memory to store information at an offsite central server over a longer period (over 3 months).
- f) Have the output capability to send information to the intruder detector systems, tamper protection devices and power supply unit to reset once an alarm has been acknowledged by the security control centre.
- g) Have input capability to monitor intruder detector alarm signals, tamper protection devices and power supply unit alarms.
- h) Have interface capability with the communication unit in order to send alarm signals to the security control room and receive instructions to reset the alarm condition.
- i) Provide an interface for connection to access control devices such as a reader controller and access control controller.
- j) The system is configured to have a decision making process at the controller so that controller transaction time does not exceed 1s.
- k) The controller is menu driven and display status of all access points simultaneously.
- l) The alarm signal has the highest priority and overrides other activities. It is possible to recall and execute the last transaction prior to the alarm condition

3.11.8 Power Supply to Security System

The *Contractor* designs two power supply solutions for the security system.

- a) Option A operates off 110V DC and will be connected to the relay house 110V DC supply which has battery backup.
- b) Option B uses 220V AC supply from the site and includes battery backup/UPS for all system devices.
- c) The *Contractor* consults the *Employer* to determine the power supply system to be used.
- d) Option A is installed whenever possible since this arrangement leverages off the battery maintenance processes already in place.
- e) Option B is used when site battery capacity is not sufficient to supply the added load of the alarm system.
- f) For both options the standing time for backup power is 12 hours at sites within 200kms of responsible Eskom DC section.
- g) For detailed technical specification on the lighting, refer to **Appendix N**.

3.11.9 Codes and Standards

All equipment and services supplied comply with the standards listed below. The *Contractor* considers the latest issued standards applicable during the execution of the Project.

CONTROLLED DISCLOSURE

a) Inner and Outer Fence

- 1) Eskom Standard on High Security Mesh Fencing (240-76368574)
- 2) BS EN 10025-2: Hot rolled products of structural steels. Technical delivery conditions for non-alloy structural steels
- 3) SANS 23-4: Steel wire and wire products for fences Part 4: Steel wire welded mesh fencing
- 4) SANS 121: Hot dip galvanized coatings on fabricated iron and steel articles — Specifications and test methods
- 5) SANS 1700-5-8: Fasteners Part 5: General requirements and mechanical properties Section 8: Mechanical properties of corrosion- resistant stainless-steel fasteners - Bolts, screws and studs
- 6) SANS 4628- Sections addressing cracking, blistering etc.
- 7) QM-58: Supplier Contract Quality

b) Energised Fence

- 1) BS EN 10025-2: Hot rolled products of structural steels. Technical delivery conditions for non-alloy structural steels
- 2) SANS 23-4: Steel wire and wire products for fences Part 4: Steel wire welded mesh fencing
- 3) SANS 121: Hot dip galvanized coatings on fabricated iron and steel articles Specifications and test methods
- 4) SANS 1700-5-8: Fasteners Part 5: General requirements and mechanical properties Section 8:
- 5) Mechanical properties of corrosion- resistant stainless-steel fasteners - Bolts, screws and studs
- 6) SANS 4628- Sections addressing cracking, blistering etc.
- 7) QM-58: Supplier Contract Quality

c) Perimeter Lighting

- 1) SANS 475:2006 Luminaires for interior lighting, street lighting and floodlighting – Performance requirements
- 2) SANS 60598-2-3 The safety of street lighting luminaires
- 3) SANS 10389-2 Exterior security lighting
- 4) ARP 035: 2005 Guidelines for the installation and maintenance of street lighting
- 5) SANS 1088: 2004 Luminaire entries and spigots
- 6) SANS 1250: 1991 Capacitors for use with fluorescent and other discharge lamp ballasts
- 7) SANS 1266: 2002 Ballasts for discharge lamps (excluding tubular fluorescent lamps)
- 8) SANS 1574: 2004 Electrical cables – flexible cords and flexible cables
- 9) SABS IEC 922: 1989 Ballasts for discharge lamps (excluding tubular fluorescent lamps) – Performance requirements
- 10) SABS IEC 926: 1995 Auxiliaries for lamps – Starting devices: General and safety requirements

CONTROLLED DISCLOSURE

-
- 11) SABS IEC 60927: 2005 Starting devices (other than glow starters) – Performance requirements
 - 12) SABS IEC 61048: 2006 Capacitors for use in tubular fluorescent and other discharge lamp circuits: General and safety requirements
 - 13) SABS IEC 61049: 1991 Capacitors for use in tubular fluorescent and other discharge lamp circuits – Performance requirements
 - 14) SANS 529: 2001 Heat-resisting wiring cables
 - 15) SANS 1507: 2002 Electric cables with extruded solid dielectric insulation for fixed installations
 - 16) VC 8011: 1999 Lamp holders
 - 17) SANS 1777: 2004 Photoelectric control units for lighting (PECUs)
 - 18) SABS ISO 1461: 2000 Hot dip galvanized coating on fabricated iron and steel articles – Specifications and test methods
 - 19) SANS 556-1: 2004 Low-voltage switchgear Part 1: Circuit-breakers
 - 20) BS 1490: 1988 Specification for aluminium and aluminium ingots and castings for general engineering purposes

d) Security Alarms

- 1) 1 SANS 2220-2-1 Electrical security systems, Part 2-1: Access control systems: General characteristics
- 2) 2 SANS 2220-1-1 Electrical security systems, Intruder alarm systems – General requirements
- 3) 3 SANS 2220-1-7 Electrical security systems, Electrical alarm systems: Power units
- 4) 4 SANS 2220-2-2 Electrical security systems, Access control systems - Central processor
- 5) 5 TST41-877 Transmission Substations Design Earthing Standard
- 7) 6 240-55410927 Cyber Security Standard For Operational Technology

-

CONTROLLED DISCLOSURE

3.12 INSPECTION, TESTING AND COMMISSIONING WORKS

- a) This section describes the type of inspections, tests and performance verification that the *Contractor* demonstrates during execution and operation of the project. These tests are defined under:
- 1) Tests before Installation;
 - 2) Tests after Installation;
 - 3) Tests on Completion; and
 - 4) Tests after Completion.

3.12.1 General Requirements

The *Contractor*:

3.12.1.1 Standards

- a) Refers IEC 62446: "Grid connected photovoltaic systems – Minimum requirements for System documentation, commissioning tests & Inspections" to complete the minimum requirements for a PV Plant commissioning;
- b) Refers IEC 60364 – 6 Ed. 1: Low Voltage Electrical installations;
- c) Refers IEC 62337 Commissioning of Electrical, Instrumentation and Control systems;
- d) Refers South African Grid Code;
- e) Refers SNAS 10173 Code of Practice for the Installation, Testing and Balancing of Air Conditioning Ductwork, or CIBS Commissioning Code A: 1996 or latest revision;
- f) Refers Automatic Controls: CIBS Commissioning Code B: 1996 or latest revision;
- g) Refers Refrigerating Systems: CIBS Commissioning Code R: 2002 or latest revision; and
- h) Uses Commissioning best practice method and any other relevant standards

3.12.1.2 Personnel and Facilities

- a) Inspects, tests, commissions and performs all relevant tests of the PV component and system at manufacturing facilities, independent laboratories and on site, as per requirements set in this document, to demonstrate compliance with the Contract, as built (design) documents and standards
- b) Provides facilities necessary to enable the inspection, testing, commissioning and performance testing of the Project to be satisfactorily completed including labour, equipment, materials, instruments, consumable materials, electrical power, fuel, lubricants, water etc.
- c) Provides staff with the relevant skills and competence for the inspection, testing, commissioning, performance testing and witnessing required
- d) Provides an ECSA registered professional engineer or technologist to declare the installation complies with all standards & requirements
- e) Ensures that the supervising commissioning engineer has a minimum of 3 years' experience in the commissioning and performance testing of utility scale PV installations
- f) Is responsible for all Health & Safety requirements during commissioning. Provides a Safety Briefing for all personnel who will carry out or witness the tests and ensures that such personnel

CONTROLLED DISCLOSURE

comply with all applicable Health & Safety procedures at all times during the tests. Ceases any testing in the event that any unsafe conditions rise

- g) Provides the opportunity to the *Employer* and *Employer's* representatives to witness all commissioning tests. The *Employer* provide reasonable and adequate notice to the *Contractor* that other parties have been invited to witness the tests and the *Contractor* provides all facilities and support that are reasonably required by the *Employer* for such parties to witness the tests
- h) Co-operates and co-ordinates with the *Employer*, *Employer's* representatives and Power Station Managers in a best way to ensure the commissioning activities are performed respecting all *Employers'* requirement and not effecting the regular Power Station's (Connection point) normal operation and maintenance
- i) Commences commissioning activities respecting all legal, environmental and administrative requirements
- j) Co-operates with the respective authorities for verification of their requirement during project installation, commissioning and operation
- k) Executes all commissioning activities at any time in the most diligent manner at highest level of professionalism and considering the best practice and in good workmanship established in the PV industry.

3.12.1.3 Instruments

- a) Provides any instruments or other equipment for the *Employer* and *Employer's* representatives to review the accuracy, quality and performance of the PV Plant.
- b) Provides any assistance required by *Employer* and *Employer's* representatives in the use of instruments and measuring equipment.
- c) Ensures that instruments used for inspection, testing, commissioning and performance monitoring are correctly calibrated and up to date, according to their relevant standards. Submits valid calibration certificates with method statements and test records.
- d) Provides temporary communication equipment as necessary to enable the commissioning team to carry out their tasks safely and effectively. Ensure temporary communication equipment does not cause interference with equipment owned or operated by any other parties.

