|  |  |  |
| --- | --- | --- |
|  | Specification | Arnot Power Station |

|  |  |  |  |
| --- | --- | --- | --- |
| Title: | Functional Specification for Solar Photovoltaic (PV) Plant at Arnot Power Station | Document Identifier: | **AEEP 0127** |
|  | Alternative Reference Number: | N/A |
|  | Area of Applicability: | Arnot Solar Photovoltaic (PV) Project |
|  | Functional Area: | Engineering |
|  | Revision: | 1 |
|  | Total Pages: | 187 |
|  | Next Review Date: | N/A |
|  | Disclosure Classification: | Controlled Disclosure |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Compiled by |  | Functional Responsibility |  | Authorized by |  | Supported by |  |
|  |  |  |  |  |  |  |  |
| VM Erasmus  Arnot: Snr. Eng. D&S |  | M Mosebo  Arnot: Acting Project Eng. Manager |  | T Mokgatle  Arnot: Eng. Manager |  | G Olukune  Renewable Division: Snr. Eng. Manager |  |
| Date: |  | Date: |  | Date: |  | Date: |  |
|  |  |  |  |  |  |  |  |

Content

Page

[1. Introduction 10](#_Toc214639910)

[2. Supporting Clauses 10](#_Toc214639911)

[2.1 Normative/Informative References 10](#_Toc214639912)

[2.1.1 Normative 10](#_Toc214639913)

[2.1.2 Informative 11](#_Toc214639914)

[2.2 Definitions 11](#_Toc214639915)

[2.3 Abbreviations 14](#_Toc214639916)

[3. Scope of works 18](#_Toc214639917)

[3.1 Engineering and Documentation 19](#_Toc214639918)

[3.1.1 Surveys, studies, and reports 20](#_Toc214639919)

[3.1.2 Engineering and design 20](#_Toc214639920)

[3.1.3 Commissioning documentation 22](#_Toc214639921)

[3.2 Construction, Installation, and Commissioning 22](#_Toc214639922)

[3.2.1 General infrastructure and utilities 23](#_Toc214639923)

[3.2.2 Preparatory works 24](#_Toc214639924)

[3.2.3 Civil Works 24](#_Toc214639925)

[3.2.4 Mechanical works 25](#_Toc214639926)

[3.2.5 Electrical works 26](#_Toc214639927)

[3.2.6 Control and Instrumentation work 27](#_Toc214639928)

[3.2.7 Buildings 28](#_Toc214639929)

[3.2.8 Commissioning and Testing 28](#_Toc214639930)

[3.2.9 Connection works 30](#_Toc214639931)

[3.2.10 Equipment 30](#_Toc214639932)

[3.2.11 Labour 30](#_Toc214639933)

[3.2.12 Cleaning and waste management 31](#_Toc214639934)

[3.2.13 Maintenance before Provisional Acceptance 31](#_Toc214639935)

[3.2.14 Removal of temporary facilities 31](#_Toc214639936)

[3.3 Digitalisation 31](#_Toc214639937)

[4. Design Data 32](#_Toc214639938)

[4.1 Introduction 32](#_Toc214639939)

[4.2 Battery Limits 32](#_Toc214639940)

[4.3 Battery Limits With the HV Subcontractor 32](#_Toc214639941)

[4.4 General Design Considerations 33](#_Toc214639942)

[4.5 Plant Location 34](#_Toc214639943)

[4.6 Climatic Conditions 35](#_Toc214639944)

[4.7 Site Terrain 35](#_Toc214639945)

[4.8 Soil and Geotechnical Data 36](#_Toc214639946)

[4.9 Hydrology 36](#_Toc214639947)

[4.10 Lightning 36](#_Toc214639948)

[4.11 Seismic Conditions 36](#_Toc214639949)

[4.12 Archaeological Data 37](#_Toc214639950)

[4.13 Biophysical Environment 37](#_Toc214639951)

[4.14 Potable- and Raw- Water Supply and sewage connection 37](#_Toc214639952)

[5. Inspection and Testing 38](#_Toc214639953)

[5.1 Construction 38](#_Toc214639954)

[5.1.1 Inspection Test Plan (ITP) 38](#_Toc214639955)

[5.1.2 Method Statement 41](#_Toc214639956)

[5.2 Inspection and testing 41](#_Toc214639957)

[5.2.1 General 41](#_Toc214639958)

[5.2.2 Test Sequence 43](#_Toc214639959)

[5.2.3 General Test Notification Requirements 43](#_Toc214639960)

[5.2.4 Safety measures 43](#_Toc214639961)

[5.2.5 Test Procedures and Reporting Requirements 44](#_Toc214639962)

[5.2.6 Factory Acceptance Tests 45](#_Toc214639963)

[5.2.7 Site Acceptance Tests 47](#_Toc214639964)

[5.2.8 Inspection And Tests During Construction 47](#_Toc214639965)

[5.2.9 Tests On Completion 54](#_Toc214639966)

[5.3 Third Party / Notified Body Certification 63](#_Toc214639967)

[6. General Technical Requirements 63](#_Toc214639968)

[6.1 General Technical Requirements – Standards and Codes 63](#_Toc214639969)

[6.2 Software 65](#_Toc214639970)

[6.3 Staffing 65](#_Toc214639971)

[6.4 Factor of Significance 65](#_Toc214639972)

[6.5 Units of Measurement 66](#_Toc214639973)

[6.6 Nameplates and Labels 66](#_Toc214639974)

[6.7 Equipment Identification System 67](#_Toc214639975)

[6.8 Quality of Materials 67](#_Toc214639976)

[6.9 Preservation 67](#_Toc214639977)

[6.10 Padlocks and Keys 67](#_Toc214639978)

[6.11 Training 68](#_Toc214639979)

[6.11.1 General 68](#_Toc214639980)

[6.11.2 Training Programme 68](#_Toc214639981)

[6.11.3 Facilities and Training Materials/Aids 69](#_Toc214639982)

[6.12 Plant Operators 69](#_Toc214639983)

[6.13 Material Handling and Storage 70](#_Toc214639984)

[6.13.1 General 70](#_Toc214639985)

[6.13.2 PV Module Handling and Storage 70](#_Toc214639986)

[6.13.3 Substructure Handling and Storage 70](#_Toc214639987)

[6.13.4 Cable Handling and Storage 71](#_Toc214639988)

[6.13.5 Electrical Components Handling and Storage 71](#_Toc214639989)

[6.13.6 Handling of Hazardous Materials 71](#_Toc214639990)

[6.13.7 Spare Parts 71](#_Toc214639991)

[6.14 Welding Requirements 74](#_Toc214639992)

[6.15 Environmental Aggressiveness 74](#_Toc214639993)

[6.16 Carbon Tax Credits 76](#_Toc214639994)

[6.17 Renewable Energy Certificates 76](#_Toc214639995)

[7. PV System Requirements 76](#_Toc214639996)

[7.1 Proven Technology 76](#_Toc214639997)

[7.2 Plant Layout 76](#_Toc214639998)

[7.3 Energy Yield Assessment (EYA) 77](#_Toc214639999)

[7.4 PV Array Design 78](#_Toc214640000)

[7.5 PV Module Requirements 79](#_Toc214640001)

[7.5.1 Electrical and Performance Characteristics 79](#_Toc214640002)

[7.5.2 Bifacial Module Requirements (if applicable) 80](#_Toc214640003)

[7.5.3 Safety and Compliance 80](#_Toc214640004)

[7.5.4 Mechanical and Environmental Requirements 80](#_Toc214640005)

[7.5.5 Manufacturer Requirements 81](#_Toc214640006)

[7.5.6 Quality Control and Testing 81](#_Toc214640007)

[7.5.7 Additional Testing Requirements 81](#_Toc214640008)

[7.5.8 Required Certifications 82](#_Toc214640009)

[7.5.9 PV Module Documentation, Labelling, and Installation Requirements 83](#_Toc214640010)

[7.5.10 Delivery and As-Built Documentation 83](#_Toc214640011)

[7.5.11 Installation and Sorting 83](#_Toc214640012)

[7.5.12 Nameplate and Labelling Requirements 84](#_Toc214640013)

[7.5.13 Bifacial Module Testing (if applicable) 84](#_Toc214640014)

[7.6 DC Interconnections and Cabling 84](#_Toc214640015)

[7.6.1 General Cable Requirements 84](#_Toc214640016)

[7.6.2 Termination and Connection 85](#_Toc214640017)

[7.6.3 Routing and Protection 85](#_Toc214640018)

[7.6.4 Labelling and Mechanical Protection 86](#_Toc214640019)

[7.6.5 Mounting Structure Integration 86](#_Toc214640020)

[7.6.6 Standards Compliance 86](#_Toc214640021)

[7.7 DC Cable 86](#_Toc214640022)

[7.7.1 Minimum Technical Characteristics: 87](#_Toc214640023)

[7.7.2 Alternative Cable Type: 87](#_Toc214640024)

[7.7.3 For Central Inverter Applications: 87](#_Toc214640025)

[7.7.4 Additional Requirements: 87](#_Toc214640026)

[7.8 LV (AC) Cabling 88](#_Toc214640027)

[7.8.1 Minimum Technical Requirements: 88](#_Toc214640028)

[7.9 PV String Combiner Box 88](#_Toc214640029)

[7.9.1 Minimum Technical Requirements: 89](#_Toc214640030)

[7.10 AC Distribution Panels 89](#_Toc214640031)

[7.11 Inverters 90](#_Toc214640032)

[7.11.1 General Requirements 90](#_Toc214640033)

[7.11.2 Manufacturer Requirements 91](#_Toc214640034)

[7.11.3 Manufacturer Certification 91](#_Toc214640035)

[7.11.4 Applicable Standards 91](#_Toc214640036)

[7.11.5 Manufacturer Facility Certification 92](#_Toc214640037)

[8. Civil Engineering and Building Works Requirements 92](#_Toc214640038)

[8.1 Site Investigations and Surveys 92](#_Toc214640039)

[8.2 Site Preparation and Earthworks 92](#_Toc214640040)

[8.2.1 General 92](#_Toc214640041)

[8.2.2 Site Clearance 93](#_Toc214640042)

[8.2.3 Excavation, Filling, and Compaction 93](#_Toc214640043)

[8.2.4 Levelling, Grading, and Drainage 93](#_Toc214640044)

[8.2.5 Flood Protection and Finished Levels 94](#_Toc214640045)

[8.2.6 Topsoil Management and Environmental Restoration 94](#_Toc214640046)

[8.2.7 Platform and Bearing Capacity Design 94](#_Toc214640047)

[8.2.8 Material Classification, Processing, and Disposal 94](#_Toc214640048)

[8.2.9 Temporary Surfacing and Construction Access 95](#_Toc214640049)

[8.3 Roads and Hardstanding Areas 95](#_Toc214640050)

[8.3.1 General Requirements 95](#_Toc214640051)

[8.3.2 Responsibilities 95](#_Toc214640052)

[8.3.3 Design Criteria 95](#_Toc214640053)

[8.3.4 Road Construction Standards 96](#_Toc214640054)

[8.3.5 Access and Circulation 96](#_Toc214640055)

[8.3.6 Hardstanding and Parking Areas 97](#_Toc214640056)

[8.3.7 Traffic and Safety Management 97](#_Toc214640057)

[8.3.8 Testing and Quality Control 97](#_Toc214640058)

[8.3.9 Maintenance During Construction 97](#_Toc214640059)

[8.4 Drainage and Stormwater Management 98](#_Toc214640060)

[8.4.1 Construction Requirements 98](#_Toc214640061)

[8.4.2 Stormwater Management Plan 98](#_Toc214640062)

[8.5 Fencing and Gates 99](#_Toc214640063)

[8.6 Trenches, Ducts and Manholes 99](#_Toc214640064)

[8.7 Foundations 101](#_Toc214640065)

[8.7.1 Piling / Mounting Structure Foundations 101](#_Toc214640066)

[8.7.2 Other Foundations 102](#_Toc214640067)

[8.7.3 Excavations and Backfilling for Foundations 103](#_Toc214640068)

[8.8 Structural Design Principles 103](#_Toc214640069)

[8.8.1 Load Assumptions 104](#_Toc214640070)

[8.8.2 Wind Loads 104](#_Toc214640071)

[8.8.3 Seismic Loads 104](#_Toc214640072)

[8.8.4 Corrosion Protection 104](#_Toc214640073)

[8.9 Civil Construction Material 104](#_Toc214640074)

[8.9.1 Steel Materials 104](#_Toc214640075)

[8.9.2 Concrete Materials 105](#_Toc214640076)

[8.9.3 Coal Ash Waste Resource 108](#_Toc214640077)

[8.10 Buildings 109](#_Toc214640078)

[8.10.1 General Building Design and Construction 109](#_Toc214640079)

[8.10.2 O&M Building 109](#_Toc214640080)

[8.10.3 Warehouse Building 111](#_Toc214640081)

[8.10.4 Office Equipment 111](#_Toc214640082)

[8.10.5 Substation Building 111](#_Toc214640083)

[9. Tracking System 112](#_Toc214640084)

[9.1 General 112](#_Toc214640085)

[9.2 Structure 112](#_Toc214640086)

[9.3 Driving Mechanism 113](#_Toc214640087)

[9.4 Earthing 113](#_Toc214640088)

[9.5 Tracker Control System 114](#_Toc214640089)

[9.6 PV Module Installation 114](#_Toc214640090)

[10. Mechanical design 115](#_Toc214640091)

[10.1 Firefighting and Fire Protection System 115](#_Toc214640092)

[10.1.1 General 115](#_Toc214640093)

[10.1.2 Portable Fire Extinguishers 115](#_Toc214640094)

[10.1.3 Fire Detection and Alarm 116](#_Toc214640095)

[10.1.4 Fire Safety in Building Design and Construction 116](#_Toc214640096)

[10.1.5 Fire Safety During Construction and Commissioning 116](#_Toc214640097)

[10.2 HVAC System 116](#_Toc214640098)

[11. Electrical Requirements 117](#_Toc214640099)

[11.1 Scope of Work 117](#_Toc214640100)

[11.2 Electrical Studies 117](#_Toc214640101)

[11.3 General Electrical Requirements 118](#_Toc214640102)

[11.4 Grid Code Requirements 119](#_Toc214640103)

[11.5 System Frequency, Voltages, Short Circuit Rating and Method of Earthing 119](#_Toc214640104)

[11.6 Grid Connection 119](#_Toc214640105)

[11.7 MV/LV Transformers 119](#_Toc214640106)

[11.7.1 General Requirements 119](#_Toc214640107)

[11.7.2 Oil-Filled Transformers 120](#_Toc214640108)

[11.7.3 Dry Type Transformers 121](#_Toc214640109)

[11.7.4 LV/MV Inverter Transformers 121](#_Toc214640110)

[11.7.5 Auxiliary Transformers 122](#_Toc214640111)

[11.8 LV/MV Substation 123](#_Toc214640112)

[11.9 Switchgear 123](#_Toc214640113)

[11.10 MV Ring Main Unit (RMU) 124](#_Toc214640114)

[11.11 Electrical System Control, Indications, and Alarms 125](#_Toc214640115)

[11.12 400–800/230 V AC and DC Sub-Distribution Boards 125](#_Toc214640116)

[11.13 Uninterruptible Power Supply Systems 126](#_Toc214640117)

[11.14 MV (AC) Cables and Installation 127](#_Toc214640118)

[11.15 Earthing System Design, Bonding, and Lightning Protection 129](#_Toc214640119)

[11.16 Protection and Control 130](#_Toc214640120)

[11.16.1 Plant Step-Up (PSU) Transformer Protection 130](#_Toc214640121)

[11.16.2 Protection of Electrical Auxiliary Systems 130](#_Toc214640122)

[12. Control, Instrumentation, and Communication Requirements 131](#_Toc214640123)

[12.1 Plant Monitoring and Control System Design Philosophy 131](#_Toc214640124)

[12.2 Hardware 133](#_Toc214640125)

[12.2.1 Control Room / Building 133](#_Toc214640126)

[12.2.2 LV/MV Power Stations 133](#_Toc214640127)

[12.2.3 Wiring 134](#_Toc214640128)

[12.2.4 Shielding and Grounding System 135](#_Toc214640129)

[12.3 SCADA Software 135](#_Toc214640130)

[12.3.1 General Description 135](#_Toc214640131)

[12.3.2 Software Architecture 136](#_Toc214640132)

[12.3.3 Network Topology 136](#_Toc214640133)

[12.3.4 Internet Connection 137](#_Toc214640134)

[12.3.5 Network Communication Medium 137](#_Toc214640135)

[12.3.6 Network Diagram 138](#_Toc214640136)

[12.3.7 Design Criteria 139](#_Toc214640137)

[12.3.8 SCADA Servers 140](#_Toc214640138)

[12.3.9 Operator System Thin Clients 141](#_Toc214640139)

[12.3.10 Installation of Thin Clients 141](#_Toc214640140)

[12.3.11 Network Switches 141](#_Toc214640141)

[12.3.12 SCADA Network Panels 142](#_Toc214640142)

[12.3.13 Server Room Network Cabinets 142](#_Toc214640143)

[12.3.14 SCADA functions 143](#_Toc214640144)

[12.3.15 Commands Requirements 144](#_Toc214640145)

[12.3.16 Monitoring System 145](#_Toc214640146)

[12.3.17 Reports 152](#_Toc214640147)

[12.3.18 Documentation 153](#_Toc214640148)

[12.3.19 Incident Handling 153](#_Toc214640149)

[12.3.20 Hardening Workstations 154](#_Toc214640150)

[12.3.21 Data Backup 154](#_Toc214640151)

[12.3.22 Response Times 155](#_Toc214640152)

[12.4 Monitoring and Control System External Interfaces 155](#_Toc214640153)

[12.4.1 Inverters 155](#_Toc214640154)

[12.4.2 DC String Combiner Boxes 155](#_Toc214640155)

[12.4.3 Switchgear 156](#_Toc214640156)

[12.4.4 Energy Meters 156](#_Toc214640157)

[12.4.5 Building Management System (BMS) 157](#_Toc214640158)

[12.5 Power Supply 160](#_Toc214640159)

[12.6 Labels, Tags, Plates, and Inscriptions 161](#_Toc214640160)

[12.7 Meteorological Station 161](#_Toc214640161)

[12.8 Soiling Station 163](#_Toc214640162)

[12.9 Station Clock 163](#_Toc214640163)

[12.10 Security System 163](#_Toc214640164)

[12.10.1 CCTV Cameras 165](#_Toc214640165)

[12.10.2 Network Video Recorder 166](#_Toc214640166)

[12.10.3 Intruder Detection System 166](#_Toc214640167)

[12.11 Telecommunications 166](#_Toc214640168)

[12.11.1 PV Modules Site Acceptance Tests 167](#_Toc214640169)

[12.11.2 Mounting structure 168](#_Toc214640170)

[13. Performance Guarantees 168](#_Toc214640171)

[13.1 General Requirements 168](#_Toc214640172)

[13.2 Performance Guarantees 168](#_Toc214640173)

[13.2.1 AC Capacity Guarantee 168](#_Toc214640174)

[13.2.2 Installed DC Capacity Guarantee 168](#_Toc214640175)

[13.2.3 Guaranteed Plant Performance Ratio during Tests on Completion 169](#_Toc214640176)

[13.2.4 Guaranteed Annual Performance Ratio 169](#_Toc214640177)

[13.2.5 Guaranteed Annual Availability 169](#_Toc214640178)

[13.3 Extended Defect Liability Period 169](#_Toc214640179)

[13.4 PV Modules Warranty Terms 170](#_Toc214640180)

[14. Grid Connection Works 171](#_Toc214640181)

[14.1 Scope of Grid Connection Works 171](#_Toc214640182)

[14.1.1 22 kV Eskom Arnot Solar Switching Station 173](#_Toc214640183)

[14.1.2 22 kV Arnot Solar Plant Substation: 175](#_Toc214640184)

[14.1.3 MV Line 176](#_Toc214640185)

[14.1.4 Rietkuil substation: 176](#_Toc214640186)

[14.2 Engineering Design 177](#_Toc214640187)

[14.3 Grid Connection Works Sub-Contractor 177](#_Toc214640188)

[14.4 Electrical Requirements 178](#_Toc214640189)

[14.4.1 MV Switchgear 178](#_Toc214640190)

[14.4.2 Substation Conductor, Hardware & Clamps 179](#_Toc214640191)

[14.5 Medium Voltage Overhead Line 179](#_Toc214640192)

[14.5.1 General 179](#_Toc214640193)

[14.5.2 Structures And Foundations 179](#_Toc214640194)

[14.5.3 Conductors And Shield Wires 180](#_Toc214640195)

[14.5.4 Labelling 180](#_Toc214640196)

[14.5.5 Insulation And Hardware 180](#_Toc214640197)

[14.5.6 Line Templating and Profiling 180](#_Toc214640198)

[14.6 Electrical System Control, Indications and Alarms 181](#_Toc214640199)

[14.6.1 400/230V AC And 110V DC Sub-Distribution Boards 181](#_Toc214640200)

[14.6.2 Batteries and Battery Chargers 182](#_Toc214640201)

[14.6.3 AC Cables and Installation 182](#_Toc214640202)

[14.6.4 Earthing System Design, Bonding and Lightning Protection 184](#_Toc214640203)

[14.6.5 Substation Lighting 185](#_Toc214640204)

[14.6.6 Protection of Electrical Auxiliary Systems 185](#_Toc214640205)

[15. Acceptance 186](#_Toc214640206)

[16. Revisions 187](#_Toc214640207)

[17. Development team 187](#_Toc214640208)

[18. Acknowledgements 187](#_Toc214640209)

[Annexure A - DC WIRING DIAGRAM- STRING COMBINER BOX (SCB) 188](#_Toc214640210)

[Annexure B - DC-AC INVERTER SINGLE LINE DIAGRAM 189](#_Toc214640211)

[Annexure C - AC WIRING DIAGRAM TRANSFORMER TO SUBSTATION 190](#_Toc214640212)

[Annexure D - Arnot PV Plant Indicative Site Location Drawings 191](#_Toc214640213)

[Annexure E - Arnot PV Plant Topographical Survey 192](#_Toc214640214)

[Annexure F - Arnot PV Plant Geotechnical Assessment 193](#_Toc214640215)

[Annexure G - Arnot PV Plant Hydrological Impact Assessment 194](#_Toc214640216)

Figures

[Figure 1 SCADA & PPC Interface Architecture 131](#_Toc214640217)

[Figure 2 Ring network topology 136](#_Toc214640218)

[Figure 3 Bus network topology 137](#_Toc214640219)

[Figure 4 Eskom Arnot Solar PV Facility SLD (VT at Eskom Rietkuil Substation not shown – bay in red colour indicates the existing bay utilised connection) 173](#_Toc214640220)

Tables

[Table 1 Requirements – Capacities for single-axis tracking 22](#_Toc214640221)

[Table 2 Project meteorological conditions 35](#_Toc214640222)

[Table 3 Project’s voltage levels 119](#_Toc214640223)

[Table 4 Indoor conditions and areas to be provided with HVAC system 158](#_Toc214640224)

[Table 5 Minimum Technical Requirements of the Meteorological station 161](#_Toc214640225)

[Table 10 Minimum Warranty Period of Main Components 169](#_Toc214640226)

# Introduction

This document provides the functional specification for the proposed PV power plant at Arnot Power Station. The DC capacity for the proposed plant shall not be less than 12.8 MW and not more than 17.2 MW.

# Supporting Clauses

## Normative/Informative References

Parties using this document shall apply the most recent edition of the documents listed in the following paragraphs.

### Normative

1. 240-43327398: Engineering Policy
2. 240-53114026: Project Engineering Change Management Procedure
3. ISO 9001 Quality Management Systems
4. 240-53114002: Engineering Change Management Procedure
5. 240-53114190: Internal Audit Procedure
6. 240-53665024: Engineering Quality Manual
7. 240-56355541: C&I Computer & Equipment Rooms Civil and General Building Requirements
8. 32-894: Eskom Server Rooms and Data Centres Standard
9. 240-56355731: Environmental Conditions for Process Control Electronic Equipment Used at Power Stations
10. 240-56355808: Ergonomic Design of Power Station Control Suites Guideline
11. 240-56737448: Fire Detection and Life Safety Design Standard
12. 240-54937450: Fire Protection and Life Safety Design Standard
13. 240-55410927: OT Cyber Security Standard
14. SANS 10142-1: The Wiring of Premises Part 1: Low Voltage Installations
15. SANS 10114-1: Interior Lighting Part 1: Artificial Lighting of Interiors
16. SANS 10114-2: Interior Lighting Part 2: Emergency Lighting
17. GGS 0386: Generation Requirements for Control and Power Cables for Power Stations Standard
18. Eskom iLanga PV Portfolio Power Stations Site Screening Report - PSTA\_SSR - Draft 1 - 27 June 2013
19. ANT-PVSROC001 – Required Operational Capability Report For Arnot Power Station PV Solar Project Rev 1 – 20 April 2016
20. Draft Environmental Management Programme – DEA Reference Number 14/12/16/3/3/2/760 – July 2015
21. Environmental Authorisation for the 17.2MW Eskom Arnot Power Station Photovoltaic Solar Energy Facility – 8 March 2016

### Informative

1. RES/RR/25/1971769 Long Duration Energy Storage Technology Scan Report
2. 240-43327398: Engineering Policy
3. 240-53114026: Project Engineering Change Management Procedure
4. ISO 9001 Quality Management Systems
5. 240-53114002: Engineering Change Management Procedure
6. 240-53114190: Internal Audit Procedure
7. 240-53665024: Engineering Quality Manual
8. EPIA Global Market Outlook for Photovoltaics - 2014-2018
9. IEA PVPS Snapshot of Global PV Markets – 2014

## Definitions

| **Term** | **Definition** |
| --- | --- |
| Applicable Laws, Codes and Standards | Where applicable for the carrying out of the Works and as amended from time to time: (a) statutes and ordinances (including regulations enacted under those statutes); (b) national, regional, provincial, state, municipal, or local laws and by laws) judgments and orders of courts of competent jurisdiction. (d) rules, regulations, and orders issued by government agencies, authorities, and other regulatory bodies) all regulatory approvals, permits, licenses, permissions, approvals, and authorisations. |
| Authorities | Official person or institution that has power, permission or right to act. |
| Commencement Date | Means the date on which the Contractor is to commence the performance of the Works according to the respective Notice to Proceed and the Contract, provided by the Employer and delivered to the Contractor. |
| Contract | Means the terms and conditions, exhibits and written amendments, modifications, supplement and change orders for the agreement between the Contractor and the Employer for the Works. |
| Contracted Capacity | Total installed capacity according to the number of the PV modules to be installed by the contractor and their rated power at STC conditions, and nominal power of the PV inverters at power factor 1 and operational temperature of 50 degrees. |
| Contractor | Main EPC company to be engaged for the Works |
| Contractor’s Documents | Documents prepared by the Contractor as part of the Works including calculations, digital files, computer programs and other software, drawings, manuals, models, specifications, and other documents of a technical nature. |
| Date of Completion | Date on which the Contractor is expected to achieve Provisional Acceptance according to the Contract. |
| Defect Liability Period | Means the period to be stated within the Contract starting on Provisional Acceptance, when the Contractor is liability to remedy any damage or defect on the Works. |
| Design Lifetime | Number of years or which the PV Plant shall be able to operate, equal to 25 years. |
| Emergency Plan | Project plan document that must describe the system of procedures to organize and supervise the safe and orderly movement of people in case evacuation from a danger zone |
| Employer | Eskom |
| Environmental and Social Management Plan | Project plan document that must describe the implementation and management of environmental and social impacts mitigation and enhancement measures during the executions of the Works |
| Excavation Management Plan | Project plan document that must describe the procedures and of health and safety risks associated with all types of excavation work |
| Good Industry Practice | means the exercise of degree of skill, diligence, prudence, efficiency, foresight, and timeliness which could be reasonably expected from a reputable and experienced EPC company. |
| Grid Code | means, as applicable, any code(s) in respect of electricity distribution or transmission system. |
| Grid Operator | Eskom |
| Guaranteed Availability | Minimum level of availability required during the contractual period defined according to the Contract. |
| Guaranteed PR | Minimum level of performance ratio required during the contractual period defined according to the Contract. |
| HV Subcontractor | The Subcontractor responsible for the HV works according to the Project battery limits under the relevant section 4.3. |
| Inspection and Test Plans | Contractor plan that collects all the inspections and tests to be carried out in the entire project for quality assurance purposed. |
| International Standards | Technical standard developed by one or more international organizations outside of South Africa. |
| Main Equipment | means the PV modules, Inverters, Mounting Structures (including Trackers) and the MV stations (including transformers and switchgears). |
| Main Right Unit | Factory assembled; metal enclosed set of switchgear used at the load connection points of the central stations. |
| Maximum AC Capacity | The maximum AC capacity as per the Table 1 to be considered for the Plant. |
| National Law | Laws that exist “within” the country of South Africa. |
| National Standards | Technical standard developed by one or more South African organizations. |
| O&M Contractor | Contractor responsible for the O&M of the Plant |
| Plant | The Solar PV Plant located at the Site, including all components thereof and related facilities. |
| Project | The PV power Plant, facilities and associated grid connection infrastructures to the point of interconnection with the electricity transmission system, the access road and the site facilities. |
| Project Agreements | the terms and conditions between two parties to enter into a business partnership focusing on a particular aspect related to the Project, such as the Power Purchase Agreement, Distribution Agreements, Site Lease Agreements, Independent Engineer Agreement, etc. |
| Project Approvals | Means all consents, permits, clearances, authorisations, rulings, exemptions, registrations, filings, decisions, licenses, required to be issued by or made with any Authority in connection with the performance of the Works. |
| Project Documents | Existing documentation related to permitting, preliminary design and other relevant information for the Project, provided by the Employer to the Contractor. |
| Project Manager | Contractor professional in the specific field, having the responsibility of the planning, procurement and execution of a defined scope. |
| Provisional Acceptance | Employer´s conditional acceptance of the Works subject to further performance testing and remedy of defects by the Contractor during the DNP |
| Prudent Industry Standards | Practices, methods, acts and equipment approved by a significant portion of the renewable energy electric generation industry operating in South Africa in prudent electrical operations that, at a particular time, in the exercise of reasonable judgment in light of the facts known or that reasonably should have been known at the time a decision was made, would reasonably have been expected to accomplish the desired result in a manner consistent with the Applicable Laws, Permits, Codes and Standards, and equipment manufacturer’s recommendations, in each case, followed in the solar power industry and such regard to reliability, safety, environmental protection, efficiency, economy, and expedition. |
| Risk Assessments | Identification and analysis of potential events that may negatively impact individuals, assets, and/or the environment. |
| Scope of Works | List of activities and responsibilities to be performed by the Contractor under the Contract. |
| Site Manager | Construction Contractor manager or site agent responsible for the day-to-day on site. |
| Site/Sites | The location where the Plant and respective interconnections to the substations will be constructed |
| Standards | National Standards and International Standards |
| Subcontractor | Means a contractor executing part of the Works on Site on behalf of the Contractor |
| Traffic Management Plan | Project plan document that must include all aspects related to traffic management procedures associated with the transport routes to Site and internal roads and traffic management |
| Testing and Commissioning Plan | Project plan document that must include all those aspects related to the commissioning and start-up activities required. |
| Warranty Period | Period during which the Contractor shall remain liable for repair or replacement of any defective part of the Works performed under the Contract. |
| Waste Management Plan | Project plan document that must include all those aspects related to the storage, production, transport and treatment of waste produced in the workplace. |
| Work Schedule | means the schedule of dates in which the contractor is required to achieve certain state of completion of the Works. |
| Works | Means the obligations, duties and responsibilities required to be performed by the Contractor according to the Contractor Scope of Works |

## Abbreviations

| **Abbreviation** | **Explanation** |
| --- | --- |
| AC | Alternating Current |
| AKZ | The Plant Designation System AKZ ((Anlagenkennzeichnungssystem) is a predecessor system for identifying plants, systems, sub-systems, and equipment items for plant operating companies |
| AN | Air Natural |
| BECW | Bare Earth Copper Wire |
| BMS | Building Management System |
| BoM | Bill of Materials |
| CB | Circuit Breaker |
| CBR | California Bearing Ratio |
| CCR | Central Control Room |
| CCTV | Closed-Circuit Television |
| CE Marking | CE marking indicates that a product has been assessed by the manufacturer and deemed to meet the European Union (EU) safety, health and environmental protection requirements. It is required for products manufactured anywhere in the world that are then marketed in the EU. |
| CEO | Chief Executive Officer |
| CFD | Computational Fluid Dynamics |
| C&I | Control and Instrumentation |
| COD | Commercial Operations Date |
| CPE | Collective Protections Equipment |
| CPU | Central Processing Unit |
| CV | Curriculum Vitae |
| DAF | Dynamic Amplification Factor |
| DC | Direct Current |
| DIN | Deutsches Institut fuer Normung |
| DMS | Document Management System |
| DNO | Distribution Network Operator |
| DNP | Defect Notification Period |
| DRCS | Design Review Comment Sheet |
| DS | Distribution System |
| EA | Environment Authorisation |
| ECC | Environmental Clearance Certificate |
| EIA | Environmental Impact Assessment |
| EL | Electroluminescence Test |
| EMPr | Environmental Management Programme |
| EN | European Standards |
| EPC | Engineering, Procurement and Construction |
| EPs | Equator Principles |
| ESS | Energy Storage System |
| ETA | Estimated Time of Arrival |
| EYA | Energy Yield Assessment |
| FAT | Factory Acceptance Test |
| FAC | Final Acceptance Certificate |
| FEM | Finite Element Method |
| FIC | Field Inspection Checklist |
| FO | Fibre optic |
| FQC | Final Quality Control |
| FSOU | Free State Operating Unit |
| FTP | File Transfer Protocol |
| GHI | Global Horizontal Irradiation (W/m²) |
| GII | Global Inclined Irradiation (W/m²) |
| GPS | Global Positioning System |
| GUI | Graphical User Interface |
| HAZOP | Hazard and Operability study |
| HDPE | High Density Polyethylene |
| HMI | Human-Machine Interface |
| HSE | Health, Safety and the Environment |
| HV | High Voltage |
| HVAC | Heating Ventilation and Air Conditioning |
| HVRT | High Voltage Ride Through |
| IBC | International Building Code |
| ICS | Integrated Control System |
| IDMT | Inverse definite minimum time relay |
| IDS | Intrusion Detection System |
| IEC | International Electrotechnical Commission |
| IED | Intelligent Electronic Device |
| IFC | International Finance Corporation |
| I/O | Input/Output |
| IP | Ingress Protection |
| IP | Internet Protocol |
| IPQC | In Process Quality Control |
| IPS | Intrusion Prevention System |
| IQC | Incoming material Quality Control |
| IR | Infrared |
| ISO | International Organization for Standardization |
| IT | Information Technology |
| ITP | Inspection Test Plan |
| KKS code | The Identification System for Power Stations (Kraftwerk-Kennzeichensystem - KKS) is a system for identifying plants, systems, subsystems, equipment items, electrical and C&I cabinets, as well as buildings and rooms, depending on the perspective of the power plant operators. |
| KPI | Key Performance Indicator |
| LAN | Local Area Network |
| LCOE | Levelized cost of energy |
| LED | Light emitting diode |
| LEMP | Lightning Electromagnetic Pulse |
| LeTID | Light and elevated-Temperature Induced Degradation |
| LID | Light Induced Degradation |
| LV | Low Voltage |
| LVRT | Low Voltage Ride Through |
| M&E | Mechanical and Electrical systems |
| MAMSL | Meters above mean sea level |
| MCB | Miniature Circuit Breaker |
| MCCB | Moulded Case Circuit Breaker |
| MDL | Master Document List |
| MET | Ministry of Environment and Tourism |
| MPPT | Maximum Power Point Tracking |
| MSDS | Material Safety Data Sheets |
| MV | Medium Voltage |
| NEC | Neutral Earthing Compensator |
| NECRT | Neutral Earthing Compensators, Resistors, and auxiliary Transformer. |
| NER | Neutral Earthing Resistor |
| NFPA | National Fire Protection Association |
| NVR | Network Video Recorder |
| O&M | Operation and Maintenance |
| OEM | Original Equipment Manufacturer |
| OHL | Overhead Line |
| ONAF | Oil Natural Air Forced |
| ONAN | Oil Natural Air Natural |
| OQC | Outgoing Quality Control |
| ORHVS | Operating Regulations for High Voltage Systems |
| OT | Operational Technology |
| PA | Public Announcement |
| PCC | Power Control Centre |
| PCU | Power Control Unit |
| PERC | Passivated emitter rear cell |
| PID | Potential Induced Degradation |
| Plant | The Solar PV Plant located at the Site, including all components thereof and related facilities. |
| PLC | Programmable Logic Controller |
| POA | Plane of Array |
| POC | Point Of Connection |
| POE | Powered Over Ethernet |
| POT | Pull Out Test |
| PPC | Power Plant Controller |
| PPE | Personal Protective Equipment |
| PR | Performance Ratio |
| PTZ | Pan-tilt-zoom |
| PV | Photovoltaic |
| PUC | Point of Utility Connection |
| PVSyst | Project Design-modelling tool to estimate PV plant production |
| PVC | Polyvinyl chloride |
| QA/QC | Quality assurance / Quality control |
| RAID | Redundant Array of Independent Disks |
| RETEC | Renewable Energy Technical Evaluation Committee |
| RfP | Request for Proposals |
| RGB | Red, Green, Blue |
| RMS | Root Mean Square |
| RMU | Ring Main Unit |
| RTU | Remote Terminal Unit |
| SACPCMP | South African Council for the Project and Construction Management Professions |
| SANBI | South African National Biodiversity Institute |
| SANS | South African National Standard |
| SAT | Site Acceptance Tests |
| SCADA | Supervisory control and data acquisition |
| SCADA HMI | SCADA Human Machine Interface |
| SE | Substation |
| SET | Intermediate Substations |
| SFRA | Sweep Frequency Response Analysis |
| SI | International System of Units |
| SLD | Single Line Diagram |
| STC | Standard Test Conditions |
| SFTP | SSH File Transfer Protocol |
| THD | Total Harmonic Distortion |
| TMY | Typical Meteorological Year |
| TS | Transmission System |
| UGL | Under-ground Line |
| UPS | Uninterruptible Power Supply |
| USB | Universal Serial Bus |
| UV | Ultraviolet radiation |
| VLF | Very Low Frequency |
| Voc | Open circuit Voltage |
| VPN | Virtual Private Network |
| WAN | Wide Area Network |
| WB | World Bank |
| WEEE | Waste Electrical and Electronic Equipment |
| XLPE | Cross-linked polyethylene |

# Scope of Works

A minimum of 12.8 MW DC capacity with a maximum export capacity of 17.2 MW PV project is proposed at Arnot Power Station using PV modules mounted on a single axis tracking system structure. The Works include the construction of a PV power plant and the connection to the grid at the Rietkuil Substation. The scope includes the reviewing of all associated documents, amending where necessary these documents, completing the design works, completion of any needed study or survey, supplying all machinery, equipment and materials to complete all the works, the construction of the power plant, its connection to the National grid and any other work that is required to deliver a fully functional PV power plant. It does not include the application to Eskom Distribution to connect to the national grid. The Contractor’s scope of work covers, among other activities indicated in these Employer’s Requirements, the following (but not limited to) in relation to the Works:

* The turnkey procurement and delivery of studies, designs, engineering, licensing and permitting, manufacturing, factory testing, deliveries to Site (including customs duties and importation), project management, project cost control, supervision, documentation, labour, execution, erection, progress reporting, commissioning, testing, completion, training, and other Works necessary to construct and safely operate the Project;
* All security, fire protection, health, safety, environmental, and socio-economic requirements as included in any relevant environmental and social assessments, Applicable Laws, Permits and Codes, and any other Project Documents;
* All plant, equipment, materials, and work required to complete the Works; and
* Making good defects and providing warranty cover during the Defects Liability Period.
* All additional surveys and studies needed to complete the works.
* The contractor ensures a fully functional PV power plant which is fully integrated to the national electricity grid.
* Training of staff for the operations and maintenance of the completed PV power plant.

The Contractor follows Good Industry Practice, Prudent Industry Standards, and complies with all requirements included in the Project Documents and the Applicable Laws, Codes, and Standards.

References in these Employer’s Requirements to the Employer are interpreted as references to the Employer or its representatives, according to the Contract or any other Project Documentation.

Further details of the Contractor’s scope of works are defined in the section below, which sets out the minimum Project requirements. It is not intended to provide a complete list of activities to be performed but rather functional specifications, which serve as a guideline and do not detail interfaces between Subcontractors.

The words “including” and “includes,” or any variants of those words, are read as if followed by the words “without limitation.”

## Engineering and Documentation

The Contractor shall bring the conceptual designs to completion. The Contractor must review and updates all necessary engineering, construction, and installation drawings, specifications, quality control procedures, inspection protocols, and commissioning documents in accordance with Good Industry Practice and in compliance with Applicable Laws, Codes, and Standards relevant to the Works.

For all Works performed under the Contract, the Contractor shall establish and maintain a comprehensive computer-based Document Management System (DMS).

The Contractor must include transmittals with all submitted documentation.

The Contractor shall design the Works with full consideration of the Site’s environmental conditions, particularly potential seismic activity, wind, dust, humidity, rain, salt, and other corrosive substances present in the atmosphere and ground conditions.