3.12.1.4 Defects and Delays

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

3.12.1.5 Test Protocols and Reports

- a) Provides, at least three (3) weeks prior to start of any tests, to the *Project Manager* detailed test protocols including information regarding on test schedules, testing methodology and equipment to be used, evaluation method and the criteria of acceptance of each test types. The *Project Manager* must accept 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;

CONTROLLED DISCLOSURE

- 2) List of equipment to be used for each test along with technical specification, measurement uncertainties and relevant certificates;
 - 3) Duration of each test;
 - 4) Test evaluation method (including equations – wherever applicable); and
 - 5) Acceptance/Rejection criteria for each test type
- b) Provides the report to the *Project Manager* upon the successful commencement of any tests during commissioning. The report includes following but not limited to,
- 1) Final test protocol;
 - 2) Raw data (un-processed);
 - 3) Evaluation of raw data (processed data); and
 - 4) Final result indicating the acceptance/rejection of each test types

3.12.2 Training during construction and Commissioning

- a) The *Contractor* provides training to *Employer's Personal and Employer's Representatives* before commencement of any Inspection, Test and Commissioning activities. Training is based, both, on classroom and on site during construction and commissioning.
- b) The *Contractor* is responsible for providing all trainings materials necessary for trainings which include the following minimum but not limited to,
- 1) Plant description and design including single line diagram
 - 2) Construction and installation method
 - 3) Safety during construction and commissioning
 - 4) Introduction to each test types and measurement methods
 - 5) Test evaluation procedures and test result interpretation
 - 6) Trouble shooting procedures
 - 7) A checklist of what to do in case of system failure
 - 8) Emergency shutdown/isolation procedures

3.12.3 Test before Installation

- a) Test before installation refers to Factory Acceptance Test, Independent Laboratory Test and Site Acceptance Test of all components to be used for the Project.

3.12.3.1 Factory Acceptance Test - FAT

- a) Factory Acceptance Tests are done only for major plant components: PV module, Inverter, Transformer, Switchgears and CMS Equipment. The tests/inspections are performed in respective components manufacturers' premises prior to the shipment of Components.
- b) At least three (3) weeks prior to the Factory Acceptance Test date, the *Contractor* submits for review and acceptance to the *Project Manager* the test program comprising but not limited to:
- 1) Date of commencement of each test type
 - 2) Detailed description of inspections/tests types.

CONTROLLED DISCLOSURE

- 3) Component certificates, technical data sheets
 - 4) Manufactures' quality certificates
 - 5) Standards to be followed during testing/inspection
 - 6) Test results of former inspections/tests, if available
- c) The *Employer and the Employer's Representatives* reserve right to attend and witness any Factory Acceptance Test at its own cost. The *Contractor* is notified for the *Employer's* interest to attend the test not later than one (1) week prior to the test.
- d) Upon the successful completion of the Factory Acceptance Test, the *Contractor* submits the test report along with the relevant documents. All test reports are prepared by the *Contractor* and contains the following minimum information:
- 1) Definition of each test type and test methods
 - 2) Technical data along with the component certificate of tested component
 - 3) Test evaluation and technical data of testing components including relevant certificates
 - 4) Compliance with the requirement for the Project and/or Industry practice
 - 5) Summary and conclusion in regard to acceptance or rejection of equipment
- e) The test reports are reviewed and accepted by the *Project Manager* prior shipment of the tested components to the Project site. The test reports and its supporting documents must be signed by the *Contractor* and the *Project Manager* prior shipment of tested components.
- f) The *Contractor* is responsible for management and any additional expenses that are caused due to requirement on repetition of Factory Acceptance Tests.

3.12.3.1.1 PV Module

- a) Quality acceptance test for PV modules is performed during the Tests before installation (prior delivery of PV modules on site). The goal of the quality acceptance tests for PV modules is to verify the power of delivered PV modules according to the manufacturer power guarantee levels and requirements set in this document and the PV modules are free from any manufacturing defects. For this purpose, the following two tests are performed:
- 1) Nominal vs. Manufacturer Flash Test Power Comparison; and
 - 2) Independent Laboratory Test – Counter Check
- b) The *Contractor* verifies that all PV modules that are delivered for the Project have been quality checked and complies with the *Employer's* requirement.

Nominal vs. Manufacturer Flash Test Power Comparison

- a) The *Contractor* provides to the *Project Manager* the module supplier's/manufacturer's measurement data on major electrical parameters (I_{sc} , V_{oc} , I_{mpp} , V_{mpp} , P_{mpp} and Fill Factor) for every individual module to be delivered to the Project in PDF and Excel table format. The common term for such kind of measured data is called flash test data.
- b) The *Contractor* is responsible to verify that all the modules to be supplied are within guaranteed nominal power and within the provided tolerances on power. For this purpose, the power at MPP in the flash test data sheet is checked against the nominal power and power tolerances. Those

CONTROLLED DISCLOSURE

modules of which power is beyond the specified rating and the respective tolerance is rejected for the Project. The flash test data and results is reviewed and accepted by the *Project Manager*.

- c) If the modules offered for the Project is of Thin Film type, the sum of power on flash test data of all modules are equal to or higher than sum of nominal power of all modules to be delivered for the Project.

Independent Laboratory Test – Counter Test

- a) The second quality check on PV modules is performed to cross check the module quality and the nominal power of modules to be delivered for the Project. This is an independent laboratory verification of compliance with the respective design qualification and type approval of the module stipulated in the required standards (i.e. IEC 61215 or IEC 61646 – whichever is applicable). Since this test aims to verify the manufacturer's compliance with the type certification and factory testing, it is also called Counter Test.
- b) The *Contractor* ensures that the independent testing laboratory for counter test is certified according to ISO/IEC 17025. The scope of the accreditation certificate of the laboratory must cover the test standards required for certification of PV modules.
- c) The counter test consists of two major inspections: Visual inspection and Power measurement.
- 1) Visual inspection on sample modules is carried out according to clause 10.1 of the IEC 61215 (or IEC 61646) standards. This clause aims to check if there is some material defect, broken cells or faulty connections in the module.
 - 2) Power measurement is done by measuring I-V curve and the electrical parameters under Standard Test Condition (STC). The measurement has to be performed according to the requirements defined in IEC 60904-1 and IEC 60904-3. The measurement uncertainty of MPP power of modules does not exceed $\pm 3\%$ (for c-Si modules) and $\pm 5\%$ (for thin film modules). The measurements are carried out with AAA class sun simulator according to IEC 60904-9.
- d) The modules to be measured belong to the samples from shipment lot or batch of modules that are going to be delivered to the Site. Upon the receipt of flash test data and result on power comparison, the *Project Manager* randomly selects the samples (refer clause g) which the *Contractor* tests in the independent laboratory.
- e) The modules are to be completely sealed from any exposure to light during packing and transport from the factory until the time that the counter test is performed. It is part of the laboratory work order to maintain the modules in a dark storage environment such that no light exposure can take place and induce any degradation or other effect prior to the Counter Test.
- f) The Counter Test is performed within fifteen (15) days after receipt of the PV modules by the laboratory. The *Contractor* is responsible for delivery of the modules to, and returns the modules from, the laboratory. All costs and expenses connected and related to the Counter Test (including the transportation of the modules and the fees for the laboratory) is the responsibility of the *Contractor*.
- g) The sampling procedure is in accordance with ISO 2859-1:1999. Special inspection level S4 with Acceptance Quality Level (AQL) 4.0 is used. The following table shows the sample size to be considered for the counter test and the acceptance and rejection size. If the number of rejected modules within the sample (inspection level S4) of a certain lot is equal to or greater than the rejection threshold AQL 4.0 according to ISO 2859, all modules of this lot are not considered for the Project and are rejected and replaced.

CONTROLLED DISCLOSURE

Lot Size [units]	Sample Size (inspection level S4) [units]	Admissible faults (AQL 4.0) [units]	Rejection threshold (AQL 4.0) [units]
1,000 – 1,200	20	2	3
1,201 – 10,000	32	3	4
10,001 – 35,000	50	5	6
35,001 – 500,000	80	7	8

- h) Upon the completion of power comparison test and counter test, PV modules fulfil the following conditions for delivery for the Project.
- Manufacturer flash test data confirm that every module to be delivered for the Project has MPP power within the provided tolerance ranges;
 - For Thin film modules (if considered by the *Contractor* for the Project), the sum on power of all modules on flash test data be higher than the sum of nominal power of all modules;
 - Visual inspection carried out on sample module according to clause 10.1 of IEC 61215 or IEC 61646 not detect any damages or abnormalities; and
 - Counter-Test on nominal power of sample modules confirm that modules are supplied with guaranteed power ratings and the module power is within the manufacturer tolerances limit.
- i) The *Contractor* delivers PV Modules to the site with all relevant documents (test reports, technical data sheet, relevant certificates, warranty, installation manuals etc.).