Design and equipment selection must take into account both prevailing and extreme environmental and ground conditions on Site. The selection must ensure that equipment is reasonably protected from exposure to conditions beyond its rated design operating limits, as defined in the respective manufacturers’ operating manuals and relevant standards, such as IEC 60721-1:2002 (Classification of environmental conditions).

The Contractor shall provide a proposed Master Document List (MDL) for the Employer’s approval. This MDL covers planning, scheduling, HSE, quality control, design, manufacture, shipping, construction, installation, commissioning, and testing documentation. The level of detail meets the Employer’s expectations and aligns with the design documentation requirements, agreed document naming conventions, and submission timelines.

### Surveys, studies, and reports

The Contractor shall review and update all topographical, geotechnical, hydrological, and other necessary surveys and studies, in addition to those provided by the Employer, to execute the Works in accordance with Good Industry Practice and in compliance with all Applicable Laws, Permits, Codes, and Standards. Any surveys and studies provided by the Employer are treated on a non-reliance basis unless otherwise communicated. The Contractor shall evaluate such documentation and conduct any further studies and investigations deemed necessary—at their own cost within the Contract price—to accept ground risk.

Additionally, the Contractor must prepare and complete the following surveys, studies, and reports to enable a completed design:

* Structural analyses, including foundation, pile load, and pull-out testing, as well as mounting structure length-pile foundation calculations and length-pile modelling;
* Pull-out tests;
* Flooding and drainage studies to support the flood risk assessment, stormwater management plan, and erosion management plan for the Site;
* Seismic study;
* Ecological regeneration plan for re-vegetation, regeneration, and restoration of the Site’s ecosystem;
* Ground resistivity test;
* Lightning risk assessment;
* Fire risk assessment;
* Electrical studies including cable sizing, earthing, protection studies, load flow analysis with loss calculations and voltage profiles, short circuit calculations, and any other studies required for the Design Lifetime;
* Grid connection studies and information required by the Grid Operator, including Grid Code compliance studies such as network compliance analysis.
* Meteorological studies necessary for Plant design, including analysis of extreme weather conditions on Site;
* Energy Yield Assessment (EYA), as described in section 7.4;
* Transportation study/logistics and expediting plan for the Plant’s equipment, including details on Bill of Materials (BoM), purchase order submission dates, origin, manufacturing date, pre-shipment FAT dates, shipment, and estimated time of arrival (ETA).

The Contractor must also prepare any other survey, study, or report not listed above that is necessary for the proper execution of the Project, in accordance with the Employer’s Requirements, the Contract, Good Industry Practice, and all Applicable Laws, Codes, and Standards.

### Engineering and design

The Contractor shall be responsible for all engineering and design activities related to the Project, including but not limited to:

* Prepares design basis statements which need to be approved by the Employer before commencement of the next step in the process. The contractor allows the employer 2 weeks for these reviews.
* Provides lists, datasheets, and specifications for main components, equipment, materials, and accessories.
* Confirms that materials and components fabricated off-site comply with relevant specifications and standards.
* Develops detailed designs and presents the designs in a project design report. These include plant layouts from the conceptual design, design drawings, design reports, execution drawings, and equipment drawings. All control and instrumentation, electrical, civil and other needed designs need to be included. All design calculations need to be included. The designs are not limited to, but include the following:
  + Designs Plant control and protection schemes.
  + Designs electrical layout diagrams.
  + Designs all roads, stormwater networks, structures, inverters, overhead line foundations, and building foundations.
  + Designs the telecommunication system for the Plant and its connection to the public telecommunications network, along with all documentation related to instrumentation and Plant control engineering.
  + Designs the data management system.
  + All designs needed to ensure connection to the national grid.
* Provides routine test certificates according to SANS standards for step-up transformers to adapt the inverter’s output voltage.
* Provides routine test certificates for MV breakers in accordance with SANS standards.
* Prepares the operation and maintenance manual for the Plant, including manuals for the Main Equipment;
* Submits any other documentation necessary for the correct operation and maintenance of the Plant.

Appropriately trained, qualified, and experienced design teams are available to attend technical discussions with the Employer’s representatives.

The detailed engineering and design comply with the requirements of the Contract, including Applicable Laws and Regulations, Codes and Standards, and the technical requirements outlined in the Employer’s Requirements. The design achieves the following objectives:

* Guaranteed Performance Ratio;
* Optimises operation and maintenance of the Works;
* Ensures installed capacity at the Point of Connection (POC) does not exceed the maximum AC export capacity of 17.2 MW.;
* Maximises Project performance over its 25-year design life;
* Delivers a high-quality installation with maximum availability, as defined in section 7.1.

Table 1 Requirements – Capacities for single-axis tracking

|  |  |
| --- | --- |
| Estimated usable area [ha] | ~ 22.5 |
| Minimum DC Capacity [MWp] | 12.8 |
| Minimum DC/AC ratio | 1.15 |
| Minimum AC Capacity [MW] | 11.1 |
| Maximum Export Limit [MW] | 17.2 |

### Commissioning documentation

The Contractor must prepare all required documentation and manuals, ensuring full compliance with IEC 62446-1 and all Applicable Laws, Codes, and Standards. This includes, but is not limited to:

* As-built documents;
* Field Inspection Checklists (FIC);
* Commissioning test results for applicable Plant equipment, including:
  + PV Modules
  + Tracker system
  + String combiner boxes
  + Inverters
  + All electrical circuits (LV DC, LV AC, MV AC, auxiliary services circuits, communication system circuits, earthing system, etc.)
  + HV circuits/substation/reactive power compensation system
* Mechanical Completion Test results and commercial operation start-up/commissioning report;
* Factory Acceptance Tests (FATs);
* Site Acceptance Tests (SATs) and performance test results;
* Other commissioning test results as required by the Contract.

## Construction, Installation, and Commissioning

The Contractor is responsible for delivering the Works in accordance with the proposed Work Schedule and ensures that the Works are fully completed in line with the Contract, the Employer’s Requirements, Good Industry Practice, and all Applicable Laws, Regulations, Codes, and Standards. The Contractor provides all necessary resources, tools, equipment, and workmanship to perform the correct construction, installation, commissioning, and testing of the Project as required.

All Works, both individually and collectively, are certified by an appropriately qualified Engineer as compliant with Applicable Laws, Codes, and Standards (i.e., certificates of compliance).

The Contractor shall supply all materials, consumables, machinery, human resources, and mechanical equipment necessary for the Works. This includes, but is not limited to: tools, personal protective equipment (PPE), service vehicles, forklifts, cranes, lifting equipment, workshop tools, storage facilities, and office equipment.

### General infrastructure and utilities

The Contractor is responsible for, but not limited to, the following:

* Provides and installs all necessary signalisation on the Site and for Site access;
* Maintains 24/7 Site security from the moment access is granted until the Date of Completion, including installation of security systems, video surveillance, and guard posts, if necessary;
* Installs temporary lighting posts, if required;
* Provides first aid and medical facilities on Site in accordance with legislation and local regulations;
* Provides changing facilities for both sexes;
* Supplies electricity, water, and other required utilities during construction and commissioning;
* Constructs sheltered areas for eating, training, and meetings, appropriately sized for the number of workers;
* Provides communal kitchen and canteen services;
* Supplies shaded areas with fresh water;
* Installs temporary firefighting supplies and systems;
* Implements erosion and sedimentation control measures;
* Manages industrial effluent handling (e.g., concrete mixer cleaning water) and removal;
* Maintains and operates clean Site facilities, including change areas, ablutions, and common areas, in line with regulations. The Employer’s authorised personnel have access as required;
* Performs housekeeping and Site establishment;
* Installs emergency lighting and signage to enable safe evacuation in case of emergency;
* Secures laydown and temporary areas external to the Site with fencing, lighting, guarding, and other necessary materials and services;
* Provides and maintains a temporary car park for use by the Contractor’s, Subcontractors’, and Employer’s personnel;
* Constructs temporary roads, hardstanding, and parking areas;
* Provides telephone and uncapped high-speed internet connections to all Site offices (temporary and permanent) and other necessary locations;
* Establishes Site offices for the Contractor, including main offices for the PV Cluster and dedicated offices at each PV Plant Site;
* Provides dedicated, fully furnished, equipped (including air conditioning, heating, printer, fridge, microwave, drinking water, washing facilities, and toilets), functional, and ready-to-use Site offices for the Employer and its representatives. These offices accommodate at least four (4) people, are made available immediately after the Notice to Proceed, and are regularly maintained and cleaned by the Contractor at its own cost;
* Provides solid waste disposal facilities;
* Installs sanitary facilities and sewage disposal systems;
* Delivers catering services during construction, ensuring hygienic practices across all food-related processes: manufacture, processing, packaging, storage, transport, distribution, preparation, handling, sale, and delivery;
* Provides temporary storage facilities for spares until the warehouse becomes operational;
* Installs backup diesel generators and one stand-alone PV system to supply, as much as practically possible, the energy needs of temporary facilities.

All facilities are in place prior to the start of construction activities, equipped with internet connection, lighting, air conditioning, heating, and proper housekeeping. The Contractor ensures lighting and air conditioning from the outset, using temporary generators if necessary.

### Preparatory works

Prior to the start of construction, the Contractor shall perform all necessary preparatory works, including but not limited to:

* Creates, modifies, extends, or upgrades access routes required for the construction and operation of the Plant. These access roads are protected, maintained, and repaired if damaged during construction. A condition assessment is recommended prior to use;
* Installs fencing;
* Installs access control and security systems;
* Installs Site offices; and
* Installs infrastructure for the provision of utilities, such as electricity.

### Civil Works

The Contractor shall execute the scope of the civil works which includes, but is not limited to, the following:

* Performs infrastructure works, including rerouting, relocation, and dismantling of existing facilities such as foundations, piping, cabling, and ducts, where necessary;
* Carries out cut and fill operations, ground levelling, removal of roots, rocks, and other materials, and vegetation clearing in accordance with Project requirements, environmental authorisations, and all Applicable Laws, Regulations, Codes, and Standards;
* Conducts ground investigations;
* Implements soil improvement measures (e.g., bearing capacity enhancement, piling, compaction), as required;
* Procures all materials, construction plant, tools, accessories, and secondary equipment necessary for the proper execution of the civil works;
* Constructs the drainage system;
* Adapts and upgrades existing watercourses and/or crossings;
* Executes foundation works for trackers, string combiner boxes, inverters, power transformers, buildings, weather stations, security systems, fences, and any other structures or equipment requiring foundations, where applicable;
* Constructs ancillary and temporary buildings, including transformer and MV installations;
* Installs Site fencing and gates for both construction and operational phases;
* Builds access roads;
* Constructs internal roads for construction and operation, using road materials that minimise dust and have a low dustiness index throughout the Design Lifetime;
* Excavates trenches for electrical works, earthing, and telecommunications systems;
* Implements environmental Site management measures;
* Manages dust control;
* Constructs permanent buildings;
* Handles waste management, including off-Site disposal as required.
* Constructs buildings required for operation of the plant.
* Constructs a sewage connection with the sewage plant to service the toilet facilities constructed.

### Mechanical works

The Contractor shall execute the scope of the mechanical works which includes, but is not limited to, the following:

* Constructs mounting structure foundations (e.g., piling, pre-drilling, concrete pads if required), using galvanised materials with sufficient coating thickness to withstand Site conditions such as corrosive soil, salty air, dust, and chemical aggressiveness, for the full expected lifetime of the Plant;
* Installs complete support structures, including motors, controllers, and all associated components (e.g., drives, bearings, track controllers);
* Supplies and installs all accessories required to mount structures, cables, and PV modules (e.g., nuts, bolts, washers, lock washers, claws, clamps);
* Applies corrosion protection (e.g., cold galvanising paint) to damaged structures in accordance with the manufacturer’s guidance and design specifications;
* Installs string combiner boxes and associated cabling mounting arrangements, where applicable;
* Installs PV modules, optimised based on manufacturer-provided short-circuit current sorting, and in full compliance with the manufacturer’s recommendations and installation manual. Installation follows Good Industry Practice to minimise module breakage, which remains at the Contractor’s expense;
* Installs inverter stations and necessary cable connection arrangements;
* Provides and installs equipment and services for buildings;
* Constructs structures required for electrical and Control & Instrumentation (C&I) systems;
* Installs heating, ventilation, and air conditioning (HVAC) systems in all applicable buildings;
* Installs auxiliary systems, where applicable;
* Equips workshops, stores, and other facilities, including storage racking;
* Installs fire protection devices and equipment in accordance with all relevant Laws, Consents, and Codes and Standards;
* Installs a security fence, including one motorised main access gate connected to the O&M building for remote operation;

### Electrical works

The Contractor shall execute the scope of the electrical works which includes, but is not limited to, the following:

* Installs electrical equipment associated with the PV plant.
* Installation of PV module strings and string combiner boxes (if applicable)
* Installation of operational meters on LV AC side
* Installation of earthing and lightning protection systems.
* Lays cables in trenches;
* Installation of cables in trays, ladders, conduits and structural supports Segregation of AC/DC and control/power cables
* Labels each cable according to the labelling system on site
* Cable testing (Megger / IR / continuity) and provision of test results, compliance with SANS 10142-1, SANS 10142-1-2, 240-56227443, NRS 097-2-1 & applicable standards
* Follows all information provided in 240-56227443 Generation Requirements for Control and Power Cables for Power Stations Standard
* Supply the cable schedules
* Supply the cable layout
* Provision of OEM certificates and type-test certificates
* Implementation of safety lock-out and permit-to-work procedures
* Installs inverter stations, operational meters at the LV AC side of each inverter (one meter per inverter station), LV/MV transformers, MV switchgears, and auxiliary transformers;
* Performs cable connections at inverters, string combiner boxes (if applicable), LV/MV transformers, auxiliary transformers, and MV switchgears;
* Installs power supply systems for trackers;
* Provides electrical building services to all buildings, including LV auxiliary distribution boards for power, lighting, emergency lighting, ventilation, etc.;
* Installs the auxiliary supply system;
* Installs Site lighting in compliance with all Applicable Laws, Codes, and Standards;
* Provides emergency power facilities;
* Constructs the underground evacuation line from the Plant to its respective substation, in accordance with Project Documentation, Applicable Laws, Permits, and national Regulations and Codes;
* Installs any additional equipment required to meet Grid Code requirements at the Point of Connection (POC), such as reactive compensation equipment or harmonic filters.
* Provide the electrical wiring diagrams for all electrical works including the manuals
* Drawings to be provided in DGN format
* Designs and installs/moves a LV line that supplies the church and houses. The line is currently running through the site.
* Ensure all electrical works follow the latest revision of SANS 10142-1: The wiring of premises — Part 1: Low‐voltage installations
* The Contractor shall be responsible for electrical testing, commissioning, and energisation activities, including functional testing, protection coordination, system earthing verification, and SCADA integration checks. Commissioning shall only be performed under approved commissioning procedures and authorised switching personnel. Comprehensive as-built documentation, redlines, test certificates, record drawings, and sign-off sheets must be submitted to the Employer prior to energisation and final acceptance.

### Control and Instrumentation work

The Contractor shall execute the scope of the Control and Instrumentation (C&I) works which includes, but is not limited to, the following:

* Installs the Supervisory Control and Data Acquisition (SCADA) system, including all necessary licenses.
* Implements the Power Plant Controller (PPC).
* Installs telecommunications systems that comply to the (240-55410927) OT Cyber Security Standard
* Installs security protection systems.
* Installs meteorological stations.
* Install fire detection systems that comply to the (240-56737448) Fire Detection and Life Safety Design Standard.
* Construct server rooms that comply to the (32-894) Eskom Server Rooms and Data Centres Standard.
* Construct C&I Computer and Equipment rooms that comply to the (240-56355541) C&I Computer & Equipment Rooms Civil and General Building Requirements Guideline
* Lays communication cabling and fibre optics.
* Labels each cable according to the labelling system on site
* Follows all information provided in Generation Requirements for Control and Power Cables for Power Stations Standard (240-56227443).
* Supply the cable schedules.
* Supply the cable layout.
* Installs security and surveillance systems and equipment which include a complete CCTV and surveillance system.
* Installs monitoring equipment.
* Drawings to be provided in DGN format

### Buildings

All buildings shall be erected in accordance with SANS 10400, all other applicable building regulations, relevant building permits, and the preliminary and existing Project Documentation (in terms of surfaces, distribution, materials, and design concepts), unless a more restrictive requirement is specified in this section or in section 8, which takes precedence.

The Contractor shall install the following buildings for the PV Plant:

* A Control and Operation building, which includes a security room, operations room, server room, office space, meeting rooms, sanitary facilities, changing rooms, storage room/space, and other areas as required by HSE standards and local regulations. This building includes a nearby parking area with a minimum of five (5) parking spaces; and
* A Storage/Warehouse building with a minimum area of 130 m², equipped with racks and adequately sized gates.

All building platforms must be waterproof and suitable for the Site’s ground conditions for the entire Design Lifetime of the Project. Platforms must be elevated at least 0.25 m above the 1:100-year return period maximum water level, with special attention to cable entries, doors, and other vulnerable areas.

Sufficient clearance must be provided around all buildings to allow for future maintenance activities, such as equipment replacement and transformer access.

All buildings must be equipped with power, telecommunications (including uncapped high-speed internet), water, fire-fighting systems, offices, restrooms, and refectory facilities required for the O&M and security teams.

Thermal insulation materials must be incorporated into the building fabric to minimise heat gain and reduce HVAC system loads. A proper waterproofing system is applied to all buildings.

### Commissioning and Testing

The Contractor shall produce a Testing and Commissioning Plan and submit it to the Employer for acceptance at least two (2) months prior to the commencement of commissioning activities. Testing does not commence until the Employer approves the plan.

The Contractor undertakes, at its own responsibility and cost, all pre-commissioning, commissioning, and other tests necessary to demonstrate the quality and reliability of the Project, in accordance with the Contract, applicable norms (including IEC 62446-1), and all relevant Laws, Consents, and Standards.

The absence of defined acceptance criteria does not relieve the Contractor from its contractual obligations, including compliance with applicable Standards, the Employer’s Requirements, and proper design and installation of the Project.

The Testing and Commissioning Plan includes:

* Verification points during commissioning;
* Personnel involved;
* Records to be maintained.

The Contractor shall provide detailed reporting of all test results to the Employer.

The Employer reserves the right to be present during or to redo any inspection, control, test, or verification. These activities are at the Employer’s cost, unless defects are identified, in which case the cost is borne by the Contractor.

The Contractor shall conduct the commissioning/start-up process, including electrical and mechanical tests, as specified in section 5.2. A non-exhaustive list of testing criteria is included in the Testing and Commissioning Plan.

The Contractor shall ensure that the Testing and Commissioning Plan complies with the relevant Grid Code requirements and the testing requirements of the Contract, where applicable.

The Contractor shall assume full responsibility for:

* Testing the Eskom Connection Works to Eskom’s satisfaction;
* Handing over the Eskom Connection Works to Eskom;
* Rectifying any defects during the applicable warranty period, as defined in the Eskom Self Build Agreement and Eskom procedures.

In consultation with NERSA’s Renewable Energy Technical Evaluation Committee (RETEC), the Contractor proposes a full test programme to demonstrate compliance with all applicable Laws, Consents, Codes, and Standards. The Contractor meets the requirements of the Grid Code compliance assessment conducted by NERSA to achieve issuance of the Time for Completion Certificate by the Time for Completion.

The Contractor provides the final Grid Code compliance testing programme no later than three (3) months prior to the planned grid connection date, as defined in the Programme and with reference to the Eskom Budget Quote, if applicable. Additionally, a provisional South African Grid Code compliance testing programme is submitted to the Employer within 30 days of the Signature Date. For clarity, Grid Code compliance is required for the Early Operating Period and Taking Over.

The Contractor supplies all consumables and power required for testing and commissioning.

All testing and commissioning activities comply with:

* In-country Laws and Regulations;
* Project Documents;
* Project Agreements;
* Applicable Laws, Permits, and Codes;
* Employer’s Requirements;
* Manufacturer’s specifications (without voiding warranties);
* Standards;
* The Contract’s Quality Management Plan;
* The Contractor’s Testing and Commissioning Plan.

Testing and commissioning activities include:

* Factory Acceptance Tests (FATs);
* Material tests;
* Site Acceptance Tests (SATs);
* Installation checks;
* Functional tests;
* Commissioning Tests;
* Provisional Acceptance Tests;
* Final Acceptance Tests.

Inspection and testing are carried out at all stages of manufacture and installation to ensure the Works and the Project conform to the Contract and Project Agreements.

If grid interconnection works are delayed, the Contractor shall provide provisional energisation using a temporary generator, ensuring commissioning activities continue without delay.