3.12.3.1.2 Inverter

- a) The *Contractor* provides to the *Project Manager* all type test and serial test results performed by the respective inverter manufacturer/supplier for the inverters to be delivered for the Project. The tests s includes all certificates according to valid IEC and South African Grid Code standard as described below:

Standard	Description
Minimum required standards	
IEC 62109	Safety of Static Inverters
IEC 61727	Characteristics of the Utility Interface
IEC 62116	Testing procedure of Islanding Prevention Methods for Utility-Interactive Photovoltaic Inverters
IEC 62103	Electronic equipment for use in power installations
IEC 61000-6-3/4	EMC Emission
IEC 61000-6-1/2	EMC Immunity
Others	South African Grid Code for Renewables

CONTROLLED DISCLOSURE

- b) The *Contractor* provides to the *Project Manager* the following minimum serial test result for the inverters to be delivered to the site. The minimum tests are:
- 1) Visual inspection
 - 2) Cabling checks
 - 3) Protective conductor test
 - 4) High Voltage test
 - 5) configuration of assembly components
 - 6) Functional test
 - 7) Long term test
 - 8) Safety and protection test
- c) The *Contractor* only delivers the inverters to site upon submission of its factory acceptance test results.
- d) The *Contractor* delivers inverters to the site with all relevant documents (test reports, relevant certificates, technical data sheet, warranty, installation manuals etc.).

3.12.3.1.3 Transformer

- a) Before being fitted to the transformers, all components are subjected to routine tests required by the relevant standards at the suppliers or sub-supplier's factory. A detailed test report, proving the successful passing of such tests, is to be provided.
- b) Unless otherwise specified, the tests are carried out in accordance with IEC standards. The following tests are performed and witnessed by the *Employer/Employer's Representative* at the manufacturer's factory prior to shipment.

Transformer Ratio Test

- a) This test is carried out with the use of a Turns Ratio Test set, the ratio of the transformer is to be proven on all the tap positions, and using the same test equipment the voltage vector relationship is also checked.
- b) The measurement of voltage ratio and check of voltage vector relationship are carried out in accordance with the procedure laid out in IEC 60076-1.
- c) The results are recorded on a test sheet.

Insulation Resistance Test

- a) This test is carried out with all cables disconnected; a 5kV insulation resistance test is to be applied.
- 1) between primary winding and earth.
 - 2) between secondary winding and earth.
 - 3) between primary and secondary winding.
- b) The results are recorded on a test sheet.

CONTROLLED DISCLOSURE

DC Winding Resistance Test

- a) The winding resistance is checked on all taps of the tap changer to verify there is no high resistance on the tap changer and windings. A DC winding resistance test set is used for this test. This test is carried out in accordance with IEC 60076-1.
- b) The results are recorded on a test sheet.

Temperature Rise Test

- a) To be carried out in accordance with SANS 60076-2, at rated voltage, rated frequency and with rated power of the secondary winding.
- b) The winding temperature is ascertained by using the resistance method. The hot spot temperatures rise is performed in accordance with the SANS 60354.
- c) Full details of the test arrangements, procedures and conditions are supplied with the test certificates.

Load Loss Measurement

- a) The *Employer* does not allow any tolerances on load losses above those stated in IEC/SANS 60076-1 Table 1.
- b) The load losses on every transformer is measured on the principal tapping position and corrected to the reference temperature specified in SANS 60076-11.

Power Frequency Voltage Withstand Test

- a) Both a separate-source AC withstand voltage test and an induced AC withstand voltage test are performed in accordance with SANS/IEC 60076-11 clauses 19 and 20.
- b) The basic insulation levels and corresponding test voltages will be in accordance with SANS 60076-3.

Lightning Impulse Test

- a) This test is carried out in accordance with SANS 60076-11.
- b) The basic insulation levels and corresponding test voltages will be in accordance with SANS/IEC 60076-3.

3.12.3.1.4 Switchgear

- a) The Factory Tests is performed in accordance with SANS 1874, including the MV test. For the individual switchgear apparatus (i.e. circuit breaker, load break switch, etc.), type and routine test certificates of the manufacturer must be supplied.
- b) The following Site tests are performed.
 - 1) Visual Inspection
 - 2) Timing and Contact Resistance Tests on Circuit Breaker
 - 3) Insulation winding resistance and Ratio test on voltage/current transformers

CONTROLLED DISCLOSURE

Visual Inspection

- a) Visual Inspection is made prior to any measurements/tests. The inspection follows the manufacturer's checklist/procedures and confirms that the component is free from any defects.

Circuit Breaker

- b) The circuit breakers offered are to be fully type tested in accordance with IEC 60056 and IEC 60694 to be witnessed by *Employer* and *Employer's* Representatives. The *Contractor* agrees to perform the type test on one independent test station.
- c) Timing Test: The circuit breaker is to be electrically operated and verified that the opening and closing times fall within the designed parameters.
- d) Contact Resistance Test: A 100 Amps micro-ohm meter is used to conduct this test. The CB is closed and a 100 Amps is passed through the breaker closed contacts from the 3 phase incoming terminals to the outgoing terminals. A voltage is detected across the contacts through the voltage detection leads connected to the same terminal pads. The test must provide a resistance in micro-ohms signifying low contact resistance.

Voltage and Current Transformers

- a) The voltage transformers for metering and protection offered is to be fully type tested in accordance with IEC 60044. Full type test certificate are submitted. The following tests are performed as minimum.
 - 1) Insulation Winding Resistance Test
 - 2) Ratio Test
 - 3) Type Test
- b) The Contractor complies with the following mandatory type tests as per 6.2 of SANS 62271-200
 - 1) Test to verify the insulation level of the equipment
 - 2) Test to prove the temperature rise of any part of the equipment and measurement of the resistance of circuits
 - 3) prove the capability of the main and earthing circuits to be subjected to the rated peak and the rated short-time withstand currents
 - 4) tests to prove the making and breaking capacity of the included switching devices
 - 5) tests to prove the satisfactory operation of the included switching devices and removable parts
 - 6) tests to verify the IP protection code
 - 7) tests to verify auxiliary and control circuits

3.12.3.1.5 CMS Test

- a) The CMS FAT is to be performed at the C&I *Contractor's*/Supplier's facility where the equipment is installed into its enclosures, connected, powered up and tested with the software application

CONTROLLED DISCLOSURE

- b) The *Contractor* provides the following factory acceptance tests (FAT) for CMS equipment, but not limited to:
- 1) Physical inspections of all CMS hardware components, cabinets and enclosures. Network cabinets and field equipment panels will be inspected at the Factory with components fully installed and functional.
 - 2) Redundancy and single fault tolerance checks will be performed on network equipment, servers, thin clients, switches, power supplies, etc.
 - 3) Application software checks will be performed as required.

3.12.3.2 Site Acceptance Test

- a) Site Acceptance Test refers to the inspections and document verification of all components immediately after the delivery of components on site.
- b) The *Contractor* verifies that all components delivered to the site are free from any defects and all documents (technical data sheet, certificates, warranty documents, Factory Test reports, and component manuals) are available.
- c) The Site Acceptance Test are witnessed and accepted by the *Project Manager*.

3.12.4 Test after Installation

- 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. These tests are related to document verification, visual inspections on site, electrical measurements, and safety check.
- b) The test after Installation must 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 Plant complies with the requirements defined for each type of inspections described below.
- d) Copies of all tests and data are provided to the *Project Manager* for review and acceptance.

3.12.4.1 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 Plant to the *Employer* and *Employer's* representative.
- b) The completeness of the documentation is reviewed and accepted by the *Project Manager* before commencement of the tests.
- c) The following non-exclusive list of Plant sections are documented and checked during the Tests after Installation:
 - 1) Basic system information:

CONTROLLED DISCLOSURE

- Project location and installation date
 - Rated system capacity (DC and AC)
 - PV modules and inverter – manufacturer, model and quantity
 - Installation date
 - Commissioning date (to be updated later if time schedule of tests not met).
- 2) System designers information (name, affiliate, contact details)
 - 3) System installer/*Contractor* information (name, affiliate, contact details)
 - 4) Detailed single line diagram of the DC, LV /MV AC part and transmission line including detailed connection and wiring diagrams for array DC junction boxes and inverter cabinets.
 - 5) General specifications of array:
 - Module type
 - Module number
 - Number of modules per string
 - Number of strings.
 - 6) PV string information:
 - String cable type, size and length
 - Specification (current and voltage rating) of overvoltage protection device.
 - 7) Electrical characteristics of array:
 - Array junction box location
 - Array main cable specification
 - Location, type and rating of over voltage protective devices
 - 8) Earthing and over voltage protections including a single line diagram showing the details of all earthing, lightning protection systems, and details of surge protection devices
 - 9) A single line diagram including DC and AC isolators location, type and rating along with similar information for AC over-current protection device
 - 10) Plant safety regulation following all MCB's, MCCB's, Isolators employed in the AC electrical boards with a padlocking facility
 - 11) Technical data sheet of all components
 - 12) Full documentation of the SCADA
 - 13) Description and documentation of all mechanical structures including details such as material type, structure mounting solution, foundation design and geotechnical study
 - 14) Warranty documentation for all strategic parts such as PV modules, inverters, structure, switchgear with the information of starting date of warranty and period of warranty
 - 15) Documentation of all required legal and administrative permits, if any
 - 16) Confirmation on project design and installation compliance with all permits (Environmental, Water Use license and grid code)
 - 17) Documentation of module flash test data
 - 18) The complete C&I design, network diagram, test certificates and test results.