The Contractor ensures that Provisional and Final Acceptance Tests demonstrate the Plant’s operational capabilities, and that the Guaranteed Performance Ratio and Guaranteed Availability Tests are fulfilled.

### Connection works

The Contractor coordinates and liaises with the HV Subcontractor regarding interfaces, battery limits, design inputs, commissioning, energisation, and Grid Code compliance for the Project.

The Contractor ensures full Grid Code compliance of the Project and obtains all relevant certifications as required by the latest version of the Grid Connection Code for Renewable Power Plants (RPPs) connected to the electricity Transmission System (TS) or Distribution System (DS) in South Africa, as well as the Eskom Standard for the Interconnection of Embedded Generation (240-61268576).

### Equipment

The Contractor provides all equipment, tools, and spares necessary to discharge its responsibilities in executing the Works, including commissioning. The Contractor is responsible for the loading, transportation, unloading, and on-Site storage of all supplied equipment, including PV modules, mounting racks, inverters, and all other required equipment.

### Labour

The Contractor provides appropriately trained, experienced, equipped, and protected competent labour resources for the proper execution of the Works.

The Contractor develops a mobilisation and training plan aligned with the schedule and sequence of the various construction and commissioning activities.

### Cleaning and waste management

Until the Date of Completion, the Contractor provides all necessary resources, equipment, and services to maintain clean, hazard-free work areas and waste management on Site, including but not limited to:

* Submits a Waste Management Plan in accordance with Applicable Laws, Regulations, Codes, and Standards;
* Keeps the Site and work areas clean and orderly during execution of the Works, and removes rubbish diligently. General cleaning of facilities is performed twice a week, and a certified legal waste management company verifies the removal of segregated waste from Site;
* Implements environmentally friendly measures such as reduce, reuse, recycle, and second-life waste management;
* Ensures that rubbish on Site does not pose any safety risks or hazards;
* Cleans equipment such as switchboards, panel boards, cabinets, enclosures, and LV/MV power stations prior to energisation and Final Acceptance;
* Ensures all installed PV modules are clean by the anticipated Date of Completion; and
* Handles disposal of rubbish and debris, unless otherwise instructed by the Employer.

### Maintenance before Provisional Acceptance

Until the Date of Completion, the Contractor maintains the Plant at its best capacity and performance, provides all necessary operation and maintenance (O&M) services, and ensures the security of the Site.

### Removal of temporary facilities

Unless otherwise agreed with the Employer, upon completion of the Works, the Contractor removes from the Site and any temporarily used areas all materials, construction plant and equipment, and temporary facilities not incorporated into the permanent Works. This includes all temporary services, screens, fences, buildings, rubbish, unused materials, storage tanks, temporary power distribution lines, wooden crates, planks, plywood used for equipment packaging, and all other temporary installations.

Burning or burying rubbish on or near the Site is not permitted.

The Contractor fills and dresses all holes and cavities created for its convenience and leaves the Site in a safe, tidy, and orderly condition to the satisfaction of the Employer.

Additionally, the Contractor ensures that all areas of the Plant disturbed during the Project are rehabilitated with grass or other naturally occurring flora in the area.

## Digitalisation

Eskom uses SAP for its Systems, Applications, and Products in Data Processing. The contractor ensures that all digitalisation, where possible, occurs within the SAP software product range. The Contractor maximises the use of digital tools for the delivery of the Works, including but not limited to:

1. Provides a PV module register that includes: module serial number, geolocation within the Plant, location in the module string, module string number, combiner box number (if applicable), inverter number, transformer number, and subfield number for each PV module. This register is stored on a cloud-based software platform (SAP) and is accessible to both office and Site personnel using standard devices.
2. Develops and provides a unified cloud-based software platform to the Employer for storing serial numbers, inspection data, test results, and other relevant metadata covering design and construction aspects of all components. All components and equipment are represented in a digital geolocation map, aiming to create a digital twin of the Plant.

# Design Data

## Introduction

This section sets out the design data for the Plant and is read in conjunction with all other parts of this document.

The design data is provided solely to assist the Contractor in making its own assessment of the Works. It does not claim to be all-inclusive, perfect, or to contain all necessary information. The Contractor conducts its own investigations, develops its own projections and conclusions, and consults its own advisers to independently verify the information provided.

Neither the Employer nor any of its representatives or advisers assumes liability for the completeness or accuracy of the information contained in, or omitted from, this document.

## Battery Limits

All terminal limit point connections are performed by the Contractor, unless otherwise indicated. The design of each connection is approved by the relevant parties responsible for supplying services up to the respective terminal point.

The Contractor liaises with the relevant parties to determine the location and details of all terminal points.

The anticipated terminal points for connections between the Plant and external services include:

* Access to the Site from Johannesburg via the N12 and N4 national roads;
* Point of Connection (POC), which is agreed upon by the Contractor, the relevant authority, and the Employer. The Contractor obtains all necessary permits. The POC is defined as the point in the grid where the Solar PV Energy Facility is connected.
* Water connection,
* Electrical infrastructure, as described in section 4.3;
* Telecommunication interfaces, as outlined in section 12.11.

Other battery limits required for the completeness of the Plant may arise during detailed design and are provided by the Contractor within the Contract price.

## Battery Limits With the HV Subcontractor

The battery limit is located at the MV voltage level within the Project’s substation.

The Contractor supplies, installs, terminates, and tests the MV circuits from the Plant to its respective substation, specifically to the MV switchgear located in the electrical room. The Contractor is responsible for performing the HV and MV tests on these circuits as outlined in section 5.2.6.2.

The HV Subcontractor handles the underground routing, including the construction of troughs and electrical raceways, for the incoming MV power cables from the Plant within the substation’s boundary fences only.

The Contractor supplies and installs the PV Plant’s Power Plant Controller (PPC) and coordinates with the HV Subcontractor during the detailed engineering phase to define space requirements for the installation of these cabinets.

The Contractor supplies and installs all patch cords and communication cables required to:

* Connect the substation control room to the Plant SCADA system via the patch panel cabinet;
* Connect power quality and metering equipment to the PPC;
* Connect the PPC to the patch panel cabinet.

The Contractor provides the make and model of the power quality and metering equipment to the HV Subcontractor in due time.

The Contractor is responsible for the supply, installation, termination, and testing of fibre optic communication cables between the substation and the PV Plant. The HV Subcontractor remains responsible for the underground routing, including the construction of troughs and electrical raceways, for the incoming communication cables within the substation’s boundary fences only.

## General Design Considerations

The Plant operates within the technical limits specified below and complies with all Applicable Laws, Regulations, Permits, and Codes and Standards:

* The metric used to evaluate the guarantee of Levelized Cost of Energy (LCOE) is the calculated cost per kWh (ZAR/kWh) based on the plant’s lifecycle CAPEX and OPEX compared against the guaranteed net energy yield and Performance Ratio delivered over the design lifetime.
* The minimum design lifetime is 25 years from the Date of Completion, without requiring major repairs or component substitutions;
* The Plant is designed to withstand the most extreme climatic conditions on Site, as further detailed in this section;
* The design takes into account the specific characteristics of the Site;
* All materials are proven to be suitable and sufficient for the minimum 25-year design lifetime;
* The manufacturer and, where possible, the type of equipment remain consistent across the Plant for all main equipment, including PV modules, trackers, DC string combiner boxes (if applicable), inverters, main DC and AC power cables, transformers, MV switchgear, LV/MV power stations, meteorological stations and components, CCTV systems and components, and monitoring system equipment;
* All electrical components are housed in component-specific enclosures, following the OEM’s recommended IP rating and considering the Site’s extreme climatic and environmental conditions;
* The Plant achieves high reliability through quality control and assurance during procurement, construction, and maintainability/operability;
* Equipment meets the minimum warranty periods specified in section 13;
* The Plant is designed to meet the guaranteed performance levels stated in the Contract;
* The Plant uses a 1,500VDC configuration;
* The mounting structure is adaptable to the Site’s topography to optimise solar irradiance on the plane of the array;
* The PV array is designed for use with either central or string inverters;
* If string inverters are used, both rows/tables of a tracker are connected to the same inverter;
* All equipment complies with SANS or equivalent international standards (IEC/EN/ISO);
* Any changes in technology or equipment suppliers, as per the Contract, require the Employer’s approval;
* The design accounts for replacement or overhaul of components with lifespans shorter than the Plant’s minimum design lifetime;
* The Plant design ensures protection of native animal and plant species;
* Equipment layout and arrangement provide at least two (2) escape routes for personnel in case of fire or other hazards during normal O&M procedures;
* Access systems to electrical equipment fully comply with relevant Standards, with particular attention to safety legislation and approved codes of practice;
* A lightning risk assessment is conducted in accordance with SANS 62305-2:2018, and a suitable lightning protection system is designed and installed per relevant Standards (e.g., SANS 62305). All elements that could cause severe unavailability events, as well as areas posing personal risk, are protected by the lightning system.
* The ability to expand the PV power plant and all the associated constraints needs to be documented and presented in a separate report.

## Plant Location

The site is located approximately 450 km north-west from Durban’s port, the largest seaport in South Africa, and approximately 160 km east of OR Tambo, the largest airport in South Africa. The Employer owns the Site and grants access to the Contractor. Access to the site from Johannesburg is provided via the N12 and N4 national roads, or alternatively directly via the N4 national road from Pretoria.

The Plant and any temporary facility used during the construction of the Plant (such as Site offices, workshops, and equipment laydown area) are located within the land plots shown in the respective general layouts provided in the Project Documents. The Contractor optimises the Plant layout within the Site.

The Contractor ascertains the nature and location and all conditions which may affect both the design and layout of the Plant. The Contractor is responsible for its own investigations to establish sufficient and accurate information to support its proposal in relation to the Site conditions. The Contractor performs additional surveys to re-evaluate the Site’s conditions that may affect both the design and layout of the Plant at its own cost. No claims are accepted by the Employer based on the accuracy or sufficiency of the assessment already carried out and provided.

The Contractor ensures a minimum clearance distance between the perimetral fence and the respective public roads’ axes of 5 m, and 3 m to the land registry limits of each Project area, unless a more restrictive indication by national or local regulations exists at a later stage.

The Contractor also ensures a minimum clearance distance between the perimetral fence and the land registry limits of each Project area of 3 m, unless a more restrictive indication by national or local regulations exists at a later stage.

## Climatic Conditions

The Contractor analyses the meteorological and environmental conditions on the Site, including the wind conditions (maximum wind speed and direction), extreme temperatures, and rainfall. The Contractor guarantees that the Plant is designed for safe operation and maximum performance across the entire range of meteorological and environmental conditions.

The mechanical and electrical designs of all equipment and systems consider operation under the most severe climatic conditions, adding a 2 ºC safety margin for temperature (-2 ºC for the minimum temperature and +2 ºC for the maximum temperature) and +5 km/h safety for wind speed.

The Contractor undertakes all necessary investigations and studies to identify the most severe climatic conditions expected on Site and defines the design criteria accordingly. The design conditions, at a minimum, comply with the following requirements:

* Minimum ambient temperature: -17 ºC
* Maximum ambient temperature: 55 ºC
* Maximum wind speed: 70 km/h

The Contractor may propose different design conditions to the Employer, provided the necessary evidence and supporting documentation for the Employer’s consideration.

The table below shows the meteorological conditions of the Site provided by the Employer for reference purposes only.

Table 2 Project meteorological conditions

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameters** | **Value** | **Units** | **Source** |
| Elevation: | 1626 | m | SolarGIS |
| Extreme maximum temperature: | 38 | °C | Visual Crossing |
| Extreme minimum temperature: | -17 | °C | Visual Crossing |
| Maximum daily precipitation: | 77 | mm | Visual Crossing |
| Maximum wind speed: | 52 | km/h | Visual Crossing |

## Site Terrain

The Project Site comprises several available plots with hardly any shadows and, in principle, suitable topographical features. A detailed topographical survey has been concluded and must be reviewed and updated where necessary by the Contractor to confirm the Site topography and assess far or near shadows in the energy yield calculations.

Earthworks across the Site may be necessary to level and prepare the terrain.

If the Contractor undertakes a topographic survey (if using drone(s), it allows a minimum level of accuracy as expected for its intended use) and submits the associated report and results to the Employer.

The Contractor also undertakes a utility services scan/survey of the Project Site to confirm the existence of any utility services such as water, sewage, telecommunications, etc., prior to any construction works taking place.

## Soil and Geotechnical Data

The Project Site’s geotechnical data and conditions are described within the respective Plant’s geotechnical assessment, which is provided on a non-reliance basis as part of the Project Documentation.

The Contractor undertakes a detailed geotechnical assessment at its own cost and submits the associated report and results to the Employer.

## Hydrology

The Plant is designed for minimum water consumption.

The Contractor ensures a minimum clearance distance between the perimetral fence and the respective stream margins of 5.0 m.

The Project Site’s hydrological data and conditions are described within the respective Plant’s hydrological impact assessment report, which is provided on a non-reliance basis as part of the Project Documentation.

The Contractor undertakes a detailed hydrological impact assessment and geohydrological survey and submits the associated report(s) and result(s) to the Employer.

The hydrological impact assessment is developed considering two different scenarios: (1) prior to PV plant construction, and (2) post PV plant execution, including the proposed drainage system. It focuses on the development of a flood risk assessment, storm water management plan, and erosion management plan to address potential issues of flooding and soil erosion.

## Lightning

The Contractor makes its own investigation of the lightning activity in the Project Site and surrounding areas. The Contractor undertakes a lightning risk assessment following applicable Standards (such as SANS 62305-2:2018) to inform the design of a suitable lightning protection system as per the relevant Standards (such as SANS 62305).

The Contractor submits a lightning risk assessment report to the Employer.

## Seismic Conditions

The Contractor makes its own investigation of the seismic activity in the area of the Site and designs the Plant accordingly.

## Archaeological Data

Archaeological and heritage surveys are conducted by the Employer as part of the Environmental Impact Assessment (EIA) process to confirm the incidence of items of cultural heritage significance and potential impacts of the construction and operation of the Project. These studies are shared as part of the Project Documentation through the Final EIA report (FEIAr) and Environmental Management Programme (EMPr).

The assessments undertaken do not identify any graves on the site. It is recommended that if archaeological sites or graves are exposed during development activities, they are immediately reported to the heritage practitioner so that an investigation and evaluation of the findings can be made.

Based on the assessments, it is not anticipated that the Project has direct or indirect significant impact on items of cultural heritage significance in the area. The Contractor, however, develops a chance finds procedure as per the requirements of the EMPr and recommendations of the specialist reports in case of any chance finds.

The Contractor complies with the requirements of the EMPr, the Environmental Authorisation (EA), and Applicable Law (including, but not limited to, the National Heritage Resources Act No. 25 of 1999).

## Biophysical Environment

Environmental assessments are carried out by the Employer, concluding that the Project Site is compatible with the construction and operation of the Project and with the conditions established in the studies.

The regional topography has a gentle slope toward the south and south-west, with slopes of less than 5%, and lies at a height of approximately 1620 to 1680 metres above sea level. The area of interest is regarded as a potential coal phase-out region.

The area receives about 696.92 mm of rain on average per year, mostly occurring from late October to February, peaking between December and January. The average daily temperature is 27 ºC during summer months and 5 ºC in winter months.

It is not anticipated that the Project has a significant impact on flora and terrestrial vertebrate species. However, the Contractor must comply with the recommendations of the specialist reports, and the requirements of the EMPr (and associated management plans including, but not limited to, the Alien Plant and Open Space Management Plan; Revegetation and Rehabilitation Plan; and Plant Rescue and Protection Plan), the EA, and Applicable Provincial and National Legislation.

## Potable- and Raw- Water Supply and sewage connection

The potable water supply and connection to the sewage plant for the PV Plant is designed and installed by the Contractor.

The Contractor ensures that all water use is metered and permanent water meters are supplied and installed.

The Contractor is responsible for conducting all investigations necessary to design the infrastructure needed to supply water to the Plant. The water supply system infrastructure is designed and constructed by the Contractor in compliance with Applicable Laws, and Codes and Standards.

The Contractor designs and enables the utilisation of a raw water supply from the Arnot Power Station’s water supply and evaluates treatment mechanisms for water to be used for cleaning the solar PV modules. Additionally, the Contractor designs and installs a suitably sized water storage tank system and associated pumping and infrastructure facilities to provide water for the O&M phase.

The Contractor installs any temporary infrastructure needed to source water during construction, subject to compliance with Applicable Laws, Permits, Authorisations, and Codes and Standards.

# Inspection and Testing

* Provides the Inspection Test Plan (ITP) and checklists for all construction activities at least two (2) weeks prior to the commencement of the associated works. The Employer indicates the items it wishes to witness, and the Contractor notifies the Employer sufficiently in advance.
* Submits the ITP/Quality Plan for the manufacturing of Main Equipment prior to the start of manufacturing. The Employer identifies the items it wishes to witness, and the Contractor provides advance notice accordingly. Hold points align with applicable standards and good practice.
* Completes all relevant Factory Acceptance Tests (FAT), Site Acceptance Tests (SAT), and any other tests in external laboratories, in accordance with the Contractor’s Quality Management Plan, Good Industry Practice, and the Employer’s Requirements. The Contractor informs the Employer in advance of the items the Employer has indicated it wishes to witness.
* Conducts regular site inspections (based on predefined ITP items or ad-hoc inspections) with the Employer and/or its representatives, providing sufficient advance notice.
* Carries out inspections with the Employer and/or its representatives during the transfer of systems from construction to commissioning.
* Performs inspections with the Employer and/or its representatives for the development of a punch list.
* Responds promptly to any queries or non-conformities raised by the Employer or its representatives.
* Submits quality testing reports for the Main Equipment, materials, and all other equipment.

## Construction

### Inspection Test Plan (ITP)

The Contractor submits to the Employer, at least two (2) weeks prior to the commencement of each construction activity, the Inspection Test Plan (ITP) for that activity. This submission includes the associated test procedures and inspection checklists to be used during implementation.

Upon receipt of the ITP, the Employer identifies the items it wishes to witness. The Contractor notifies the Employer of the scheduled dates for these items with at least five (5) days’ notice.

Each ITP item provides for sign-off by the Contractor and, where applicable, the Subcontractor, as well as confirmation of witnessing by the Employer.

The Contractor witnesses and signs off 100% of the ITP items, Quality Plans, and inspection checklists for all construction activities involving its Subcontractors.

The Contractor develops, at a minimum, an ITP for the following activities:

* Levelling and grading;
* Module mounting structure installation;
* PV module installation;
* String combiner box installation (if applicable);
* Trenches;
* Cable laying;
* Inverter station foundation;
* Inverter transformer foundation;
* Ring Main Unit (RMU) and LV panel foundation;
* Buildings;
* Site fence and gate;
* Roads;
* CCTV installation;
* Inverter installation and terminations;
* Inverter transformer installation and terminations;
* RMU installation and terminations;
* LV/Auxiliary panel installation and terminations;
* MV switchgear installation and terminations;
* SCADA installation;
* Meteorological stations installation;
* Earth mat installation;
* Battery and Uninterruptible Power Supply (UPS) installation;
* Diesel Generator;
* HV transformer;
* HV switchgear; and,
* OHL/UGL, if applicable.

The Employer may request additional ITPs depending on the specificity of the Project and the method statements provided.

Witnessing of ITP items by the Employer does not relieve the Contractor of any responsibility for defects or failures that may arise during the warranty period of any components, equipment, or systems associated with the Project.

The Contractor prepares inspection checklists and submits them to the Employer for review. These checklists are used by the Contractor, its Subcontractors, the Employer, and the Employer’s Representatives to control the main inspection points of each activity.

Each checklist describes the specific activities associated with inspections as defined in the field Quality Plan.

A minimum set of typical inspection checklists is provided, and the Employer may request additional checklists depending on the specificity of the Project and the erection methodologies.

* Checklist for material inspection;
* Civil clearing and grubbing checklist;
* Civil checklist for perimeter and internal fence installation;
* Civil checklist for Site levelling and grading;
* Civil checklist for pre and post concrete pouring (per element);
* Civil checklist for concrete curing;
* Civil checklist for backfilling works;
* Civil checklist for buildings (per building);
* Civil checklist brick masonry works;
* Civil checklist for plastering works;
* Civil checklist for painting;
* Civil checklist for fencing;
* Civil checklist for form works;
* Civil checklist re-bar works;
* Civil checklist for roads;
* Civil checklist for stormwater;
* Civil checklist for traffic and other signage;
* Civil checklist for cable trenching;
* Civil checklist for ramming post and pre-drilling posts, when required;
* Checklist for module mounting structure installation;
* Checklist for PV module installation;
* Checklist for setting out;
* Checklist for excavation;
* Checklist for DC Cable installation and termination works;
* Checklist for MV & LV cable installation and termination works;
* Checklist for DCB installation and termination works;
* Checklist for inverter installation and termination works;
* Checklist for transformer installation and termination works;
* Checklist for MV panel installation and termination works;
* Checklist for LV panel installation and termination works;
* SF6 Installation and termination works (if applicable);
* Weather station installation works;
* Checklist for plumbing works;
* Checklist for sanitary works;
* Checklist for building electrical works;
* Checklist for false ceiling works;
* Checklist for doors and windows fitment works;
* Checklist for flooring and tile fixing works;
* Checklist for gate fitment work;
* Checklist for DC cable IR and continuity test;
* Checklist for LV cable IR test;
* Checklist for MV cable IR test;
* Checklist for SCADA installation;
* Checklist for earthing system works – internal;
* Checklist for CCTV installation;
* Checklist for earthing system works – external;
* Checklist for Sites levelling and grading; and,
* Additional inspection checklists may be requested by the Employer depending on the specificity of the Project and method statements.

### Method Statement

The Contractor submits to the Employer a method statement for each construction activity at least one (1) week prior to the commencement of that activity. Each method statement describes the construction procedures, tools, machinery, QA/QC measures, and HSE (Health, Safety, and Environmental) considerations.

The Contractor does not proceed with any construction activity until the corresponding method statement is submitted to the Employer.

## Inspection and testing

### General

The connections to respective substations and materials shall be subject to inspection and testing during, and on completion of, the manufacture and erection of the Works to ensure compliance with the Employer’s Requirements, the requirements of the regulatory authorities, and to confirm the satisfactory functionality, operability, and acceptance criteria of the Plant have been achieved, including the performance guarantees.

In summary, the testing and commissioning of the Plant and transmission connection to the respective substation shall include, but not be limited to the following:

− Factory Acceptance Tests - inspection and tests at manufacturer’s works;

− Site Acceptance Tests;

− Inspection and tests during construction;

− Tests on Completion (Commissioning);

− Commissioning (Cold Commissioning);

* Visual inspection;
* Functional tests;
* Electrical safety tests.

− Grid Code compliance tests; and,

− Commissioning (Hot Commissioning).

Additionally, the Contractor shall undertake any tests as specifically required under the Contract documents and by the Project’s permits and consents.

The Contractor shall have the responsibility for all aspects of testing and commissioning preparations and execution, including the provision of procedures, temporary facilities, consumables, utilities, labour, special tools, measurement equipment, spare parts, etc. To the maximum extent possible, the on-Site tests will make use of the permanently installed instrumentation. This same instrumentation shall be suitable for use for the Performance Ratio tests.

It will be expected that the Plant commissioning and tests will follow the guidelines set forth in these Employer’s Requirements. The Contractor shall provide at least two (2) months prior to the commencement of the commissioning activities, testing procedures and protocols that need to be reviewed and commented on by the Employer. Additionally, the Contractor shall provide TOP documentation for the different systems at least two (2) weeks prior to commencement of the commissioning activities for the relevant system for Employer’s review. The Employer may call for additional tests it considers necessary.

The Contractor shall provide a proposed Inspection and Test plan covering the construction works. The plan shall identify all inspection points and reporting actions and have the Employer witness and hold points at both at the Site and manufacturers’ works.

Written advance notices shall be provided for all inspections and tests requiring the involvement of third parties and such notice periods shall in any case be no less than that required by statutory authorities or third parties (i.e., Grid Operator). The Contractor shall be responsible for coordinating any inspections and tests required by third parties. The Contractor shall make allowance for third parties (i.e., Grid Operator) to witness key tests and to receive copies of the corresponding data and reports.

The Contractor shall inform the Employer on the date it intends to synchronise the Plant to the Grid. At least 21 days written notice shall be provided.

The Contractor shall remain fully responsible for the operation, maintenance, and cleaning of equipment as necessary throughout the commissioning and testing period up to the Date of Completion. All test instrumentation shall be properly calibrated by the Contractor prior to testing and rechecked after testing. Valid calibration certificates shall be provided for all instrumentation to be used during the tests as part of the test protocol to be submitted to the Employer prior to the commencement of the commissioning.

The lack of an acceptance criteria shall not relieve the Contractor from its contractual obligations, such as compliance with the applicable standards/technical requirements or the proper design and installation of the Plant.

Once the component or system is charged, energised, or otherwise made live, the Contractor shall conduct further tests to demonstrate that the system and its constituent components function collectively as designed and in accordance with all the applicable standards and manufacturer’s specifications and guidelines.

If any portion of the Works fails under test, such further tests or re-testing shall be conducted to demonstrate the successful completion of such tests (and compliance with the Contract) by the Contractor. The whole costs of retesting, including costs incurred by the Employer in witnessing such (repeat) tests, shall be borne by the Contractor.

### Test Sequence

The erection, mechanical completion milestone, cold commissioning, and appropriate third-party tests and checks on the interconnection related systems shall have been completed by the Contractor prior to the application for energisation.

Tests to demonstrate interactive operation of components within the system shall also be completed prior to first energisation.

Grid Code compliance testing is to be undertaken as required by the Grid Operator and as appropriate and convenient during the commissioning and testing period, but, in any event, prior to the commencement of the Provisional Acceptance Tests. Further, the Provisional Acceptance tests shall only commence once the Plant has reached the satisfactory conditions for continuous uninterrupted operation.

For the systems as defined in section 3, Tests during Construction shall have been completed and the Mechanical Completion milestone achieved prior to the commencement of the commissioning activities (Tests on Completion).

Any test required to demonstrate compliance with the environmental requirements shall be also performed prior to the commencement of the Acceptance tests, or as agreed with the Employer and all relevant consenting authorities. The requirements of the environmental permits shall be complied with at all times during testing.

### General Test Notification Requirements

No later than fourteen (14) days’ notice shall be given to the Employer of all inspection and tests in order that the Employer may be present to witness the tests.

All inspections and testing shall be scheduled to commence during ordinary business hours, unless specifically agreed in advance by the Employer.

In general, the erection, commissioning, and functional test requirements are to be notified during daily and weekly erection/commissioning meetings held at Site; this shall include upcoming site inspections/test, where applicable.

No section of the Works shall be covered up without carrying out any test or inspection required under the Contract. The Contractor shall discuss and agree on the work which the Employer's personnel shall be entitled to examine, inspect, and/or witness of functional tests before it is covered up, consistent with the Employer’s Requirements.

### Safety measures

The testing and commissioning may only be performed by well qualified and trained personnel. Relevant PPE must always be worn.

The Contractor shall pay specific attention to electrical risks posed during the testing and commissioning works when connecting multiple power sources and potential circulating currents.

The following five safety rules must be managed and observed by the Contractor at any time under all circumstances, particularly for switching operations and for voltage disconnection:

* Disconnect;
* Secure against reconnection;
* Check for zero potential;

Connect to ground and short-circuit; and, Cover or barrier neighbouring live parts.

### Test Procedures and Reporting Requirements

The Contractor shall also submit detailed specific test procedures and commissioning procedures (and the associated testing protocols or checklists) for each test or series of tests described in the following sections and in accordance with the relevant codes and standards as detailed in the Contract. The Employer shall respond with written comments and the Contractor shall subsequently revise and resubmit the test procedure as per the Contract. The test procedure and revisions shall be referenced in the test notification.

The following information shall be included as a minimum in the test procedure:

* Objectives and scope of the test and definitions of the test boundaries;
* Acceptance criteria;
* Health and Safety procedures and implications for all parties on Site;
* Codes and standards to be used or referenced, particularly the following standards:

− Grid Connection Code for Renewable Power Plants (RPPs) connected to the electricity Transmission System (TS) or the Distribution System (DS) in South Africa, Latest Version;

− SANS 61724-1:2019 –- Photovoltaic system performance–- Part 1: Monitoring;

− IEC 62446-1 –- Photovoltaic (PV) systems – Requirements for testing, documentation, and maintenance - Part 1: Grid connected systems - Documentation, commissioning tests and inspection;

* Quality Assurance procedures proposed for testing;
* Test Duration and number of runs, starting and stopping criteria;
* Plant operating conditions, permissible modes of control and operational limits during the tests;
* Prerequisites and precautions for the conducting of the tests, including safety checks and Power Plant stability requirements;
* Methods of data collection, identification of instrumentation to be used for tests, sampling requirements;
* Test schedules showing major activities planned for performing all required tests;
* Sample calculations demonstrating how tests results will be corrected;
* Test report requirements;
* Test organisation including designation of test director, testing personnel operator responsibilities, communication schedule, witnessing and preparation of test reports;
* A list of all the required settings and configuring of all protective devices and alarms for that section of the Plant; and,
* Copies of the Contractor's check sheets for the pre-commissioning, commissioning, and testing of the Plant item or system.

The Contractor shall supply to the Employer as soon as practicable, but not later than two (2) weeks after a test or inspection has been conducted, an electronic copy of the preliminary test reports which shall contain details of each test performed and shall be prepared as required by Employer. Records, results, and calculations of all tests shall be provided.

The test report shall include as a minimum but not limited to the following information:

* Test procedure;
* Description of test conditions;
* Description of any deviations from the test procedure of unusual events which occurred during the tests;
* Summary of test results;
* Calculations with definition of terminology;
* Copy of raw data the Contractor has collected during the tests immediately following each series of tests, test data sheets;
* Copies of instrument calibration records; and,
* All information reasonably necessary to evaluate the test results.

Once the preliminary report is reviewed a final report shall be submitted to the Employer within fourteen (14) days of receipt of the Employer’s comments, including two (2) hard copies and an electronic version.

### Factory Acceptance Tests

All items under the Contractor’s scope of work shall be subjected to visual, dimensional, material, non-destructive, functional, and performance tests as applicable at the factory facilities. As a minimum the tests to be carried out shall be strictly in accordance with the relevant standards. All relevant material and works certificates shall be available at the time of test.

All electrical equipment shall be ‘routine’ and ‘type’ tested in the factory in accordance with the applicable standards. Type tests shall not be repeated if *bona fide* type test certificates of identical or similar (‘similar’ according to the definition of SANS/IEC) equipment are available.

The detailed testing procedures shall be agreed with the Employer during the detailed design phase, and shall include, but not be limited to, the following:

* MV switchgear, and,
* Relay control panels, battery chargers, SCADA/RTU & telecommunication panels.

The Contractor shall attend the FATs in person (or via Subcontractor(s)), and prior to the performance of the FATs the Contractor shall provide to the Employer all relevant FAT procedures, which shall include, at least, the following information:

* Test program (dates, location and duration of each test);
* Test standards;
* Type of inspection and tests;
* Reviewed design drawings/document relevant for the test’
* Material certificates that will be attached to the FAT report and technical data sheets relevant for the test’
* Methodology of tests’
* Check lists including process data to be recorded where applicable’
* Equations for process data where applicable;
* Description of the instrumentation to be used (including but to not limited to KKS code (or other Eskom defined system), type of instrument, measure range and accuracy) including calibration certificates of testing equipment;
* Forms of test records and test report template; and,
* Complete factory QA/QC dossier of the inspections performed prior to the respective FAT.

The Contractor shall submit a FAT report no later than ten (10) days after completion of each FAT. The FAT report shall include data as recorded, including valid calibration certificates (dating back no more than twelve (12) months for temporarily installed performance test instrumentation, unless a more restrictive validity period is imposed by the applicable reference standards), and at least, the following information:

* The type of test, applicable test procedure and test standards;
* The date and time of each test, including the start and completion time of the test;
* A description of conditions under which the test was conducted;
* A summary of the quality control procedures, instrumentation used and instrument; calibration instructions from the Original Equipment Manufacturer (OEM), historical and up to-date calibration certificates;
* A summary of test results;
* A comparison of test results to relevant contractual values where applicable;
* The conclusion from test results, including whether the acceptance criteria were met; and,
* The identification of any abnormal conditions presents during the test period.

Upon successful completion of each FAT in accordance with the Employer, a Factory Certificate shall be provided. The successful completion of all FAT shall be a condition precedent for the issuance of the Taking-Over.

#### HV and MV switchgear

HV and MV switchgear shall be factory tested as per SANS 62271 “Standards for high voltage switchgear and control gear”.

A certificate from an internationally reputable independent third party shall be made available to demonstrate that all equipment (and its component parts) has been fully type tested in accordance with the appropriate SANS/IEC Standards and the specified ratings. In the absence of satisfactory evidence, type tests shall be carried out by the Contractor. Type tests shall not be repeated; however, valid Type Test report & Certificates for offered switchgear shall be provided. Switchgear shall be supplied with all required documentation, spare parts lists, protection relay settings and drawings. The equipment shall be supported by ISO 9001 certified manufacturing processes and meet defined reliability, safety, internal arc and operational performance requirements.

Each switchgear system shall be routine tested, in accordance with SANS 62271 “Standards for high voltage switchgear and control gear”.

Internal Arc Classification (IAC): HV/MV switchgear shall be certified with Internal Arc Classification per IEC 62271-200, with arc fault containment and pressure relief directed away from operators and public walkways. Interlocking and Safety: Mechanical and electrical interlocking shall prevent unsafe operations, including racking of circuit breakers under load and closing of earthing switches onto live circuits.

SCADA / Remote Operation: Switchgear shall support remote supervisory control and indication, including status, alarms, protection trips, and interlocking conditions. Arc flash detection and indication (where applicable) shall be integrated and interface with MV protection and tripping schemes.

#### MV cables

MV cables shall comply with SANS 60502-2 / 60502-4:2013

A certificate from an independent third party shall be made available to demonstrate that MV cables have been fully type tested in accordance with the appropriate SANS/IEC Standards and the specified ratings. In the absence of satisfactory evidence, type tests shall be carried out by the Contractor. Type test shall not be repeated, however valid Type Test report & Certificates for offered cables shall be provided.

Routine tests shall be carried out on each type of manufactured cable. The number of lengths can only be reduced if approved by the Employer according to the agreed quality control procedures. The routine tests shall include but not necessarily be limited to:

* Non-electrical tests (radial dimensions, thickness of insulation, embossing and marking);
* Hot set test of insulation;
* AC high voltage test and/or spark test;
* Conductor resistance;
* Insulation resistance;
* Capacitance test measurement (for MV cables);
* Partial discharge test (for MV cables); and,
* DC test on outer sheath (for MV cables).

### Site Acceptance Tests

As far as applicable, the Contractor will carry out site acceptance testing for all Materials. Where materials can be tested on-Site, the Contractor shall not incorporate materials into the Work until site acceptance testing has been carried out. On arrival at the Site, and during the performance of the Work, all items of materials shall be inspected and tested by the Contractor as appropriate to ensure there is no delay in construction, installation, and commissioning arising from defects, damage and / or deterioration of parts. The Employer has the right to review the material reception report from the Contractor.

Materials reception and warehouse management procedure shall be issued by the Contractor as part of the Quality Plans. As a minimum criterion for all mechanical and electrical equipment received on-site, the following shall be checked:

* Identification and traceability data is provided;
* Equipment certifications and type test certificates are provided; and,
* Visual inspection shall be performed including packaging being undamaged.

### Inspection And Tests During Construction

The inspection and testing activities shall be performed in a logical and sequential manner, including the division of the Plant into different systems and sub-system, which shall undergo different quality control levels allowing for all items identified during the initial quality control levels to be traced through the entire quality control and testing process until they have all been completed as per the Contractor’s Scope of Work.

During the construction and erection period, the Contractor shall undertake all installation checks, preliminary mechanical and electrical checks, proving the integrity of all connections (mechanical and electrical), safety systems and verification that all plant is functionally complete.

Throughout construction, all incomplete work and deficiencies shall be recorded in a punch list, which latest version (i.e., only non-rectified items) shall be included in the TOP documentation.

Inspection and tests during construction shall include and not limited to the following:

* Trenching;
* Road works;
* Fence works;
* Foundations;
* AC & DC and control cabling;
* AC & DC boards and switchgear;
* Circuit Breakers;
* Current transformers;
* Voltage transformers;
* Disconnector and earthing switches;
* Surge arrestors;
* SCADA/RTU & telecommunication panels;
* Security system;
* Firefighting system;
* Earthing system;
* Lightning protection system; and,
* MV switchboards and RMUs.

In performing the inspection and tests during Construction, the Contractor must verify that all systems and components of the Plant comply with the Contract, and that all equipment has been installed according to their manufacturer’' installation manuals and guidelines.

For the avoidance of doubt, the tests during Construction shall not require any connection to the grid.

Successful completion of these tests together with the delivery to the Employer of the associated test reports or checklists is a requirement for the achievement of the Mechanical Completion milestone.

#### Trenches

The Contractor shall check the compliance of the following items with the civil works drawing:

Trench routing/alignment; and,

Position of the trench drainage traps.

The Contractor shall check the compliance of the following items with the trench drawing:

* Depth;
* Length;
* Width;
* Thickness of the bottom sand layer;
* Diameter, position and colour of the sleeves;
* Thickness of the top sand layer;
* Quality and composition of the backfill material;
* Presence, position, and colour of the warning net; and,
* Presence, type of material and size of the earth cable.

The Contractor shall check the correct installation:

* Sleeves have not been damaged; and,
* Connection between sleeves is fully tightened.

All trench excavation, bedding, laying of cables, mechanical protection, backfilling and warning tape placement shall comply with the applicable requirements of SANS 10198, SANS 10142-1, SANS 10299-2, NRS 089 and relevant Eskom construction standards.

#### Roads

The Contractor shall check the compliance of the roads alignment with the civil works drawing. Further, the Contractor shall check the compliance of the following items with the civil works technical specification:

* Length, width and thickness of the roads;
* Presence and type of the geotextile layer (if applicable);
* Size of the material (gravel, stones…); and,
* Completion of compaction.

#### Fences

The Contractor shall check the compliance of the following items with the fence technical specification:

* Type of fence;
* Dimensions of the fence;
* Mesh size;
* Thickness of the galvanisation on fence poles; and,
* Colour.

The Contractor shall check on the whole length of the fence:

* The fence has been founded and installed according to the drawing;
* The fence is not damaged;
* The fence is installed vertically correctly;
* Proper distance maintained between the ground level and the bottom of the fence;
* Distance between earth rods is correct;
* Depths of driving in of the earth rods is correct;
* Quantity of concrete on the rods foundations by a visual inspection;
* The gates have been installed vertically correctly;
* The opening/closing of the gates is correct; and,
* The locking/unlocking of the gates is correct.

#### Foundations

The Contractor shall check the compliance of the following foundation items with the drawings:

* Position;
* Length;
* Width;
* Depth;
* Thickness; and,
* Presence, type of material and size of the earth conductors.

For the respective concrete foundations:

* Compliance of the rebar framework with the bending schedules;
* Rebar specified minimum cover afforded to base and edge of foundation excavations;
* Quality of concrete through a visual inspection; and,
* Concrete cube test results.

#### DC Wiring

With respect to DC wiring, the Contractor shall:Verify cable identification is in place and correct for identification and durability;

* Verify condition of cable;
* Verify cables are landed and lugs are torqued to appropriate value in accordance with manufacturer’s data;
* Verify that all electrical safety certificates have been issued by the relevant authority;
* Verify that all cabling is installed as per design with service loops and cable protection conduits as a UV barrier;
* Cabling must not be exposed to the sun directly;
* Verify that all the cables are fastened at regular intervals and that no sharp edges prevail which may damage the cables; and,
* Verify that all cable transitions (e.g., above ground to below ground, etc.) are appropriately fastened using weather resistant jointing elements which are also rodent barriers for prevention of egress into the cable conduits.
* No DC wiring shall be energised or closed until all inspections, polarity checks, insulation resistance tests and documentation have been completed and accepted.
* DC wiring installation shall comply with the latest revisions of SANS 10142-1, SANS 10142-1-2, SANS 1507, IEC 62548, IEC 60364-7-712 and NRCS VC 8075.

#### Cabling

For the AC cabling, both LV and MV cables, the Contractor shall:

* Compare cable type data with drawings and specifications;
* Verify cable identification is in place and correct for identification and durability;
* Verify condition of cable; and,
* Verify cables are landed and bolted connections torqued to the appropriate value(s) in accordance with manufacturer’s data.
* AC cabling installation shall comply with the latest revisions of SANS 10142-1, SANS 10198, SANS 60502-1/2/4, NRS 089, and NRCS VC 8075.

#### AC Boards and Switchgear

With respect to commissioning tests for AC boards and switchgear, the Contractor shall:

* Inspect AC cabling and switches and verify that types, sizes and lengths are in accordance with the Agreement requirements and are correctly labelled and in line with respective diagrams;
* Verify lightning protection measures, if applicable;
* Verify voltage rating;
* Verify protection device setting and suitability; and,
* Verify protection device settings, trip curves, coordination and suitability for operating conditions
* Verify correct operation of interlocks (mechanical and electrical)
* Verify correct operation of control circuits, signalling and instrumentation
* Verify compliance to requirements and standards.
* Verify enclosure IP rating, mechanical condition and safety clearances
* Commissioning of AC boards and switchgear shall comply with SANS 10142-1, SANS/IEC 61439, SANS/IEC 62271, NRS standards and OEM technical specifications.