CONTROLLED DISCLOSURE

3.12.4.2 Mechanical Completion Test

- a) Upon completion of the actual installation *works*, an inspection is conducted. The purpose is to verify that the *Contractor* has executed all installation *works* in accordance with the Contract and as built design and is compliant with applicable norms and standards. At this inspection it is tested that the *works* prove to be of good workmanship established in the PV industry, and are free from any material/construction defects. During the inspection, the correctness of the documentation of the *works* in the As-Built Drawings is checked and verified.
- b) Prior to the Inspection, the *Contractor* conducts an internal inspection that verifies the compliance of the *works* with the design and the *Employer's* Requirements. The minor deviations on execution of work are recorded under the Punch-List. Punch list does not contain any outstanding issue which has an effect on safe operation, monitoring, plant performance and administrative/legal requirements. The Punch-List must be reviewed and accepted by the *Employer* before the Mechanical Completion Test.
- c) The *Contractor* undertake the following, but not limited to, to verify the physical installation is completed according the design:
 - 1) General:
 - Verify all parts of the PV Plant are in line with the Final Design;
 - Verify the PV Plant construction is according to the provisions of the Contract;
 - Verify all equipment and parts have been installed according to their manufacturers' installation manuals.
 - 2) PV Modules:
 - Inspect Modules as installed and verify absence of any breakages, scratches, damage on back sheet, junction box, frame distortions and bending or any other signs of incorrect or incomplete installation;
 - Verify that Modules have been sorted according to their Flash Test Data;
 - Verify that serial number of each modules is documents according to installation location on site; and
 - Verify that the installation was done according to manufacturer's recommendation and/or requirements.
 - 3) PV String Combiners:
 - Verify that PV String cables have been permanently marked and numbered;
 - Check cable Pulling Test records;
 - Inspect DC cabling between modules and verify that cable types, sizes and lengths as well as cable connector types are in accordance with the design;
 - Verify the integrity of Surge Protection Devices and all Earthing connections; and
 - Verify the installation according to design and manufacturer's recommendation
 - Verify that the string monitoring system have been installed according to design and requirement for communication to CMS system
 - 4) PV Mounting Structures:
 - Verify correct Orientation and Inclination angles for the PV Modules;

CONTROLLED DISCLOSURE

- Verify that the installation is free from any corrosion; and
 - Verify fastening with recommended torque, overall set-out distances, surfacing, alignment and completeness of the assembly.
- 5) Foundation and Civil *works*
- Verify all civil *works* (O&M building, foundation, security systems, internal roads) are completed according to design and according to permits for the Project; and
 - Verify that security system (fences, video surveillance) are installed according to *Employer's* requirement
 - Verify HVAC, drainage and sewage systems installed according to as built design
- 6) PV Inverters:
- Verify that all cables and switches have been marked and numbered permanently;
 - Inspect all DC & AC cabling and verify that cable types, sizes and lengths are in accordance with the design; and
 - Verify all inverter parameters are set up within Manufacturer's recommendations, grid requirements and local regulations; and
 - Verify the ventilation of inverter cabin is installed according to design and inverter manufacturer's recommendation (if any) for operation in project location
- 7) MV Cabins and Switchgear
- Verify that all cables and switches have been marked and numbered permanently;
 - Inspect AC cabling and switches and verify that types, sizes and lengths are in accordance with the design;
 - Verify Voltage Controls; and
 - Inspect Insulation Test records on all cables and circuits.
 - Proper Installation and safety during operation
 - Verify the physical installation of energy meters, protections, earthing and lightning
- 8) Control and Monitoring System :
- Verify all system components and respective electrical and data connections are according to design;
 - Verify all Calibration Certificates are available; 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 array boxes) carry a warning label indicating that active parts inside the boxes are fed from a PV array and may still be alive after isolation from the PV inverter and public supply.
 - Verify the main AC isolating switch is clearly labelled.
 - Verify Dual supply warning labels are fitted at point of interconnection.
 - Verify a single line wiring diagram is displayed on site.
 - Verify the Inverter protection settings and installer details are displayed on site.

CONTROLLED DISCLOSURE

- 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 Mechanical Completion Test, Mechanical Completion Certificate will be issued by the *Employer*.

3.12.4.3 Electrical Completion Test

- a) Electrical Completion Test is performed to verify the proper functionality, configuration and installation of the PV Plant. The electrical configuration tests are considered as minimum requirement and are performed according to IEC 62446, IEC 60364-6, SA Grid code for renewables and current best practice. The tests are witnessed by the *Employer* and *Employer's* representative.
- b) The *Contractor* undertake the following:
- 1) Tests on AC circuits
 - Continuity of conductors in accordance with IEC 60364 – 6 Ed. 1 Clause 61.3.2
 - An electrical continuity test be made on
 - Protective conductors, including main and supplementary equipotential bonding conductors, and
 - In the case of ring final circuits, live conductors.
 - Insulation resistance of the electrical installation in accordance with IEC 60364-6 Ed.1 Clause 61.3.3
 - The insulation resistance is measured between live conductors and the protective conductor connected to the Earthing arrangement.
 - Protection by SELV, PELV or by electrical separation in accordance with IEC 60364-6 Ed.1 Clause 61.3.4
 - Insulation resistance/impedance of floors and walls in accordance with IEC 60364-6 Ed.1 Clause 61.3.5.
 - Protection by automatic disconnection of the supply in accordance with IEC 60364-6 Ed.1 Clause 61.3.6
 - Additional protection's in accordance with IEC 60364-6 Ed.1 Clause 61.3.7.
 - Polarity test in accordance with IEC 60364-6 Ed.1 Clause 61.3.8
 - Check of phase sequence in accordance with IEC 60364-6 Ed.1 Clause 61.3.9
 - Functional tests in accordance with IEC 60364-6 Ed.1 Clause 61.3.10
 - Verification of voltage drop in accordance with IEC 60364-6 Ed.1 Clause 61.3.11

Once tests on AC circuits are completed, the following tests are carried out on DC circuits forming the PV array.

2) Tests on DC circuits

- Continuity of protective Earthing and/or equipotential bonding conductors, where fitted in accordance with IEC 62446 Ed.1 Clause 5.4.2.
 - Where protective or bonding conductors are fitted on the DC side, such as bonding of the array frame, an electrical continuity test is made on all such conductors.
 - The connection to the main Earthing terminal should also be verified.

CONTROLLED DISCLOSURE

-
- Polarity Test in accordance with IEC 62446 Ed.1 Clause 5.4.3
 - The polarity of all DC cables is verified using suitable test apparatus. Once polarity is confirmed, cables be checked to ensure they are correctly identified and correctly connected into system devices such as switching devices or inverters.
 - I-V curve measurement on all strings – The nominal power of strings is measured and their respective power to be verified against the sum of name plate power of modules connected to string. Open circuit voltage and PV current to be verified according to IEC 62446 Ed.1 Clause 5.4.4 and clause 5.4.5 and clause 5.4.6.
 - Functional tests in accordance with IEC 62446 Ed.1 Clause 5.4.6 : The following functional tests be performed:
 - Switchgear and other control apparatus to be tested to ensure correct operation and that they are properly mounted and connected.
 - A loss of mains test to be performed: With the system operating, the main AC isolator is opened – it should be observed (e.g. on a display meter) that the PV Plant immediately ceases to generate. Following this, the AC isolator should be re-closed and it should be observed that the system reverts to normal operation.
 - PV array Insulation resistance test in accordance with IEC 62446 Ed.1 Clause 5.4.7
- 3) All inverters forming part of the PV Plant be tested to ensure correct operation. The test procedure should be the procedure defined by the inverter manufacturer/supplier. During electrical completion test, the *Contractor* provide a proof of inverter commissioning test report/certificate which verify that all the inverters installed on site fulfils the requirements defined by manufacturer for the safe and efficient long term operation.
- 4) The *Contractor* pays a special attention to the operating temperature of the inverter and inverter cabin. For this purpose, the *Contractor* measures the operating temperature of inverter/inverter cabin for at least seven consecutive days and verifies that the operation of inverter (without derating) is within the manufacturer's recommended range.
- 5) Functional Test of Meteorological System and C&I system,
- Functional test procedure and check sheets be provided to ensure that the CMS meets the requirements as specified in the Scope of work
 - All meteorological stations signal be working properly and the data are being recorded into the monitoring system
 - Commissioning of C&I system be according to IEC62337 Commissioning of Electrical, Instrumentation and Control systems
 - Test communications with string combiner boxes and inverters;
 - Verify format and handling of acquired data set;
 - Check threshold alarm controls;
 - Inspect all system displays, event recording and timing synchronization regime and data storage and upload from local to remote;
 - Inspect the site communication systems - broadband cable distribution and GSM (backup, if provided);
 - Inspect operation of display and data-processing software and check visualization from local to remote;
 - Control of remote system access and data downloading;

CONTROLLED DISCLOSURE

- Handover of access rights and passwords
- 6) Infrared Thermography
- Infrared scanning on all PV modules as well as in electrical connections is performed in order to verify that modules are free from any hot spots and electrical connections are properly made. Infrared scanning is done when irradiation on module plane is greater than 500 W/m².
- 7) Grid Code connection test
- The Contractor performs the Grid Connection test according to SA grid code for Renewables and provides a test report. In any case the Grid Connection Test is witnessed by the *Employer* and the *Employer's Representative*. The test is approved by a third party provided by the *Employer*.
 - The *Contractor* provides an ECSA registered professional engineer or technologist to declare the installation complies with all standards and requirements.
 - Upon the successful completion of Grid code test, the *Contractor* provide a Certificate of Compliance (COC) of the PV Plant certified by the ECSA registered professional engineer or technologist and the responsible person.

8) HVAC System

The complete HVAC system is to be commissioned in accordance with the following SANS and Chartered Institution of Building Services Engineers (CIBSE) codes or such other recognized commissioning procedure or code accepted by the *Project Manager*:

- a) Air distribution systems
 - i. SANS 10173: Code of Practice for the Installation, Testing and Balancing of Air Conditioning Ductwork, or
 - ii. CIBS Commissioning Code A: 1996 or latest revision
- b) Automatic controls: CIBS Commissioning Code C: 2001 or latest revision
- c) Refrigerating Systems: CIBS Commissioning Code R: 2002 or latest revision

3.12.4.4 Reporting

- a) Once the Electrical Completion tests are successfully performed, the *Contractor* provide the report to the *Project Manager*, for review and acceptance, including the following,
 - A report, signed by the *Contractor*, summarizing each test performed and their acceptance or rejection according to the test protocol, relevant standards and requirements;
 - Test raw data and processed data;
 - Final Test protocol along with list of measurement equipment considered during testing and their specification
- b) Upon the successful completion of Electrical Completion Test, the *Employer* issue Commissioning Certificate to the *Contractor*.

CONTROLLED DISCLOSURE

3.12.5 Test on Completion

- a) Test on Completion refers to the “Provisional Acceptance Test (PAT)” which verifies both performance ratio and availability of the plant against the *Contractor’s* guarantee.
- b) The test introduction, test methodology and evaluation procedures are defined in detail in section 3.12.5 of this document.
- c) PAT is witnessed by the *Employer* and the *Employer’s* representative.

3.12.5.1 Provisional Acceptance Test - Pre-Requirement

The following to be completed before the start of PAT,

- a) Mechanical Completion Certificate, Certificate of Compliance (COC), Commissioning Certificate have been accepted by the Project Manager;
- b) Training on Construction and Commissioning to the *Employer’s* Representative and Operators, Facility managers have been completed;
- c) The *Contractor* has provided O&M Manual to the *Employer* and the *Employer’* representative, which include minimum but not limited to,
 - Procedures for verifying correct system operation (Start-up / Shut down of PV Plant , HMI operation, Single line diagram, Regular Maintenance on Modules, Inverter first line maintenance, transformer, switchgear, ups, etc.);
 - Safety Guidelines including emergency shutdown/isolation procedures;
 - Preventive and corrective maintenance procedures including site inspection checklist for each component including power evacuation line and security systems;
 - scheduling of routine maintenance;
 - A checklist of what to do in case of system failure;
 - Documentation on stock of spare parts and spare parts management including contact information and procedures for replacement of defective components;
 - Inverter O&M Manual (troubleshooting for error codes, repair, software for inverter, Fault finding on the DC Plant);
 - Data Acquisition System and CMS O&M Manual (troubleshooting, equipment descriptions, repair, metering equipment downloading, weather station);
 - Method of PV module cleaning;
 - Operation and maintenance manual for inverter, transformer and module from respective manufacturers; and
 - Performance monitoring and reporting procedures

CONTROLLED DISCLOSURE

3.13 CONTRACTORS GUARANTEE ON PERFORMANCE AND AVAILABILITY

- a) The *Contractor* provides guaranteed values of:
- 1) Performance Ratio (PR);
 - 2) Plant Availability;
- b) These guaranteed Performances are verified during PAT and Defects Period.

Table 3-5: Plant Performance Guarantee – From the *Contractor*

Parameter	Minimum required for <i>Tenderers</i> proposal	Guaranteed by <i>Contractor</i>
First year guaranteed annual average Performance Ratio	78.0%	
Second year guaranteed annual average Performance Ratio	77.5%	
Guaranteed plant availability during PAT	99.5 %	
Guaranteed annual average plant availability during Defects period	98.5 %	

- c) The guaranteed Performance Ratio shall be evaluated at 100% plant availability, as the availability factor will be separately evaluated as described in section 3.14.1 and section 3.14.2.
- d) Monthly breakdown of first year annual guaranteed Performance Ratio along with estimation of solar irradiation on module plane are provided by the *Contractor* in a tabular format shown below,

Table 3-6: Monthly Breakdown of First Year Guaranteed Performance Ratio

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

CONTROLLED DISCLOSURE

- e) The PR guaranteed for Provisional Acceptance Test will be the corresponding monthly average PR (shown in table above) during which the PAT is performed. If the PAT duration covers period of two consecutive months, then the guaranteed PR during PAT is calculated based on weighted average PR.

CONTROLLED DISCLOSURE

3.14 PROVISIONAL ACCEPTANCE TEST (PAT) WORKS

- a) The *Contractor* executes the Provisional Acceptance Test and is witnessed by the *Employer/Employer's Representative*.
- b) The *Contractor* prepares a detailed test program and test protocol based on requirements described below and submits to the *Employer* for approval according to requirement set in **Appendix G**.
- c) The Test program and the test protocol must be accepted by the *Employer/Employer's Representative* before the commencement of the test.
- d) The SCADA system must be available all time during the test period and the verification of Performance Ratio and Availability must be made through the data recorded in SCADA system.
- e) The *Contractor* is allowed to run Performance Ratio and Availability test simultaneously or separately. In each case, the test period must be 15 consecutive valid days.
- f) A valid day during the test period is defined as a day during which a daily average solar irradiation on module plane is greater than 2.0 kWh/m², measured by reference cells installed on the site. During the measurement period (15 consecutive days) if any day does not represent a valid day(s), the period of measurement will be extended consecutively with the same number of those days.
- g) Such extension can be done up to a limit up to the *Contractor's* guaranteed substantial completion date. If despite this extension, the required number of valid days are not achieved, then evaluation is be made only for available valid days.

3.14.1 Test Procedure

3.14.1.1 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
 - AC Energy output at the Point of Connection (PoC) [kWh]
 - Global solar irradiation on plane of array [kWh/m²]
 - Global solar irradiation on horizontal surface [kWh/m²]
 - Module temperature [°C]
 - AC Energy output from each inverter [kWh]
 - Ambient air temperature [°C]
- b) The first two technical parameters (major parameters) mentioned above are used directly to verify the performance of the Plant. The later four parameters are used as back up to verify consistency of measurement of major parameters. These parameters are to be stored in a 15 minutes interval. The logged data is to be checked for consistency and validity, and has to be found free from obvious anomalies or irregularities.

3.14.1.2 PAT Stopping and Restarting Procedure

- a) The PAT is stopped and restarted
 - If the Plant, wholly or in part, ceases to operate at any time during PAT due to causes beyond the control of the *Contractor*, then the PAT is suspended during that time and

CONTROLLED DISCLOSURE

resume following restoration of operation, until the total PAT duration has reached the required length of 5 days.

- In the event of any disruptions due to Force Majeure, grid failure and caused by the *Employer's* for the period longer than the *Contractor's* guaranteed substantial dates.
- b) The *Contractor* maintains a log of any such event, including the cause, the duration and the times at which PAT was suspended and resumed. The *Contractor* provides written notice to the *Employer* within eight (8) hours following each such PAT suspension and resumption. All prerequisites specified must remain satisfied on any such PAT resumption.
- c) If at any point during PAT the *Contractor* deems that it is unlikely to pass the PAT, then the *Contractor* notifies the *Project Manager* and may discontinue the PAT. The *Contractor* may subsequently commence a new PAT, subject to compliance with all provisions and procedures within this Section.

3.14.1.3 PR Evaluation Procedure

- a) The plant Performance Ratio (PR) is evaluated according to equations below,

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

Where:

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

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

$[E_{PV}]_{PAT}$ = Theoretical energy that could have been produced by PV modules during the Provisional Acceptance Test period, expressed in kWh

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

Where:

P_{Nom} = Nominal Peak Power of the PV Modules, sum of name plate power of modules installed in the plant, expressed in kWp

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

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

CONTROLLED DISCLOSURE

3.14.1.4 Plant Availability Evaluation

- a) Availability is measured for consecutive 15 days period for PAT purpose.
- b) The availability of the Plant is evaluated based on technical availability of the inverter. The Plant must deliver energy to the meter at point of connection during the period when the Plant is considered as available. Otherwise, the Plant is considered as unavailable.
- c) The evaluation of Plant Availability is done only for the periods during which the global solar irradiation on module plane is higher than threshold level of solar irradiation. The threshold value of solar irradiation on module plane for plant availability is 100 W/m². This level of irradiation is considered as the minimum level of irradiation required to overcome inverter's threshold power.
- d) The stoppage of plant due to events caused by followings is not considered while evaluating the plant availability :
 - events caused by faults, except than *Contractor* (e.g. manual shut-down, inspections not attributable to the *Contractor*)
 - required by third parties (e.g. insurance companies, authorities)
 - attributable to the grid operator/the *Employer*
 - the result of Force Majeure events.
- e) The Plant Availability $[AV]$ is defined as average of individual inverter availability, as shown in the equations below:

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

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

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

- f) All technical parameters mentioned in equations above are calculated for the period during which the solar irradiation on module plane is higher than the threshold level (i.e. 100 W/m²).

Where,

T_{op} = Total time during the measurement period where the inverter was producing energy and energy was supplied to the grid, expressed in 15 minutes interval

T_{tot} = Total time during the measurement period where the irradiation on module plane was higher than 100 W/m², expressed in expressed in 15 minutes interval

CONTROLLED DISCLOSURE

T_{grid} = Time period during which the grid was not available (although the inverter is available), expressed in 15 minutes interval. The *Contractor* shall provide a written proof from the grid operator including hours during which there was a failure from grid and the Plant could not feed energy to the grid.