#### Power and Earthing Transformers

Contractor shall execute the following actions and checks, where devices are installed and/or where applicable:

* Visual inspection, of transformer condition and nameplate verification.
* Check correct earthing and bonding of transformer tank, neutral and structure
* Check transformer oil level and confirm suitability for energisation
* Check tightening torque of bolted connections after completion of all tests;
* Check oil leakages;
* Check oil level;
* Check of protection devices operation;
* Verify compliance to requirements, drawings, and standards
* Check of alarms and trip initiation (oil level, Buchholz, temperature, overpressure valve); and,
* Check (non) saturation of dehumidifying crystals and oil bath level.
* Transformer installation, protection and commissioning shall comply with SANS 780, SANS/IEC 60076 and SANS 10142-1.

#### Current Transformers

The Contractor shall verify compliance with the following items, including all requirements reasonably necessary to ensure full functionality and safety of the equipment, and shall not be limited to the listed items:

* Visual inspection including corrosion and alignment;
* Check unused secondary windings are short circuited and earthed;
* Check earthing;
* Completeness of installation and cleanliness of insulators;
* Check SF₆ pressure or oil level (where applicable)
* Check connections;
* Verify correct functioning with protection, metering and Scada circuits
* CT installation and commissioning shall comply with SANS/IEC 61869 series, SANS 10142-1 and OEM specifications.
* Check ratios and data sheet parameters;

#### Voltage Transformers

The Contractor shall check the compliance of the following items:

* Visual inspection including corrosion, alignment and nameplate verification
* Check unused secondary windings are open circuited and earthed in one end;
* Check correct earthing of VT secondary circuits and chassis
* Check tightening torque of all bolted electrical and mechanical connections
* Completeness of installation and cleanliness of insulators;
* Check oil level (where applicable)
* VT installation and commissioning shall comply with SANS/IEC 61869-3, SANS 10142-1 and OEM specifications.
* Check ratios, polarity and datasheet parameters against approved SLD and technical data

#### Disconnector and Earthing Switches

The Contractor shall check the compliance of the following items:

* Check correct grounding and bonding connections
* Check tightening torque of all bolted connections
* Completeness of installation and cleanliness of insulators;
* Check alignment, mechanical operation and interlocking functions
* Verify lubrication of main contacts and moving parts.
* Disconnector and earthing switch installation and commissioning shall comply with SANS/IEC 62271 and OEM specifications.

#### Surge Arrestors

The Contractor shall check compliance with, including but not limited to, the following items:

* Check grounding of supports;
* Check grounding of dischargers;
* Check grounding of counter;
* Check tightening of bolts; and,
* Completeness of installation and cleanliness of insulators.
* The Contractor shall check compliance, including but not limited to correct grounding of supports, dischargers and counters, tightening of bolts, cleanliness and completeness of installation, and compliance with SANS/IEC 60099-4, SANS/IEC 60099-5, SANS 62271, Eskom Standard 240-56356935, and all relevant OEM specifications.

#### Earthing

The Contractor shall check compliance, including but not limited to, the position of earth conductors and rods, dimensions and material type, visual verification of welding and joint integrity, and verification of earth bonding between structures and the earth grid through current injection, in accordance with SANS/IEC 60364, SANS 62305, SANS 725, EN 50522:2010, IEEE 80, Eskom Standard 240-134369472, and approved earth grid design calculations and drawings.

#### Security system

The Contractor shall check the compliance of the following items with the anti-intrusion drawings:

* Position of the CCTV cameras and perimeter floodlights which are integrated in the IDS functionality as described in the Employer’s Requirements;
* Mounting height of the cameras & floodlights support poles;
* Installation of the IDS along the full length of the perimeter fence (mounted on fence and buried along the outer boundary of the fence);
* Installation of the IDS across the full length of the gates;
* Installation of the intrusion/detection system on/off switch;
* Installation of magnetic contact switches at all perimeter gates and key entrances in the PV Plant; and,
* Ensure there are no blind spots.

The Contractor shall check the compliance of the following items with the anti-intrusion technical specification:

* Type and performance of the cameras; and,
* Type of IDS for the perimeter fence.

#### PV Plant SCADA system

With respect to commissioning tests for the SCADA system, the Contractor shall:

* Verify compliance to requirements and standards;
* Verify accuracy classes are within requirements and inspect calibration certificates; and,
* Verify that all electricity meters (input and output) and corresponding secondary circuits connections are sealed.

### Tests On Completion

The Plant shall be commissioned and tested in compliance with the Employer’s Requirements, internationally recognised codes and standards, and the current best commissioning practice of solar PV plants. The Tests on Completion shall include but is not limited to the following:

* Pre-Commissioning (Cold Commissioning);
  + Visual inspection
  + Functional tests.
  + Electrical safety tests.
* Grid Code Compliance test;
* Commissioning (Hot Commissioning):

− Security System Commissioning.

− Commissioning of Components and Systems (MV circuit breakers, Current transformers, Voltage transformers, MV disconnectors, Surge arrestors, MV cables, MV switchgear, Auxiliary transformers, AC &DC panels, Battery chargers & rectifiers, Protection devices, Fire alarm system, Lighting system, Diesel generator & other systems).

The Plant shall undergo full Cold and Hot Commissioning in accordance with Employer’s Requirements, Applicable Laws, international Standards, and best industry practice. Commissioning shall verify safe and reliable operation of all equipment, correct protection and interlocking performance, full SCADA and telecommunications integration, Grid Code compliance, power quality and performance tests, synchronization with the Grid, and emergency shutdown and backup power functionality. A reliability run and Performance Ratio test shall confirm stable operation before Provisional Acceptance.

#### Personnel

The Contractor shall procure the services of an Authorised Person (OEM Approved) during testing and commissioning of the PV Plant for all switching, linking, safety testing, and earthing operations.

#### Pre-Commissioning (Cold Commissioning)

The Pre-commissioning shall include, but is not limited to, the following:

* Visual inspection;
* Functional tests; and,
* Electrical safety tests.

The minimum required information is to be provided prior to commencement of the pre-commissioning tests, which shall include, but not be limited to, the following:

* Rated component capacity (DC and AC);
* Detailed design pack consisting of the following:

− Up to date SLD of the facility;

− Specification of overvoltage protection devices (current and voltage rating). Location, type and rating of overvoltage protection devices should be specified;

− Details of all LV and MV cables used in the substations on Site. This includes cable type, size, OEM, and length;

− A SLD detailing all earthing, lightning protection system, and details of the surge protection devices installed; and,

− A SLD detailing the AC isolators and over current protection devices, location, type, and rating.

#### Visual Inspection

The envisaged scope of the visual inspection will consist of, but is not limited to, the following:

* The Plant is free from any defect other than minor defects that do not exceed one (1%) of the Contract price, excluding those defects that have an adverse effect on the safety, operation, and performance of the Plant;
* The component has been installed and wired in accordance with the approved design and good practice, relevant codes, and OEM guidelines;
* Review the selection and usage of materials and proper installations appropriate with the environment in which the component is to be utilised;
* The state of readiness of the installation and of the setting of all protection and signalling equipment;
* The availability of electrical drawings, safety manuals and usage handbooks, and factory test reports or quality test reports from manufacturer, when applicable;
* Spare parts available on Site;
* Labelling, marking and identification of cables, fuses, panels cubicles etc.; and,
* Adequate protection afforded from live parts.

Visual checks are applicable on all the components that form part of the Plant, and shall include as a minimum the following parts:

* Foundations;
* Trenches, cabling, electrical boxes and protection devices;
* Monitoring System including any UPS;
* LV installation, including protection equipment;
* MV installation, including transformers and protection equipment;
* Interconnection Facilities;
* Security system;
* Grid connection line tower and assembly system;
* Equipment labelling in agreement with plans; and,
* Health and safety signage.

In addition to the aforementioned, the visual inspection shall verify the installation of the system components comply with the designs. This includes a review of the following:

* Durable, easily legible labels and markings;
* Durable, easily legible safety signs in accordance with local laws, regulations, and standards; Rating of components;
* Number of components;
* Distances, heights, and positions of components and systems in accordance with OEM guidelines and national standards;
* Verify sizing of cables, wires, and busbars are in accordance with the design; and,
* Tightening torque of bolts.

#### Functional Test

The two substations shall be subject to functional tests which shall include confirmation that components operate within the expected parameters as well as respond correctly to transient conditions.

#### Electrical Safety Tests

The electrical safety tests shall include, but not be limited to, the following:

##### LV System

* Low-voltage DC and AC cables shall be tested for insulation resistance in accordance with IEC 60364, IEC 60364-6, and SANS 60364-7-712;
* Continuity testing of all DC and LV AC cable;
* Verify the polarity and voltage rating of cables;
* LV protections and switchgear functional tests; and,
* Verification of (no) hot spots in electrical connections.

##### MV System

* MV protections and switchgear tests;
* Verification of (no) hot spots in electrical connections;
* Perform and record conductor continuity testing;
* Perform and record insulation resistance testing;
* Perform dielectric strength withstand testing;
* Perform VLF voltage withstand testing; and,
* Perform partial discharge testing.
* MV electrical safety testing shall comply with SANS 10198, SANS 60502-4, IEC 60229, IEC 60060, and applicable OEM testing standards.

##### Power and Earthing Transformers

* Insulation check (with measurement of insulation resistance) (primary to secondary – primary to earth – secondary to earth);
* Measurement of voltage ratio at each tap setting and vector group;
* Measurement of no-load losses and current;
* Measurement of short circuit impedance and load losses;
* Measurement of winding resistance at each tap setting;
* AC voltage withstand test;
* Tan delta tests performed on all bushings with test taps;
* Test tap changer manual and electrical operation;
* Dielectric tests;
* Functional tests (feedings and auxiliary circuits, ventilators, cooling fans, oil pumps);
* Sweep Frequency Response Analysis (SFRA)
* No-load test (when applicable).
* Transformer electrical testing shall comply with SANS/IEC 60076, SANS 780, SANS 10142-1 and applicable OEM test standards

##### Current Transformers

* Measurement of winding resistance;
* Ratio and Polarity Test;
* Turns ratio test;
* Check saturation curves of protection cores; and,
* Verification by injection of primary current.
* CT electrical testing shall comply with SANS/IEC 61869-2, SANS 10142-1 and OEM t

##### Voltage Transformers

* Measurement of winding resistance;
* Check voltage ratio; and,
* Verification by injection of voltage to the primary.
* VT electrical testing shall comply with SANS/IEC 61869-3, SANS 10142-1 and OEM test specifications.

##### Disconnector and Earthing Switches

* Check setting of limit switches;
* Check interlocking between earthing and disconnector;
* Perform electrical operations;
* Perform mechanical operations;
* Perform Functional tests;
* Measure resistance of main contacts.
* Testing of disconnectors and earthing switches shall comply with SANS/IEC 62271 and OEM test specifications.

##### Surge Arrestors

* Measure insulation resistance;
* Register number of discharges recorded by the counter before activation; and,
* Measure residual resistance before activation.
* Verify surge arrestor ratings (continuous operating voltage, discharge current class, energy rating) against design and nameplate
* Verify physical condition (porcelain / polymer housing, signs of cracking, tracking or contamination)
* Surge arrestor testing shall comply with SANS/IEC 60099-4, SANS 10142-1 and OEM test specifications.

#### Earthing

The Contractor shall supply to the Employer the results of all tests associated with the earthing system, including without limitation the results of:

* Earth resistance tests for each isolated PCU;
* Earth conductor continuity tests and resistance tests; and,
* Electrical continuity of the Project earthing (all metallic and electrical equipment).
* Full compliance with relevant local standards shall be verified by way of current injection tests and step and touch voltage measurements and analysis.
* The earth grid shall be tested at the Solar Plant Substation, the Eskom Switching Station as well Rietkuil Substation.

Validation tests shall be undertaken, including:

* Resistance and continuity tests of the earth grid;
* An ‘off frequency’ current injection test to determine the impedance and earth potential rise of the complete earthing system;
* Voltage gradient tests to determine the extent of earth potential rise contours; and,
* Step, touch, and transfer potential measurements throughout the Project to determine the performance of the installed earthing system under simulated fault conditions.

##### Grid Code Compliance Tests

It is the Contractor’s obligation to ensure that the design and installation of the Plant are in compliance with all applicable requirements and regulatory approvals, including national grid code requirements (Latest revision of Grid Connection Code for Renewable Power Plants (RPPs) connected to the electricity Transmission System (TS) or the Distribution System (DS) in South Africa, Version 3.1/January 2022, as may be amended from time to time). The responsibility is on the Contractor to support and drive all required permitting applications and the application process for grid interconnection and compliance in relation to the PV Plant and related Grid Connection system.

The Contractor will ensure all required hardware that is to be specified to allow for grid interconnection is included in its scope. All required SLD’s and layouts will be submitted as part of the design package in support of the grid interconnection application.

The Contractor shall coordinate and schedule witness testing with the Grid Operator and Employer, perform protection relay coordination and settings verification in accordance with Grid Code requirements, carry out and document SCADA, communication and remote-control integration tests, ensure post-energisation performance monitoring and reporting as required by the Grid Operator, provide training and handover to operational staff on Grid Code-related systems, and submit the Final Grid Code Compliance Certificate / Letter of Authority to the Employer

The results of the electrical grid tests shall be presented in a manner that will be acceptable to the Grid Operator and the Employer.

#### Commissioning (Hot Commissioning)

##### General

For safety reasons, Hot Commissioning activities shall only start when the earthing system commissioning has been completed, and the results accepted by the Employer. The commissioning tests are performed to determine and verify the proper operation of all component parts, subsystems, and systems constituting the works and of the Project in its entirety.

The Commissioning shall include, but is not limited to, the following:

* SCADA and monitoring system commissioning test;
* Security system commissioning tests;
* Protection systems/settings, in accordance with the agreed design and the requirements of the power interconnection system; and,
* Connection facilities commissioning.

The equipment shall be tested and commissioned using OEM approved procedures and trained personnel.

##### SCADA and Monitoring System Commissioning Tests

The SCADA and monitoring system shall be commissioned according to manufacturer specifications and industry best practice. Tests shall verify the correct operation of the SCADA system and meters, while verifying the correct data input logging from breakers and other components monitored by the system. The SCADA system shall be fully accessible remotely.

Every instrument required for the measurement of data shall have been previously calibrated and certified by third party experts. Calibration certificates shall be provided for the instruments at the time of test. The costs involved in preparation of calibration certificates shall be borne by the Contractor.

Prior to the Provisional Acceptance tests, every test instrument required for the measurement of test data shall be checked and recalibrated if necessary. This test shall verify that the data collected is correctly received by the SCADA System and can be used to produce any required performance or operation reports. Each row of data shall report the exact date and time in a suitable format.

The Employer shall review the calibration certificates of each sensor and all related documentation like certifications and installation manuals.

Formal approval and acceptance from the System Operator as to the correct interfacing of the SCADA system with their systems is required for Taking Over. All FO cable installations are to be compliant with SANS 10340-1/2:2006 Standards.

##### Security System Commissioning Test

Security system equipment shall be commissioned, tested, and calibrated by a certified installer of the equipment manufacturer using the manufacturer’s specified procedures.

Security system testing shall include testing of all operating modes and alarm conditions, including testing of:

* Cameras and dome cameras;
* InfraRed sensors / projectors;
* Lights;
* Sirens; and,
* Reaction time of security company.

A security system commissioning protocol or report shall be provided by the Contractor to the Employer.

##### Connection Facilities Commissioning

All tests prescribed by the manufacturers shall be executed in accordance with the prescriptions contained in the respective installation and commissioning manuals. The following list of tests shall be complied with by the Contractor whenever manufacturers’ tests are less restrictive than what is presented below.

###### MV Circuit Breakers

* Check grounding;
* Completeness of installation and cleanliness of insulators;
* SF6 pressure (where applicable);
* Functional tests;
* Tests for verifying opening / closing time;
* Measurement of power absorption of the coils; and,
* Measurement of resistance of the main contacts.

###### C*urrent Transformers*

* Check grounding;
* Completeness of installation and cleanliness of insulators;
* SF6 pressure or oil level (where applicable);
* Check connections;
* Check ratios and data sheet parameters;
* Turn ratio test; and,
* Verification by injection of current to the primary. *Voltage Transformers*
* Check grounding;
* Check tightening of bolts;
* Completeness of installation and cleanliness of insulators;
* Oil level; and,
* Check ratios and data sheet parameters. *MV Disconnectors*
* Check grounding;
* Check tightening of bolts;
* Completeness of installation and cleanliness of insulators;
* Verify greasing of main contacts and moving parts;
* Check setting of limit switches;
* Check interlocking between earthing and disconnector;
* Perform electrical operations;
* Perform mechanical operations;
* Functional tests; and,
* Measure resistance of main contacts; Surge *Dischargers*
* Check grounding of supports;
* Check grounding of dischargers;
* Check grounding of counter;
* Check tightening of bolts;
* Completeness of installation and cleanliness of insulators;
* Measure insulation resistance;
* Register number of discharges recorded by the counter before activation; and,
* Measure residual resistance before activation; MV *Cables*
* Check clamping;
* Check correct positioning and orientation of toroid CTs;
* Check grounding of shields;
* Dielectric test according to Laws and Standards; and
* Check compliance to SANS 1339:2020 Standard. *AC and DC Panels*
* Check correct mounting and fixing;
* Check correct grounding;
* Verify correct setting of protections; and,
* Functional tests.

###### Battery Chargers and Rectifiers

* Check correct mounting and fixing;
* Check correct grounding;
* Check correct installation of battery units;
* Check levels of liquids (if applicable);
* Check seal and filler caps (if applicable);
* Check proper functioning of HVAC system in the battery room;
* Check feeding voltage and phase sequence;
* Check output voltage (Facility and battery side);
* Check polarity; and,
* Check alarms and signals.

###### Protection Devices

* Check correct mounting and fixing;
* Check correct grounding;
* Check feeding voltage;
* Verify correctness of settings;
* Functional tests; and,
* Check rational and correct tripping of protections, including discrimination.

###### Fire Alarms, Lightning Protection System, Diesel Generator, and Other Systems

* Check correct mounting and fixing;
* Check correct grounding;
* Verify correct setting of protections; and,
* Functional tests. *Overhead line*
* Check setting out during construction of foundations;
* Check clearances;
* Check transmission pole alignment and fixing;
* Check structures assemblies, ties, clamps, conductor attachment;
* Check labelling;
* Check transmission pole footing resistance;

## Third Party / Notified Body Certification

The Contractor, at its own expense, arranges for a notified body or independent third-party organisation to certify that the design, materials, and construction of relevant equipment and components comply with regulatory requirements. These certifications cover fabrication at the manufacturer’s facilities.

The Contractor is also responsible for obtaining all necessary design and regulatory approvals from relevant national or local authorities, including any required signatures in accordance with Applicable Laws, Regulations, Permits, and Codes and Standards.

# General Technical Requirements

## General Technical Requirements – Standards and Codes

The Contractor ensures that the design, materials, engineering, fabrication, inspection, testing, certification, stamping, cleaning, painting, and erection—including all auxiliary facilities and systems—comply with the applicable provisions of the Standards and Codes specified herein. This applies to both Contractor and Subcontractor works.

In addition, the Contractor conforms to all applicable national and local regulations.

All referenced Standards and Codes are applied in their latest edition, including applicable addenda and code cases effective on the date of the Contract, unless otherwise stated. The application of subsequent addenda and code cases, published before or after the Contract date, is subject to agreement between the Employer and the Contractor.

The Contractor is responsible for procuring all applicable standards. Eskom standards form part of the tender package and are referenced throughout the documentation and in the Annexures.

Where equivalent national and international standards exist, national standards take precedence. However, international equivalents may be accepted, provided they do not materially affect the quality or performance of the Project.

Order of Precedence for Standards:

1. National Standards
2. International Electrotechnical Commission (IEC)
3. International Organisation for Standardisation (ISO)
4. European Standards (EN)
5. Other International Standards (e.g., ASTM, ENA, IEEE)

National Standards Include:

* SANS (South African National Standards)
* Roads Codes and Standards:
  + T.R.H Series (Technical Recommendations for Highways)
  + T.H.M Series (Technical Methods for Highways)
  + UTG Series (Urban Transport Guidelines)
  + COTO Standard Specifications for Road and Bridge Works
* Eskom Standards
* Local Authority Requirements, including Metsimahalo municipality codes for civil works and buildings

International Standards Include:

* ISO – International Organisation for Standardisation
* IEC – International Electrotechnical Commission
* ASCE – American Society of Civil Engineers
* EN – European Standards
* ANSI – American National Standards Institute
* DIN – Deutsches Institut für Normung
* NFPA – National Fire Protection Association

Other Applicable Standards and Instructions:

* Manufacturer instructions and warranties
* Quality Assurance documentation
* Health and Safety regulations, Security Plan
* Labour and union regulations
* IFC standards (if required by financial entities)
* Permits and authorisations
* Environmental and social assessments
* Site layout requirements
* Insurance policy requirements
* All other contractual standards and obligations

Recognised Recommendations Include:

* AASHTO, CMA, AGMA, ASME, AISI, ASHRAE, ASTM, AWS, AWWA
* CIRIA, HIS, ICE, IEEE, IPCEA, ISA, NACE, SAICE
* VDE, VDI, ITU-T, VGB
* Other internationally accepted national standards

The Contractor may propose alternative recognised Codes and Standards by submitting a report detailing the differences between the proposed alternatives and the specified standards. These proposals are subject to Employer approval.