T_p = Time period that the inverter was not in operation (the inverter is not available) because of stoppages ordered by the *Employer*/third parties (insurance or authority) requirement, expressed in 15 minutes interval

T_{fm} = Time period that the Plant did not operate because of Force Majeure events, expressed in 15 minutes interval

3.14.1.5 Criteria for PAT Acceptance

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

3.14.1.6 Criteria for Issuance of Substantial Completion Certificate

- a) The substantial completion certificate is issued by the *Project Manager*, if,
- PAT requirements are successfully completed
 - The complete O&M manual is provided and by the *Project Manager*
 - Punch List is reviewed and accepted by the *Project Manager*
 - All guarantees and Warranties are successfully transferred to the *Project Manager* and the plant is substantially hand-over to the *Employer*
 - The *Contractor* has stored on-site the minimum required spare parts (**Appendix E**) for the Project
 - The site is free from any wastes, residues from site establishment and construction
- If applicable, any delay liquidated damage (Appendix H) payable to the Employer by the Contactor is completed.

3.14.2 Test after Completion

- a) Test after Completion refers to “Final Acceptance Test (FAT)”. Final Acceptance Test is performed during the Defects period and includes the following tests/inspections

Test Types	Test Frequency and Test Schedule
Performance Ratio Test	Two times - Each year after the issuance of Substantial Completion Certificate
Plant Availability Test	Two times - Each year after the issuance of Substantial Completion Certificate

CONTROLLED DISCLOSURE

Visual Inspection	One time- 2 years after the issuance of Substantial Completion Certificate
Electrical Measurements/Tests	One time- 2 years after the issuance of Substantial Completion Certificate

3.14.2.1 Performance Ratio Test

- The *Contractor* performs annual performance ratio test for the plant operation during the Defect Warranty period. There are two performance ratio tests during the Defect Warranty period; First Performance Ratio Test and Second Performance Ratio Test.
- Performance Ratio test is performed for the operational plant parameters (presented in section 3.14.1.1) measured during one complete year period.
- There are no irradiation threshold and valid days criteria for performance ratio evaluation during the Defects period.
- The Performance Ratio is only evaluated for the period during which the plant is available. The plant availability is evaluated separately according to section 3.14.1.4.
- The following equation is used to evaluate Performance Ratio of the plant during First Performance Ratio Test.

$$[PR_{measured}]_{year1} = \frac{[E_{prod}]_{year1}}{[E_{PV}]_{year1}}$$

Where:

$[PR_{measured}]_{year1}$ = First year annual average measured PR when the plant was available during first year operational period, expressed in %

$[E_{prod}]_{year1}$ = Sum of energy measured in energy meters installed at point of connection during complete first year operational period, expressed in kWh

$[E_{PV}]_{year1}$ = Theoretical energy that could have been produced by PV modules during complete first year operational period, expressed in kWh

$$[E_{PV}]_{year1} = P_{Nom} \times \frac{[Irr_{POA-measured}]_{year1}}{[Irr_{STC}]}$$

Where:

P_{Nom} = Nominal Peak Power of the PV Modules, sum of name plate power of modules installed in the plant, expressed in kWp

$[Irr_{POA-measured}]_{year1}$ = Annual average solar irradiation measured on Plane of Array during the complete first year period when the plant was available, expressed in kWh/m²

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

- The following equation shall be used to evaluate plant Performance Ratio for second Performance Ratio Test

CONTROLLED DISCLOSURE

$$[PR_{measured}]_{year2} = \frac{[E_{prod}]_{year2}}{[E_{PV}]_{year2}}$$

Where:

$[PR_{measured}]_{year2}$ = Second year annual average measured PR when the plant was available during second year operational period, expressed in %

$[E_{prod}]_{year2}$ = Sum of energy measured in energy meters installed at point of connection during complete second year operational period, expressed in kWh

$[E_{PV}]_{year2}$ = Theoretical energy that could have been produced by PV modules during complete first year operational period, expressed in kWh

$$[E_{PV}]_{year2} = P_{Nom} \times \frac{[Irr_{POA-measured}]_{year2}}{[Irr_{STC}]}$$

Where:

P_{Nom} = Nominal Peak Power of the PV Modules, sum of name plate power of modules installed in the plant, expressed in kWp

$[Irr_{POA-measured}]_{year2}$ = Annual average solar irradiation measured on Plane of Array during the complete second year period when the plant was available, expressed in kWh/m²

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

- g) The annual average solar irradiation ($[Irr_{POA-measured}]_{year1}$ and $[Irr_{POA-measured}]_{year2}$ in above equations) is calculated based on arithmetic average of four reference cells (two in grass land section and two in ash disposal section) installed on module plane. In the case, where reference cell(s) were not recording data and/or not working properly during the measurement period, the irradiation value is the average of the reference cells which are working properly.
- h) In the case where all four reference cells were not working (or SCADA system were not recording data) for some period, the irradiation value to be considered for those periods in the performance ratio test shall be based on the solar irradiation on module plane estimated by the *Contractor* presented in Table 3-6.
- i) The Performance Ratio tests during Defects period is considered successful if
- The performance ratio evaluated for the first year of operation period is equal to or greater than the performance ratio guaranteed by the *Contractor* during the first year period (guaranteed values presented in Table 3-5); and
 - The performance ratio evaluated for the second year of operation period is equal to or greater than the performance ratio guaranteed by the *Contractor* during the second year period (guaranteed values presented in Table 3-5)
- j) The *Contractor* is subjected to the performance Liquidated damage if the measured performance ratio is less than respective guaranteed performance ratio during the defect warranty period, according to **Appendix H**.

3.14.2.2 Availability Tests

- a) The *Contractor* performs annual availability test for the plant operation during the Defect Warranty period. There be two availability tests during the Defect Warranty period; First Availability Test and Second Availability Test

CONTROLLED DISCLOSURE

- b) Availability test is performed according to test procedure presented in section 3.14.1.4 for complete one year period during each availability test.
- c) The evaluation of Plant Availability is done only for the periods during which the global solar irradiation on module plane is higher than threshold level of solar irradiation. The threshold value of solar irradiation on module plane for plant availability is 100 W/m^2 . This level of irradiation is considered as the minimum level of irradiation required to overcome inverter's threshold power.
- d) The solar irradiation is calculated based on arithmetic average of four reference cells (two in grass land section and two in ash disposal section) installed on module plane. In the case where reference cell/s are not recording data and/or not working properly, the irradiation value is the average of the reference cells which are working properly.
- e) In the case where all reference cells are not working (or SCADA system are not recording data) for some period but the inverter is producing energy and energy being fed into the meter/grid, those periods are considered as available and those periods are counted in T_{op} in availability evaluation equation.
- f) In the case where all reference cells are not working (or SCADA system are not recording data) for some period and the inverter is not producing energy, those periods are considered as unavailable and those periods are counted in T_{tot} in availability evaluation equation.
- g) The Availability tests during defect warranty period be considered successful if
- The annual availability evaluated for the first year of operation period is equal to or greater than the annual average availability guaranteed by the *Contractor* during the Defects Period (guaranteed values presented in **Appendix M**); and
 - The annual availability evaluated for the second year of operation period is equal to or greater than the annual average availability guaranteed by the *Contractor* Defects Period (guaranteed values presented in **Appendix M**)
- h) The *Contractor* is subjected for the Liquidated damage if the measured availability at any year is less than annual average guaranteed performance ratio during the Defects Period, according to **Appendix H**.

3.14.2.3 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,
- PV Module,
 - Foundation and Mounting structure
 - Security System and Civil structures (O&M building, PV Plant Substation)
 - DC Cables, cable routing, electrical connections,
 - Junction boxes, fuses, isolation switches, Protection device
 - Inverter and Inverter cabin
 - Transformer and Switch gear
 - Power evacuation line and point of connection
 - Energy meter
 - Meteorological Stations

CONTROLLED DISCLOSURE

- Monitoring and C&I system
 - Remote communication
 - Security system
 - And any other plant components
- c) The *Contractor* verifies that the plant is free from any defects and the plant does not pose any risk for the safe operation.
- d) The *Contractor* verifies that the site is free from any wastes, residues from construction, operation and maintenance.
- e) The *Contractor* verifies that the minimum level of spare parts is available on site according to the *Employer's* requirement (**Appendix E**).

3.14.2.4 Electrical Measurements

- a) The *Contractor* performs
- Continuity test, polarity test, protective earthing test, insulation resistance test, fire protection system, protection device test according to requirement in section 3.14.2.4 and verify the proper functioning of all electrical equipment.
 - Infrared scanning on all (100%) 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 is done when irradiation on module plane is greater than 500 W/m².

3.14.2.5 Criteria for Acceptance of FAT

- b) The Final Acceptance Test is considered successful if,
- 1) Measured performance ratios during first and second performance tests are equal to or greater than respective performance ratios guaranteed by the *Contractor*.
 - 2) Measured plant availability during the first and second availability tests are equal to or greater than annual average guaranteed availability by the *Contractor* during defect warranty period.
 - 3) Any applicable liquidated damage payable (**Appendix H**) to the *Employer* by the *Contractor* is completed.
 - 4) The visual inspection is successfully completed and the plant is free from any defects, and
 - 5) Electrical measurements are successfully completed, and
 - 6) The O&M training is successfully completed and
 - 7) The complete plant O&M manual and component O&M manual are delivered to the *Project Manager*.
 - 8) The minimum level of spare parts have been stored on site and transferred to the *Employer*.
 - 9) All guarantees and Warranties of components are successfully transferred to the *Employer*.

CONTROLLED DISCLOSURE

3.15 OPERATION AND MAINTENANCE WORKS

3.15.1 General

The *Contractor*:

- a) Is responsible for the complete operation and maintenance (preventive, corrective and spare parts replacement) activities during the Defect warranty period.
- b) Maintains the PV Plant and operate the PV Plant (including the complete solar PV Plant, the PV Plant Substation, Power evacuation line, Point of Connections, and the Support Facilities), in good condition and performs the agreed O&M services in good faith, in accordance with the best industry practice.
- c) Performs periodic inspection and testing of PV Plant and each component and report on the status of modules, cabling, structures, inverters, transformers, security system, monitoring system, power evacuation lines etc.
- d) Repairs any defect or replace any item, equipment and component.
- e) Performs maintenance activities as minimum as defined under preventive maintenance and corrective maintenance.
- f) Supply all required tools, equipment and facilities which are necessary for carrying out the operation and maintenance of the PV Plant.
- g) Guarantees at all times the on-site availability of minimum spare parts.
- h) Operates the plant to meet the guaranteed performance ratio and availability.
- i) Maintains and ensures the compliance of the plant in respect to safety laws and regulations, also in respect of the safety of the workers and performing the services.
- j) Follows the maintenance manuals for entire plant monitoring including the operational manual of specific components and safety instructions.
- k) Protects any plant warranties and support the *Project Manager* on negotiation of any warranty or the claims available to *Employer* for material or equipment supply and for the performance work associated with the plant.
- l) Responds in the shortest possible of time to any alarm generated in PV Plant and take the necessary actions (repair or replacement) and report to the *Project Manager*.
- m) Operates and provides the maintenance of surveillance and control system, communications, security and meteorological stations.
- n) Provides O&M training to the *Project Manager* along with all required material in hard copy and in electronic copy.
- o) Co-operates and co-ordinates with the *Project Manager*, Power Station managers and security managers in a best way to ensure the operation and maintenance activities are performed respecting all *Employers'* requirement and not effecting the regular Power station's normal operation and maintenance.
- p) Commences with Operation and Maintenance activities respecting all legal, environmental and administrative requirements
- q) Co-operates with third parties (upon request from the *Employer*) and with the Authorities for verification of their requirement during project installation, commissioning and operation.

CONTROLLED DISCLOSURE

- r) Reports periodically regarding the status of the plant, maintenance work and the performance evaluation of the plant according to the reporting schedule defined in this document.

3.15.2 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 3-7 to avoid or anticipate possible or future malfunctions of the plant.
- b) The *Contractor* defines the preventive maintenance plan for the PV Plant including the frequency and scheduling of each maintenance activity. The frequency of preventive maintenance depends upon the level of impact on energy production that it would produce if the component stops functioning. In this regard, the preventive maintenance of the inverter receives the greatest focus among all. The *Contractor* pays high level of attention to such components in its O&M plan. Preventive inverter maintenance includes at least
- 1) the inspection and tightening connections,
 - 2) ensuring water and dust tightness,
 - 3) cleaning and replacing filters, lubricating moving parts like fan, handles and disconnects,
 - 4) running electronic diagnostics,
 - 5) routine maintenance according to manufacturer's recommendation
- c) Preventive maintenance also involves module cleaning, inverter servicing, foundation and mounting structure maintenance and balance of system inspection. The inspection on balance of system includes but is not limited to the inspection of junction box, conduit runs, combiner box, communication equipment, monitoring equipment, O&M building, PV Plant Substation, security system etc.
- d) Preventive maintenance also includes erosion control, drainage system control and vegetation management. Vegetation control be made to meet following criteria
- 1) Modules are not shaded
 - 2) A fire hazard is not created
 - 3) Unrestricted access to the major equipment of the site is maintained.
- e) It is expected that the *Contractor* proposes suitable cleaning method as well as frequency for the PV Plant design proposed, but at least according to the requirements as mentioned below.
- f) The *Contractor* prepares the report according to minimum requirements presented in reporting template presented in **Appendix K**.
- g) 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, manufacturer's recommendation and local grid requirements. Therefore, the *Contractor* provides the detailed preventive maintenance plan of each equipment, configuration, and systems considered in the plant.

CONTROLLED DISCLOSURE

Table 3-7: Preventive Maintenance Plan – Guideline as Minimum Requirement

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

CONTROLLED DISCLOSURE

S.No.	Items	Frequency
	meter)	
5.2	cleaning of air filter - as per manufacturer's recommendation	MS
5.3	checking and replacement of ventilation system (if required) - as per manufacturer's recommendation	MS
5.4	visual inspection of earth connections	M
5.5	Checking and verification of proper functioning of safety switches, fuses, cooling fan	M
5.6	Control and LCD display operation	M
5.7	Check of inverter according to manufacturer's operation and maintenance manual	MS
6	Inverter Cabin	
6.1	Visual inspection of inverter cabin	M
6.3	Visual inspection of ventilation system, earthing and fire protection system	M
6.4	Check inverter temperature while running during the day and verify that ventilation is working properly and inverter operating temperature is within manufacturer's recommended range	M
6.5	Visual inspection of transformer, switchgear board and protection device and verify that they all are running without any defects	M
7	Electrical Wiring	
7.1	Check on integrity and completeness of all electrical cables from PV module to connection point	M
7.2	Check for any damaged or discolored cable	M
7.3	Check on status of fuses, circuit breakers and safety switches	M
7.4	verification of proper earthing connections of the plant components	M
7.5	Verification of water tightening of electric cables and conduits	M
7.6	Electrical Insulation and grounding measurement of DC and AC cables	once in two years
7.7	Check and verify the labeling on electrical cables	M
7.7	IR scanning of electrical cable connection and verify that all cable connection are made properly and no heat generation in the connection	A
8	Security and Site Condition	
8.1	Check of integrity of security fences	SA
8.2	Verify that all security cameras and gates are working properly	M
8.3	Verify that communication of security systems with power station security system	M
8.4	Verify that internal roads are in good conditions	M

CONTROLLED DISCLOSURE

S.No.	Items	Frequency
8.5	Keeping plant clean and free from waste and taking proper steps of the disposal of waste according to local regulation and procedures	SA
8.6	On Site presence – immediate answering to all alarms by an emergency service assuring on-site presence	
8.7	Check the vegetation level and ensure that they are controlled	M
8.8	Check the drainage channels and erosion control	M
9	O&M Building and Switchgear Room	
9.1	Visual inspection of O&M building, switchgear room and their walls, roofs, foundation and verify that there is no visual damage	M
9.2	Verify that control system, server and its back up system are working properly	M
9.3	Verify that the inventory of spare parts are maintained according to the contract requirement	M
9.4	Verify that all security measures in side O&M and switchgear room are free of any defects and working properly	M
10	Power Evacuation	
10.1	Visual inspection of power evacuation route and verify that all poles and lines are in good condition	M
11	Meteorological Stations and Monitoring System	
11.1	Cleaning of meteorological stations (reference cell and pyranometer)	W
11.2	Calibration of meteorological equipment, if required	MS
11.3	Check of connection on meteorological components and communication with monitoring system	M
11.4	Check the weather station mounting structure and general physical condition	M
11.5	Check the slope and azimuth of reference cells. pyranometers	M
11.6	Check on online record of energy output and irradiation through remote monitoring system	D
11.5	Check on alarm, event and status database - through remote monitoring system	D
11.6	Check on online record of availability of each inverter and availability of the plant - through remote monitoring system	D
12	Reporting	
12.1	Report on plant performance ratio and plant availability	M
12.2	Report on energy production recorded through inverters, meters at site and meters at point of connection	M

CONTROLLED DISCLOSURE

S.No.	Items	Frequency
12.3	Report on meteorological measurement on site	M
12.4	Submission of raw and processed data on meteorological measurements and performance measurement to the <i>Employer</i>	M
12.5	Report on status of plant component and status of preventive maintenance	M
12.6	Report on alarms, events and status recorded	M
12.7	List of damage and faults verified	M
12.8	List of corrective maintenance service performed	M
12.9	List of spare parts available in inventory	M

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

MS → Manufacturer specification and operation manual

Module Cleaning Requirement:

- a) The *Contractor* uses the methods, tool and recommendation from module manufacturer for cleaning PV module;
- b) The *Contractor* provides all necessary tools for cleaning PV modules and transfers to the *Employer* after the issuance of Final Acceptance Certificate;
- c) The *Contractor* cleans all PV modules on site upon following situation whichever occurs earlier,
 - 1) When the solar irradiation measured by two reference cells (one cleaned minimum on weekly basis and another not cleaned) installed on weather station 3 differs by more than 5% for continuous five days period; or
 - 2) On quarterly basis.
- d) The *Contractor* is responsible for all necessary arrangement for PV module cleaning during contract period.