A Bidder is not disadvantaged for proposing equipment, technology, or systems that comply with a more recent internationally equivalent version of a national standard, provided the differences do not adversely affect the Project’s quality or performance.

To avoid repetition, only national standards are listed. Equivalent international standards are accepted if the accompanying documentation (e.g., datasheets) demonstrates compliance.

If no applicable regulation or industry standard governs specific features of any item of the Works, Contractor or equipment manufacturer standards are applied, subject to Employer review and approval.

The Contractor ensures that all Subcontractors comply with the applicable Codes and Standards.

## Software

The Contractor uses only industry-recognised software systems.

Licences for all software systems are purchased by the Contractor and made available with step-in rights for future purchasers and operators of the Plant.

The Contractor provides all project-specific software, firmware, and operating systems developed for and applicable to the control and monitoring systems. The SCADA system includes advanced modelling approaches and techno-financial indicators that enable operators to predict failures, identify root causes of errors, and optimise Plant operation cost-effectively.

All software is fully documented and provided on a non-proprietary basis.

The Contractor provides a remote monitoring system and supervisory software with access to historical data.

Custom software required to adapt or configure control and monitoring systems is supplied by the Contractor, along with all necessary licences and duplicate software to enable remote operation of the Plant via desktop PCs or laptops, as required by the Employer.

## Staffing

The Plant is designed for operation and maintenance (O&M) with minimal staffing, consistent with safe, efficient, and reliable operation in accordance with good industry practice.

The Plant incorporates a sufficient level of automation to ensure that all operations—including start-up and shutdown—are performed from the PPC control room/building, without requiring local (field) operations.

## Factor of Significance

The Contractor takes into account the following factors, which are considered particularly important (in no specific order):

* Proven performance in Plant technology selection and configuration
* Operational simplicity, minimal staffing, and safety
* Maintenance ease, accessibility, simplicity, minimal staffing, safety, long service intervals, and use of standard tools
* High reliability and availability
* Design optimised for efficient and flexible operation
* Practical construction with maximum factory fabrication and testing, and minimal Site work
* Compliance with environmental requirements
* High level of automation

## Units of Measurement

All units of measurement and symbols conform to the Système International d’Unités (SI units) for basic and derived units.

SI units are used in all correspondence, documentation, calculations, drawings, and measurements. If non-standard units must be referenced, the SI unit is quoted first in brackets, followed by the non-standard unit.

All timestamped measurements are formatted using the correct UTM zone applicable to the Project Site location.

## Nameplates and Labels

Each nameplate includes the year of manufacture, manufacturer’s name, country of origin, type of equipment, KKS code (or other Eskom defined code), serial number, and main design data, along with any other relevant information that supports future maintenance and spare parts procurement. All this information need to be programmed into SAP.

Nameplates are securely attached to the equipment itself, or, in the case of small equipment, to an adjacent pipe or structure. “Securely fixed” means using stainless steel fixing screws or other approved methods that allow for easy replacement. The use of adhesives is not permitted.

All instruction plates, nameplates, labels, and warning signs are in English and remain suitable for the minimum Design Lifetime of 25 years.

Installation Requirements:

* Indoor installations: Use trifoliate materials unless the local environment requires otherwise.
* Outdoor installations: Use stainless steel or aluminium with a matte or satin finish.

Instruction plates, nameplates, and labels are installed after construction completion and before commissioning, on all equipment. Lettering is a minimum of 5 mm high, in uppercase.

Control and instrument panels, control centres, and junction boxes are labelled in accordance with the equipment identification system. Instrument and control panels have labels on both front and rear sides.

Each MV circuit includes unique identifier symbols on both the front and rear of the switchboard to prevent human error.

## Equipment Identification System

The Contractor submits to the Employer, for approval, an equipment identification system based on the RDS-PP (Reference Designation System for Power Plants – KKS system or other defined by Eskom). This system ensures unique identification for each Plant item.

The Contractor applies the equipment identification system consistently across all Contractor documents.

## Quality of Materials

All materials are new, unused, and in optimal condition. They are proven to be suitable and sufficient for the Project’s purpose.

Materials withstand operational temperature variations without distortion, deterioration, or undue strain that could affect Plant efficiency, reliability, or structural integrity.

All equipment is selected to suit local conditions and complies with the design data.

Material quality meets or exceeds the requirements of the most recent applicable National and International Standards at the time of Contract signature.

## Preservation

The Contractor preserves all Plant, equipment, and systems throughout all stages of the Works, in accordance with the Employer’s Requirements and OEM guidelines. This includes preservation during manufacturing, packing, transport, storage, construction, commissioning, start-up, and up to Provisional Acceptance.

Preservation records are maintained by the Contractor and made available for inspection by the Employer at any time.

## Padlocks and Keys

For safety and compliance with maintenance procedures and permits to work, all electrical isolation points and equipment—including switchgear cubicles and hand switches—are suitable for padlocking.

Each isolating device (e.g., power supplies, circuit breakers, isolators, earthing switches, control selector switches) is equipped with a padlocking system. No work on live equipment is undertaken without full compliance with the permit-to-work procedures.

The Contractor supplies all locking devices during the execution of the Works. All padlocks intended for use after commissioning (with two sets of keys) are provided by the Contractor.

Padlocks and keys are properly labelled for identification.

## Training

### General

The Contractor provides training to the O&M Contractor and the Employer in English. Training covers all equipment supplied under the Contract and addresses all O&M aspects necessary for safe and efficient Plant operation.

Training takes place early enough to allow the O&M Contractor to participate in the commissioning process, which is led by the Contractor.

Training includes both theoretical and practical components.

Within 90 days from the Notice to Proceed, the Contractor submits a complete training programme to the Employer, based on the guidelines and requirements specified in this section. The Contractor coordinates with the Employer to finalise the programme and ensures its integration with the Employer’s training and development agenda. The programme is agreed at least two (2) months before commissioning begins.

The Contractor arranges for representatives or approved personnel from OEMs and suppliers of PV modules, inverters, module mounting structures, LV/MV power stations, SCADA, and weather stations to deliver specific instruction as part of the overall training programme.

Training is conducted on Site. Training manuals are submitted one (1) month prior to the start of training.

Objectives of the Training Programme:

* Deliver comprehensive training to ensure high awareness, knowledge, and understanding of the Plant, its systems, and operational, instrumentation, electrical, and mechanical components
* Contribute effectively to the overall development of the O&M Contractor
* Ensure adequate training in codes of practice and safety rules
* Qualify each trainee to competently operate the Plant
* Enable the O&M Contractor/operator to perform corrective maintenance without voiding equipment warranties

Trainers are experienced commissioning engineers with subject matter expertise and are competent in adult education techniques, instruction methods, student evaluation, and support procedures to ensure successful learning outcomes.

Trainees undergo competency assessments at two stages: before commissioning begins and upon completion of training. The Contractor maintains comprehensive training records in a format agreed with the Employer. These records become the property of the Employer.

### Training Programme

Training is provided to approximately 10–20 personnel, including managers, engineers, team leaders, operations technicians, and maintenance technicians.

Each training module includes instruction in system fundamentals, start-up, normal operation, shutdown, and emergency procedures for all listed components.

Training covers the following disciplines:

* Operations
* Maintenance
* Electrical and Control & Instrumentation (C&I)
* Stock and spares control
* Safety
* Environmental
* Emergency response

Each module focuses on specific systems or Plant areas and includes:

* Task steps
* Standard performance criteria
* Required tools and equipment
* Safety requirements
* Reference materials (e.g., manufacturer’s manuals, O&M manuals, drawings, Plant documentation)

Initial training is delivered prior to commissioning to prepare operators to assist safely and effectively under the Contractor’s direction.

Additional subjects may be proposed by the Contractor to ensure complete understanding of Plant O&M.

### Facilities and Training Materials/Aids

The Contractor provides suitable facilities and accommodation on Site to support the training programme. If available, the Employer’s facilities may be used.

The Contractor supplies all training materials, including textbooks, manuals, and other required resources. Classroom equipment such as projectors, whiteboards/blackboards, and monitors is provided.

Training aids—including films, slides, interactive videos, software packages, and other materials—are supplied to support and enhance the training programme.

## Plant Operators

The Contractor remains responsible for commissioning, operation, and maintenance of the Plant up to Provisional Acceptance. The Contractor does not rely on the availability of O&M Contractor personnel to fulfil its duties during this period.

All Contractor personnel involved in O&M activities have prior experience in photovoltaic (PV) generation plants. All operators are trained in ORHVS (operating regulations for high voltage systems).

## Material Handling and Storage

### General

Materials are handled as little as possible, and always with care to minimise physical impact or exposure to harmful environments. Handling and storage comply with the manufacturer’s recommendations.

Damaged materials are separated from usable stock and placed in a designated quarantine area.

The following materials are not permitted in any Plant materials, components, or equipment:

* Asbestos or asbestos-containing materials
* Lead-based paints
* Isocyanides
* Non-compliant naturally occurring aggregates for reinforced concrete
* Polychlorinated biphenyls (PCBs)
* Chlorofluorocarbons (CFCs) or other ozone-depleting substances (unless unavoidable and pre-approved in writing)
* Carcinogenic materials (including hydrazine)
* Toxic inhalation hazardous chemicals (unless unavoidable and pre-approved in writing)
* Cadmium-plated nuts and bolts
* Any other materials known in the construction industry to be deleterious to health

### PV Module Handling and Storage

* PV module pallets are not stacked more than two (2) high unless otherwise specified by the manufacturer.
* Storage foundations are levelled and compacted to prevent subsidence.
* PV modules are handled by at least two (2) installers, holding the module at four (4) points.
* Modules are never placed face down or stacked horizontally; instead, they rest vertically against each other.
* Storage ensures protection from the elements per manufacturer guidelines.
* Modules are packed on pallets according to power nameplate and current sorting.

### Substructure Handling and Storage

* Substructure components are identified upon arrival and grouped by part number.
* Motors, gears, electronics, and water-sensitive components are covered with industrial-grade plastic (minimum 50 microns).
* Torque tubes are stacked flat and not balanced over objects that could cause bowing.
* Components are handled using a telehandler, forklift, or multiple installers, with individual lifting weights not exceeding 20 kg.

### Cable Handling and Storage

* Cables are stored out of direct sunlight, either under plastic or indoors.
* Care is taken to avoid damaging insulation during handling.
* Cables are stored on drums and installed using machinery that supports the drum during unwinding to prevent twisting.
* All handling and storage practices shall comply with manufacturer recommendations and applicable Standards (SANS 1507, SANS 10198, and relevant OEM manuals).

### Electrical Components Handling and Storage

* Electrical components, including string combiner boxes, are stored upright and covered with plastic or kept indoors.
* When transporting materials to the field, care is taken to avoid damage from road bumps.
* Sensitive components are not transported on vehicles without shock absorbers (e.g., forklifts).
* All handling and storage shall comply with manufacturer instructions and applicable codes and standards, including **SANS 10142-1, SANS 1973, SANS 1186, SANS 61643, and IEC 60664** (where relevant to electronics).

### Handling of Hazardous Materials

* Manual handling of hazardous materials and chemicals is minimised; automatic or remote-controlled equipment is preferred.
* Where manual handling is unavoidable, safe handling systems are implemented in accordance with local regulations.
* Residual exposure risks are mitigated through mandatory organisational safety measures, including the use of personal protective equipment (PPE).
* These requirements are specified in method statements and O&M manuals.
* Contractor shall ensure that hazardous area classification is implemented, Ex equipment is correctly selected and installed for each zone, and compliance is verified through certification, inspection, and approved documentation in accordance with relevant SANS 60079 / SANS 10108 requirements.

### Spare Parts

Spare parts are classified into the following categories:

* Maintenance spares and consumables: Items that the Contractor anticipates will be required during normal operation of the Plant.
* Strategic spares: Items that the Contractor anticipates may be required in the event of breakdowns that could jeopardise the performance, availability, or safety of the Plant.

The Contractor defines, procures, and provides the minimum stock of spare parts required for the operation and maintenance (O&M) of the Plant during the Defects Liability Period. This stock is determined based on:

* OEM recommendations
* Site location
* Lead times for procurement and delivery

The minimum stock of spare parts includes a defined level of Strategic spares and meets or exceeds the manufacturers’ recommendations. The Contractor provides written confirmation from each manufacturer regarding the recommended spare parts.

The spare parts strategy takes into account the specific requirements outlined in the Contract and any additional needs identified during the design and commissioning phases.

A minimum level of maintenance spares and consumables is recommended by the Contractor held at Site for each component at all times based on the OEM requirements. It considers the different systems and equipment of the Plant, such as DC String Combiner Boxes (if applicable), AC Junction Boxes, LV cabinets, communication system, CCTV system, etc.

#### Minimum Spare Parts Requirements

The Contractor ensures that the minimum stock of spare parts includes the following, based on OEM recommendations and the specific needs of the Project:

#### Photovoltaic (PV) Modules

* Minimum of 0.5% of the total installed PV modules.

#### Inverters (including cooling mechanisms)

* Central inverters: The Contractor requests the manufacturer to provide a recommended spare parts list, including unit codes, descriptions, and quantities, considering the number of inverters and Project location.
* String inverters: Minimum of 30 units, or as recommended by the manufacturer.

#### Tracker (Module) Mounting Structure

* Posts: 0.5% of total quantity
* Module mounting rails: 0.5%
* Torque tubes/beams: 0.5%
* Motors and drive-unit mechanisms: 0.5%
* Power supply sources: 0.5%
* Backup power supply sources: 0.5%
* Inclinometers: 0.5%
* Controllers/control units: 0.5%
* Structural components (bolts, nuts, washers, flanges, bearings, brackets, splices, etc.): 0.2%
* Complete tables: 0.5%

#### Single axis tracking Mounting Structure

* Posts: 0.5%
* Module mounting rails and cross beams: 0.5%
* Structural components (bolts, nuts, washers, flanges, brackets, splices, etc.): 0.2%
* Complete tables: 0.5%

#### Cabling and Connectors

* DC cables: 0.5% per size (mm²)
* AC cables: 0.5% per size (mm²)
* Communication cables: 0.5%
* Cable trays (if applicable): 0.5%
* LV connectors (MC4 male and female): 0.5%

#### Electrical Components

* PV String Combiner Boxes (if applicable): 0.5%
* PV String Combiner Box communication cards (if applicable): 5%
* LV fuses: 4%
* LV switchgear: 0.5%
* LV/MV transformers: 3 units
* MV switchgear/RMU: 3 units
* Auxiliary transformer: 1 unit

#### Monitoring and Control Systems

* Meteorological station: 1 unit
* Soiling station: 1 unit
* SCADA system: 0.5% of all components
* PPC system: 0.5% of all components
* UPS: 3% of total quantity

#### Security and Lighting

* CCTV system (cameras, poles, fixtures, etc.): The Contractor requests a manufacturer-recommended spare parts list based on system size and Project location. This list defines the minimum stock to be held on Site.
* Lighting: The Contractor requests a manufacturer-recommended spare parts list based on light types, quantities, and Project location. This list defines the minimum stock to be held on Site.

## Welding Requirements

Welding on Site is minimised, and all materials requiring welding are welded in a controlled factory environment whenever possible.

If welding is required on Site, it is performed in accordance with applicable international and local standards, including but not limited to:

* SANS 10238
* SANS 1400:2010
* SANS 3834 Parts 1–6
* SANS 6520 Parts 1 & 2
* SANS 15609 Parts 1–5
* SANS 15614 Parts 1–13
* SANS 17660 Parts 1 & 2
* BS-EN 1011-1:2010
* BS-EN 1708-1:2011

All welders and operators are properly trained and qualified in accordance with the applicable design codes and weld quality standards. Weld inspections comply with all Applicable Laws, Regulations, and Codes and Standards.

## Environmental Aggressiveness

The Contractor considers Site and subsurface conditions to prevent corrosion aboveground and underground, especially for outdoor equipment installations. Environmental requirements are incorporated following the Environmental Impact Assessment (EIA) submission.

The Contractor confirms the atmosphere and soil corrosivity category and designs protection measures in accordance with SANS 12944 Parts 1–8 for steel structures. Corrosion protection is designed for a minimum operational lifespan of 25 years, considering:

* Soil chemical testing results
* Humidity
* Wind loading
* Ambient temperature
* Soil aggressiveness
* Air corrosivity

During transportation, the Contractor ensures that equipment and protective treatments are not damaged, with packing and crating methods confirmed by the manufacturer. Any damage to paintwork or galvanising is repaired on Site. Surfaces are cleaned thoroughly before painting, in accordance with the paint manufacturer’s specifications.

Paint is stored in dry, covered conditions and is not used if stored for more than three (3) months, or six (6) months after the manufacture date.

Unless otherwise specified, galvanising is performed using hot-dip methods in accordance with:

* SANS 121:2011
* SANS 14713-2:2011

Bolts, nuts, washers, and other threaded fasteners are finished with centrifugal galvanised coatings per the same standards. Zinc thickness exceeds the minimum calculated thickness on all sides and parts, and local mean thicknesses below minimum are avoided.

All drilling, punching, stamping, cutting, welding, and burr removal are completed before galvanising. Any Site modifications to galvanised steelwork are repaired using an approved cold galvanising system, subject to Employer review.

Materials and coatings for all structures are selected based on soil chemical testing and designed for a minimum durability of 25 years.

The Contractor provides details of any special finishes, including those on aluminium or steel sheet components.

All ferrous metals are protected from corrosion in accordance with:

* SANS 121:2011
* SANS 14713-2:2011
* SANS 12944
* Or equivalent National/International Standards

Exposure conditions are suitable for the intended purpose and location of each structure.

Where paint systems are used for corrosion protection, the Contractor ensures full compliance with the manufacturer’s application guidelines. Each coat is sourced from the same manufacturer.

The Contractor submits full details of corrosion protection proposals for Employer review. Proper analysis is conducted to avoid galvanic corrosion due to contact between dissimilar metals, with justification provided if required.

All external coating systems are designed to be UV-resistant, based on the expected UV radiation spectrum at the Site.

The Contractor implements fauna protection measures for all equipment and materials that may come into contact with rodents or vermin. This includes:

* Cable sheaths
* Outdoor switchboards and DC boxes
* Outdoor inverters
* Transformer centres and/or switchgear buildings
* O&M buildings
* Substations

Protection measures comply with planning approval conditions and the environmental management plan.

The Works are adequately protected against frost damage, where applicable to the Site location.

## Carbon Tax Credits

All carbon tax credits for the Plant are owned by, and accrue to, the Employer.

## Renewable Energy Certificates

All renewable energy certificates for the Plant are owned by, and accrue to, the Employer.

# PV System Requirements

## Proven Technology

The Contractor ensures that all equipment and materials proposed for the Plant have a proven track record in similar service environments. Availability and reliability are considered equally important as net electrical output. Therefore, the use of prototypes or modified designs of proven equipment is not permitted.

This requirement applies to the following main equipment:

* PV modules
* Inverters
* String combiner boxes (if applicable)
* Transformers
* Module mounting structures

Module mounting structures and inverters are sourced from experienced and financially stable OEMs with a national presence and a strong track record.

Where equipment or components require approval by an independent certifying authority, the Contractor (or the OEM/Subcontractor) procures and bears the cost of such certification.

## Plant Layout

The Plant layout complies with the following requirements:

* Tracking systems: Minimum motion range of ±50°, with backtracking to reduce inter-row shading.
* Inter-row spacing: Minimum 3 m (horizontal module position), allowing access for cleaning vehicles.
* Maintenance access: At least 3 m wide unobstructed paths for light all-road vehicles.
* Perimeter clearance:
  + 3.5 m between PV arrays and perimeter fence
  + 5 m between perimeter fence and water streams
  + 3 m between perimeter fence and land registry boundaries
  + 5 m between perimeter fence and public road centrelines
* Inverter and cable routing: Optimised for lowest CAPEX/OPEX and maximum efficiency.
* Design standard: Complies with IEC TS 62738:2018 for ground-mounted PV plants.