3.15.3 Corrective Maintenance

- a) Corrective maintenance includes at all times during the contract period and in all cases attending to and repairing breakdowns and failures of the components of the plant caused by wear and tear and/or 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 preventive maintenance visits (if the faults/failures do not effect on energy production) or when the remote monitoring system registers an operational problem. In case of corrective maintenance, the *Contractor* performs:
 - 3) A problem diagnosis, performance notification and which parts needs to be replaced,
 - 4) Supplying the component parts needed to replace in the event of breakdown or anomaly,
 - 5) Repairing or Replacing, when necessary, the affected component/equipment from inventory and brining the plant back in working condition,

CONTROLLED DISCLOSURE

-
- 6) 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 (with the spare parts) 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* is 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.
 - f) All work related to the corrective maintenance of each component part must be performed in accordance with the relevant manufacturer's manual and recommendations. All materials and component parts used by the *Contractor* must be new.
 - g) In case the incident or breakdown or malfunction is caused by Force Majeure or by the *Employer's* actions, not authorized by the *Contractor*, the *Contractor* performs all necessary activities (procurement, transportation, installation/repair/removal etc.) of corrective maintenance. Prior to such corrective maintenance activities, the *Contractor* notifies the *Employer* for the necessary cost and plan. The *Contractor* offers must be according to the market competitive. Only upon the approval from the *Employer*, the *Contractor* will execute the process. To avoid doubt, if such malfunction or breakdown requires the replacement of the components and the necessary components are available in the inventory of spare parts, the *Contractor* immediately corrects the breakdown or malfunction with the available spare parts.
 - h) The *Contractor*, in any case warrants the absence of defects on any repair, replacement and generally on any activities of corrective maintenance for two years in case of replacement and one year in case of repair.

3.15.4 O&M Training

- a) O&M Training is provided to the *Employer* and *Employers'* representatives' within six (6) months after the issuance of Substantial Completion Certificate. The Training is based on Classroom and Onsite Training.
 - 1) The *Contractor* provides formal classroom training of the operations, maintenance to ensure *Employer's* representatives' has a sound understanding of the plant layout, characteristics and functionality.
 - 2) Training material for classroom training is based on O&M manual content (O&M Manual requirement is presented in in this document) and contains evaluation criteria on each section of the plant covered in order to establish the level of *Employer's* representatives' understanding.
- b) The *Contractor* provides formal on-site training of the operations, maintenance of the plant is essential to ensure *Employer's* representatives' have a sound understanding of the plant functionality and O&M requirements.

CONTROLLED DISCLOSURE

- 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.
- d) Training focuses on following area,
 - 1) Operation and Maintenance of the Facility
 - 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 and PLC Training
- e) The *Contractor* provides all training materials of in hard copy and electronic copy to the trainees prior to the actual commencement of O&M training
- f) The *Contractor* ensures that all trainings are conducted by experienced personnel (minimum 5 years of experience in operation and maintenance of utility scale PV projects) in professional manner.

3.15.5 Spares

The *Contractor* provides and ensures that such minimum levels are always available in inventory during the plant operation according to **Appendix E**.

CONTROLLED DISCLOSURE

4. DOCUMENTATION MANAGEMENT AND SUBMITTALS

4.1 TENDER PHASE

The tender returnables are completed and submitted according Tender Technical Schedules to **Appendix M**, **Appendix L** and the relevant sections in this document.

4.2 CONTRACT PHASE

4.2.1 Document Submittals

After contract award, the documentation management and submittals will be done according to **Appendix G** and the relevant sections in this document

4.2.2 Design Review

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:

- a) Design Freeze Review
- b) Integrated Design Review
- c) Construction Completion Review
- d) Acceptance Testing Review

The following process is followed during submission of documents:

- a) The *Contractor* submits the documents/drawings to the Project Manager.
- b) The *Employer's* Document Controller registers the documents.
- c) The *Employer's* Document Controller will supply the documents/drawings to all relevant parties within the *Employer's* project team.
- d) The *Employer's* project team reviews the documents/drawings and submits all comments or inputs to the *Project Manager* and the *Project Manager* submits to the *Contractor* for consideration.
- e) If the *Employer* finds major deficiencies in the submitted documents/drawings, the *Contractor* revises the documents/drawings and resubmits to the *Project Manager*.
- f) The *Employer* reviews the documents/drawings and if no major deficiencies are found, the *Contractor* organises a Design Review session.
- g) The *Employer* and the *Contractor* conduct a Design Review.
- h) If any fundamental errors were found in the designs or further actions are required, the *Contractor* record all concerns raised and revises the designs.
- i) The *Contractor* organises a Design Review session once all designs were revised according to the concerns raised by the *Employer*.
- j) If no fundamental errors were found in the designs during the Design Review session, the *Contractor* compiles the Design Review minutes or report and submits it to the *Project Manager*.

CONTROLLED DISCLOSURE

- k) The *Employer's* Document Controller registers the report.
- l) 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*.
- m) The Project Manager accepts the *Contractor's* design once the report/minutes are accepted by the *Employer's* project team.

5. APPENDICES

Appendix A – Pervious Studies and Site Layout

Appendix A - 01 (part 1): Environmental Approval and Draft EMPr

Appendix A - 01 (part 2): Water Use License Application - Information to Bidders

Appendix A – 02: Geotechnical Study

Appendix A – 03: Switchgear Board Station 1 and 2 (Point of Connection)

Appendix A – 04: Site Map (Cadastral Map)

Appendix A05 – Cadastral and Satellite Map (Overlapping)

Appendix B: TMY Data Sheet

Appendix C: Indicative PV Array Layout and Single Line Drawings

Appendix C - 01: Indicative PV Array Layout

Appendix C - 02: Indicative Single Line Diagram

Appendix C – 03: Indicative O&M Building Layout

Appendix C – 04: Indicative PV Plant Substation Layout

Appendix C – 05: Indicative Evacuation Route layout

Appendix D – Board voltage profile

Appendix E - Spare Parts List_After_2years

Appendix F - Facility Performance Guarantees

Appendix G - Documentation Requirements

Appendix H – Liquidated Damages

Appendix I - CMS Network Diagram

Appendix J – CMS Signal List

Appendix K – O&M Reporting Requirement

Appendix L – LCOE Models and Instruction to Tenderers

Appendix M – Tender technical schedules

Appendix N – Security System Requirements

CONTROLLED DISCLOSURE

APPENDIX A: PREVIOUS STUDIES AND SITE LAYOUT

CONTROLLED DISCLOSURE

When downloaded from the EDMS database, this document is uncontrolled and the responsibility rests with the user to ensure it
is in line with the authorized version in the database.

APPENDIX B: TMY DATA SET

CONTROLLED DISCLOSURE

When downloaded from the EDMS database, this document is uncontrolled and the responsibility rests with the user to ensure it
is in line with the authorized version in the database.

APPENDIX C: PV ARRAY LAYOUT AND SINGLE LINE DRAWINGS

CONTROLLED DISCLOSURE

When downloaded from the EDMS database, this document is uncontrolled and the responsibility rests with the user to ensure it

is in line with the authorized version in the database.

APPENDIX D: BOARD VOLTAGE PROFILE

CONTROLLED DISCLOSURE

When downloaded from the EDMS database, this document is uncontrolled and the responsibility rests with the user to ensure it is in line with the authorized version in the database.

APPENDIX E: SPARE PART LIST

CONTROLLED DISCLOSURE

When downloaded from the EDMS database, this document is uncontrolled and the responsibility rests with the user to ensure it is in line with the authorized version in the database.

APPENDIX F: FACILITY PERFORMANCE GUARANTEES

CONTROLLED DISCLOSURE

When downloaded from the EDMS database, this document is uncontrolled and the responsibility rests with the user to ensure it is in line with the authorized version in the database.

APPENDIX G: DOCUMENT REQUIREMENT

CONTROLLED DISCLOSURE

When downloaded from the EDMS database, this document is uncontrolled and the responsibility rests with the user to ensure it is in line with the authorized version in the database.

APPENDIX H: PERFORMANCE LIQUIDATED DAMAGES

CONTROLLED DISCLOSURE

When downloaded from the EDMS database, this document is uncontrolled and the responsibility rests with the user to ensure it is in line with the authorized version in the database.

APPENDIX I: CMS NETWORK DIAGRAM

CONTROLLED DISCLOSURE

When downloaded from the EDMS database, this document is uncontrolled and the responsibility rests with the user to ensure it is in line with the authorized version in the database.

APPENDIX J: CMS LIST OF PARAMETERS

CONTROLLED DISCLOSURE

When downloaded from the EDMS database, this document is uncontrolled and the responsibility rests with the user to ensure it is in line with the authorized version in the database.

APPENDIX K: O&M REPORTING REQUIREMENT

CONTROLLED DISCLOSURE

When downloaded from the EDMS database, this document is uncontrolled and the responsibility rests with the user to ensure it is in line with the authorized version in the database.

APPENDIX L: LCOE MODEL AND INSTRUCTION TO TENDERERS

CONTROLLED DISCLOSURE

When downloaded from the EDMS database, this document is uncontrolled and the responsibility rests with the user to ensure it is in line with the authorised version on the database.

APPENDIX M: TENDER TECHNICAL SCHEDULES

CONTROLLED DISCLOSURE

When downloaded from the EDMS database, this document is uncontrolled and the responsibility rests with the user to ensure it
is in line with the authorized version in the database.

APPENDIX N: SECURITY SYSTEM REQUIREMENTS

CONTROLLED DISCLOSURE

When downloaded from the EDMS database, this document is uncontrolled and the responsibility rests with the user to ensure it is in line with the authorized version in the database.