The layout ensures:

* Ease of operation and maintenance
* Minimal crossover of services, cables, and access ways
* Sufficient laydown areas and lifting equipment (details provided to the Employer)
* Maintenance of non-critical systems without impacting Plant output
* Access for emergency response and major equipment transport
* Space for substations, transformers, switching stations, and grid connection facilities
* Environmental integration per the HSE File and Environmental and Social Management Plan
* Protection of native flora and fauna
* Use of suitably classified equipment in hazardous areas
* Full perimeter security fencing with emergency exits, gates, and lighting

## Energy Yield Assessment (EYA)

The Contractor submits a detailed Energy Yield Assessment (EYA), including a PVSyst report (version 8.0.18 or higher), based on:

* SolarGIS TMY data (provided by the Employer)
* Near and far shading files (defined by the Contractor using the Plant’s central coordinates)

If alternative meteorological data is used, the Contractor justifies its use and obtains prior Employer approval.

The EYA includes the following loss factors:

* Incidence angle loss
* Low irradiance loss
* Temperature and thermal losses
* Shading losses (mutual and external)
* Soiling loss (based on cleaning frequency stated by the Contractor)
* Mismatch and power tolerance losses
* AC and DC cabling losses
* Transformer and inverter losses
* Transmission losses up to the HV Contractor battery limit
* System technical unavailability (per Contract and Section 7.4)
* Annual degradation (per module datasheet)
* Rear shading factor (for bifacial modules)
* Auxiliary consumption
* Light Induced Degradation (LID)

The total auxiliary losses due to self-consumption do not exceed 1% of the Plant’s output.

If bifacial modules are used, the Contractor provides supporting documentation for the albedo factor used in the EYA.

The Contractor submits third-party documentation to support LID assumptions.

The EYA includes:

* P50 and P90 exceedance probabilities for each year over the 25-year Plant design life
* Uncertainty assumptions, including:
  + Resource data
  + Modelling
  + Irradiance variability

## PV Array Design

The Contractor undertakes the PV array design in accordance with the following considerations:

* Array stringing design is compatible with the inverter’s DC input operational range, including maximum and minimum voltages for Maximum Power Point Tracking (MPPT) and maximum open-circuit voltage (Voc). The maximum Voc is calculated using the minimum expected module operating temperature, without correction for radiation or its influence on cell temperature. Extreme minimum and maximum Site temperatures are considered.
* PV panels are securely fastened to the mounting structure frame in accordance with the manufacturer’s installation specifications, with appropriate protection against damage.
* Earthing of the array and mounting structure frame complies with National and International Standards for DC, AC, and PV power systems, including:
  + EN 50522:2010
  + Eskom 240-56356396
  + Eskom 240-75880946
  + SANS 10142-1:2021
* Junction/combiner boxes feature gland-secured cable entry and exit points.
* Cable terminals connected to junction/combiner boxes are crimped properly, and main DC cables are torqued to specification.
* All cables, inverters, buildings, and components are clearly marked with permanent labels that are durable for the minimum design life of the Plant (25 years).
* Each string combiner box includes a layout showing its location and number relative to the overall array.
* All array rows and PV tables are labelled with engraved labels indicating row and table numbers.
* All string combiner boxes are labelled with permanent markings denoting the associated string or subarray number, in accordance with as-built drawings and applicable standards.
* A lightning risk assessment for the Plant is conducted as per SANS 62305-2:2018, and a suitable lightning protection system is designed and installed in accordance with SANS 62305.
* For tracking systems, the minimum height above ground to the lowest point of the PV modules throughout the tracker’s motion range is considered in the design.
* For string inverters, the height of the inverter and its stand, canopy, or enclosure is designed to avoid shading on PV modules. A minimum clearance of 0.5 m between inverter structures and PV modules is maintained.
* The number of PV modules per tracker table is determined by the structure’s capacity. PV strings are not split between trackers or tables. Adequate spacing between modules is provided to allow for thermal expansion.
* The PV array design complies with IEC 62548:2016 – Photovoltaic (PV) arrays – Design requirements.

## PV Module Requirements

The PV modules are crystalline silicon technology, bifacial, and must have been installed in at least three (3) commercial plants of similar size (≥17.2 MWac) that have been in successful operation for a minimum of one (1) year.

As stated in Section 7.1, the following requirements are mandatory:

* PV modules must be Tier 1, as defined by Bloomberg New Energy Finance.
* Modules must have a proven track record and must be certified by one or more of the following reputable institutions:
  + DNV
  + TÜV
  + Bureau Veritas
  + IEC

Frameless PV modules are not permitted.

PV module warranty requirements are defined in Section 13.4 of the Employer’s Requirements.

The PV modules comply with the following technical specifications:

### Electrical and Performance Characteristics

* Positive power tolerance: Between 0 to +5 W or 0 to +3%
* Module efficiency: ≥ 20%
* Minimum cell temperature: -40 °C
* Operating temperature range: -40 °C to 85 °C
* System voltage compatibility: ≥ 1500 VDC
* Design lifetime: ≥ 25 years
* Nominal Module Operating Temperature (NMOT): ≤ 44 °C ± 2 °C (NMOT @800 W/m², 20 °C, AM 1.5, wind speed 1 m/s)
* Temperature coefficient: ≥ -0.37%/°C
* Light Induced Degradation (LID) loss: ≤ 2%

### Bifacial Module Requirements (if applicable)

* p-type bifacial module bifaciality factor: ≥ 70% ± 5%
* n-type bifacial module bifaciality factor: ≥ 85% ± 5%

### Safety and Compliance

* PV cells activate within the solar spectrum defined by STC in IEC 61215-1-1:2021
* Minimum Safety Class II compliance with:
  + SANS 60364-7-712:2018
  + IEC 60364-4-41:2005+AMD1:2017
  + IEC 60364-4-42:2010+AMD1:2014
  + IEC 60364-4-43:2008
  + IEC 60364-4-44:2007+AMD1:2015+AMD2:2018
  + SANS 61140
  + SANS 61204

### Mechanical and Environmental Requirements

* Rear junction box includes at least three (3) bypass diodes and IP67-rated pin-type “Multi-Contact” connectors or equivalent, with clear polarity indication. Connectors must not be interchangeable and must be rated for ampacity ≥ maximum series fuse rating.
* Independent PID testing and verification performed per IEC 61215-2:2021 and IEC 61730-2:2016
* Modules operate reliably under extreme climatic and environmental conditions for ≥ 25 years
* Certified for:
  + Suction pressure: ≥ 2400 Pa
  + Static mechanical load: ≥ 2400 Pa
  + Distributed mechanical load (front glass): ≥ 5400 Pa
* Active electrical components are insulated from the frame, rear cover, and front glass, with insulation withstanding 1500 VDC
* Factory-fitted cables are long enough for series interconnection
* Cable connectors meet IP67 rating per SANS 60529:2013 and safety requirements of SANS 62852:2020
* Front surface is protected with tempered glass and anti-reflective coating
* All modules and connectors are of the same type and from a single manufacturer

### Manufacturer Requirements

The PV module manufacturer **must**:

* Have manufactured PV modules for ≥ 5 years
* Operate the proposed factory for ≥ 2 years
* Have cumulative installed capacity > 1,000 MWp
* Have annual production capacity > 500 MWp
* Have supplied modules to ≥ 3 commercial projects of similar size (≥ 17.2 MWac) in operation for ≥ 1 year at bid submission
* Be certified to:
  + ISO 9001:2015
  + ISO 45001:2018
  + ISO 14001:2015

### Quality Control and Testing

The manufacturer and Contractor accept material control procedures and a production test plan covering:

* Raw material storage
* Solar cells and connectors
* Encapsulation materials (EVA, PO, POE)
* Rear cover (back sheet), sealants, front glass
* Framing, junction boxes, labels, RFID, packing materials

Transport of PV modules complies with IEC 62759-1:2022.

Third-party quality control and testing is accepted per IEC TS 62782:2016, with the third-party inspector holding:

* SANS 17020:2012
* SANS 17025:2018

### Additional Testing Requirements

The Contractor provides results for the following tests, conducted by a certified inspection company approved by the Employer as a minimum:

* Visual inspection, insulation test, wet leakage test
* Damp heat test (≥ 2,000 hours)
* Humidity freeze test
* Thermal cycling test
* PID test
* Mechanical load test sequence
* LID and LeTID tests

The Contractor also provides results of extended durability testing and LID/LeTID testing for the selected module type, performed to recognised standards by an independent third party.

### Required Certifications

The PV modules must hold valid certifications issued by reputable testing institutions in accordance with the following standards:

* IEC 61215 – Crystalline silicon terrestrial photovoltaic (PV) modules – Design qualification and type approval
* IEC 61730 – Photovoltaic (PV) module safety qualification – Part 1: Requirements for construction; Part 2: Requirements for testing
* IEC 62804 – Photovoltaic (PV) modules – Test methods for potential-induced degradation
* IEC 62790 – Junction boxes for photovoltaic modules – Safety requirements
* IEC 60068 – Environmental testing standards
* UL 1703 (if applicable) – Standard for flat-plate photovoltaic modules and panels
* ISO 9001 – Quality management systems certification for the manufacturer
* ISO 14001 – Environmental management systems certification for the manufacturer
* OHSAS 18001 / ISO 45001 – Occupational health and safety management systems certification
* SANS 61730-1:2016 (IEC 61730-1): Photovoltaic (PV) module safety qualification, Part 1: Requirements for construction;
* IEC 61730-2:2016: Photovoltaic (PV) module safety qualification, Part 2: Requirements for testing;
* SANS 61215:2015 (IEC 61215): Crystalline silicon terrestrial photovoltaic (PV) modules — Design qualification and type approval;
* IEC 61701:2020: Photovoltaic (PV) modules – Salt mist corrosion testing;
* IEC 62716:2013: Photovoltaic (PV) modules – Ammonia corrosion testing;
* IEC 60068-2-78:2012: Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state;
* IEC 60068-2-68:2012: Environmental testing — Part 2-68: Tests — Test L: Dust and sand;
* Module flash test data from manufacturer, measurement according to IEC 60904-1:2020 Photovoltaic Devices – Part I: Measurement of photovoltaic current-voltage characteristics;
* For bifacial modules, bifacial module flash test data from manufacturer, measurement according to IEC TS 60904 – 1-2:2019 Measurement of current-voltage characteristics of bifacial photovoltaic (PV) devices;
* IEC TS 62804-1:2015: Photovoltaic (PV) modules – Test methods for the detection of potential-induced degradation – Part 1: Crystalline silicon; and,
* CE Certification.

### PV Module Documentation, Labelling, and Installation Requirements

#### Manufacturer Documentation

The PV module manufacturer provides the following documentation and information to the Employer:

* Factory certificates
* Company (factory) business licence
* Quality Control Plan
* List of testing equipment (including serial numbers)
* List of appointed manufacturing workshops for each production Site
* Bill of Materials (BoM)
* Mandatory product certificates
* Packaging design

The manufacturer must also provide quality control records, including:

* Incoming Quality Control (IQC)
* In-Process Quality Control (IPQC)
* Final Quality Control (FQC)
* Outgoing Quality Control (OQC)

### Delivery and As-Built Documentation

Upon delivery of PV modules to Site, the Contractor submits post-production flash test reports for each PV module batch at STC in electronic format (Excel files).

As part of the As-Built documentation, the Contractor provides a summary spreadsheet containing:

* All PV module documentation
* Bill of Materials (BoM)
* Full installed capacity

### Installation and Sorting

PV modules are installed according to current sorting to minimise mismatch losses.

Installation complies with the PV module manufacturer’s guidelines. Any deviation from these guidelines must be agreed upon between the PV module manufacturer and the module mounting structure manufacturer. Written confirmation is provided by both parties that the installation method does not invalidate warranties.

These confirmations are submitted to the Employer for review and acceptance prior to installation.

### Nameplate and Labelling Requirements

Each PV module displays a permanent technical characteristics nameplate with the following minimum information:

* Manufacturer name
* Type or model number
* Serial number
* Terminal or lead polarity (colour coding acceptable)
* Maximum system voltage
* Safety class
* Date and place of manufacture (on label or traceable via serial number)

The nameplate is designed to last for a minimum of 25 years under high UV radiation and temperature conditions.

### Bifacial Module Testing (if applicable)

If bifacial PV modules are proposed, the Contractor submits the methodology for post-production performance testing of the rear side—both factory and on-Site—to the Employer prior to the start of production.

## DC Interconnections and Cabling

Purpose-designed, double-insulated solar-grade PV cables and safety connectors are used for all DC connections. These components comply with applicable National and International Standards and meet the following minimum technical requirements:

### General Cable Requirements

* All cables and connectors are rated for harsh climatic conditions, including high temperatures, UV radiation, rain, humidity, and dirt, for a minimum design lifetime of 25 years.
* Cable insulation material and routing methods comply with Site-specific restrictions.
* For bifacial PV modules, the maximum current from the rear side is considered in cable sizing. This includes worst-case scenarios combining:
  + Highest Site albedo
  + Maximum bifacial gain across tracker motion range (if applicable), sun geometry, and irradiance
  + DC cable routing shall ensure **segregation from AC cabling** to minimise electromagnetic interference and fault risk.
  + Cable management shall prevent mechanical stress, abrasion, sharp-edge contact, and excessive bending beyond manufacturer limits.
  + All DC wiring installations shall comply with **creepage and clearance distances** specified by OEMs and SANS requirements.
* Wires are sized to ensure the maximum DC voltage drop (including diode drop) between PV modules and inverters at full power complies with all applicable SANS Standards and Codes.

### Termination and Connection

* Cable terminations use suitable lugs and sockets, crimped properly, and passed through brass compression-type cable glands or equivalent.
* Tinned copper lugs are used for copper conductors; aluminium lugs for aluminium conductors.
* Bimetallic lugs are used when terminating aluminium conductors onto copper or brass terminals.
* All cables/wires are permanently marked with UV-resistant labels indicating type, place of manufacture, and date of manufacture.
* Cables have enhanced resistance to heat and fire, emit low smoke, and are halogen-free.
* DC voltage rating: ≥ 1,500 V

### Routing and Protection

* Above-ground wiring is secured to the PV module mounting structure using UV-resistant devices, avoiding contact with unfinished metal edges or direct sunlight.
* DC cabling is not routed above ground except when fastened along mounting structures.
* DC cable runs between structure rows are routed underground.
* String cables between PV modules and string combiner boxes/inverters:
  + Do not require armouring if directly buried
  + Must be protected by corrugated HDPE conduit from trench to termination point or up to 1 m above ground
  + Conduits are sealed to prevent water and animal ingress
* Cables between string combiner boxes and inverters:
  + Do not require armouring if directly buried
  + Must comply with Section 8.6
  + Both ends are protected by HDPE conduit and sealed with expanded foam spray or equivalent

### Labelling and Mechanical Protection

* All string and main cables are permanently labelled at both ends, indicating:
  + String inverter
  + String combiner box (if applicable)
  + String number
* Cables are fixed securely and do not bear mechanical load at terminations (strain relief is mandatory).
* Cables are tied or cleated to cableways using UV-resistant tie elements.
* Cables are arranged neatly, bundled where appropriate, and not fastened with conductive ties on single-phase cables.
* Cableways are selected and installed to minimise damage from mechanical stress (impact, abrasion, tension, etc.).

### Mounting Structure Integration

* Cables are securely fastened to the module mounting structure using suitable cable tie solutions.
* Cables avoid direct contact with sharp metallic edges.
* Cables are protected from direct sunlight using UV ducting where necessary.
* Plastic ties:
  + Must be UV-protected
  + Designed for cable fastening
  + Have a minimum design life of 25 years
* Metallic ties:
  + Must include edge protection to prevent cable damage
* Cable joints are not permitted under any circumstances.

### Standards Compliance

Where applicable, the Contractor adheres to:

* Eskom Field Instrument Installation Standard: Junction Boxes and Cable Termination (240-56355815)
* Eskom Field Instrument Installation Standard (240-56355754)

## DC Cable

The solar cable used for DC interconnections is unipolar electrolytic tinned copper, Class 5 (flexible), and complies with ZZ-F solar type cable specifications in accordance with:

* IEC 60228 (Conductors of insulated cables)
* SANS 10142-1:2021 / IEC 60364

### Minimum Technical Characteristics:

* Flame retardant: SANS 60332-1 and -3
* Halogen-free: SANS 60754-1:2020 and -2:2020
* Low smoke emission: SANS 61034-1/2 (luminous transmittance > 60%)
* Low corrosive gas emission: SANS 60754-2:2020
* Minimum lifetime: 25 years (IEC 60216-2)

### Alternative Cable Type:

H1Z2Z2-K 1.5/1.5 1 kV (1.8 kV) DC cable may be used, compliant with:

* IEC 62930:2017 / TÜV 2Pfg 1169-08 / UTE C 32-502

With the following characteristics:

* Flame retardant: SANS 60332-1 and -3
* Fire protection: EN 50305-9; DIN VDE 0482 Part 266-2-5
* Halogen-free: SANS 60754-1:2020
* Low smoke emission: SANS 61034-1/2
* Low corrosive gas emission: SANS 60754-2:2020
* Lifetime: 25 years
* UV resistance: SANS 62930:2021 and TÜV 2Pfg 1169-08

### For Central Inverter Applications:

AL XZ1 (S) 1.5/1.5 (1.8 kV) cable is used between string combiner boxes and central inverters:

* Insulation: Cross-linked polyethylene (XLPE)
* Outer sheath: LSZH polyolefin DMO1 (HD 603-1)
* Ambient temperature: -40 °C to +90 °C
* Short circuit temperature: 250 °C (5 seconds max)

### Additional Requirements:

* Derating factors are applied per applicable National Standards.
* LV cables are sized based on ampacity, voltage drop, and let-through energy.
* Colour coding:
  + Brown, Black, Grey, Blue (R, S, T, N)
  + Green/Yellow for earthing

Where applicable, the Contractor complies with:

* Eskom Field Instrument Installation Standard: Junction Boxes and Cable Termination (240-56355815)
* Eskom Field Instrument Installation Standard (240-56355754)

## LV (AC) Cabling

LV AC cabling complies with the Eskom standard (240-56227443)

### Minimum Technical Requirements:

* Conductor material: Copper or aluminium
* Insulation: XLPE or HEPR
* Standards compliance:
  + SANS 6282:2007
  + SANS 6283:2007
  + SANS 6284:2007
  + IEC 60502-2:2014
* Flame retardant: SANS 60332-1 and -3
* Design lifetime: ≥ 25 years
* Marking: Properly identified and labelled
* Operating temperature:
  + ≥ 90 ºC (normal)
  + ≥ 250 ºC (short circuit, 5 seconds)
* Withstands all electrical loads and through faults without insulation or screen damage
* UV protection: Manufacturer certification required
* Voltage drop: ≤ 1.5% between inverter and LV/MV transformer at full power
* Derating factors: Applied per applicable standards
* Colour coding:
  + Brown, Black, Grey, Blue (R, S, T, N)
  + Green/Yellow for earthing

Where applicable, the Contractor complies with the Eskom standards listed above.

## PV String Combiner Box

For central inverter applications, PV module strings may be combined in a string combiner box, which is sized according to the number of string inputs, power, and voltage.

### Minimum Technical Requirements:

* Material: Metallic enclosure with sun protection (plastic not accepted)
* Ingress protection: IP65 or higher
* Switchgear: Double-pole load break switch disconnectors (DC21B, SANS 60947-5-1)
* Door interlock switch
* Over-current protection: Fuses with disconnect bases on both positive and negative inputs
* Surge protection: PV-specific Type 2 surge arresters with appropriate discharge capacity
* Monitoring:
  + Single string current monitoring
  + SCADA and PPC system interface
  + Visual alarm in PPC room
  + Time-stamped I/O protocol for alarms
* Earthing: Bars connected to the Plant earthing system
* Ventilation: Lugs to prevent condensation
* Wiring: Fully labelled and colour-coded
* Cable entry: Only through bottom or sides
* Cable labelling: As per industry best practices

Where applicable, the Contractor complies with:

* Eskom Field Instrument Installation Standard: Junction Boxes and Cable Termination (240-56355815)
* Eskom Field Instrument Installation Standard (240-56355754)

## AC Distribution Panels

All AC distribution panels are equipped with:

* Appropriate functionality, safety, and protection measures
* Bus-bar arrangements of proper sizing for terminal connections
* Cable entry points fitted with appropriately sized cable glands for both incoming and outgoing cables
* Fuses and disconnectors rated for expected operating conditions (e.g., voltage levels)
* Environmental ratings suitable for Site conditions, in accordance with:
  + SANS 62208
  + IEC 60068-2-68:2012
  + IEC 60068-2-78:2012
* All metallic parts are properly earthed to ensure safe operation
* Panels are mounted to prevent direct sun exposure
* Miniature Circuit Breakers (MCBs) are monitored via an MCB status monitoring system, which includes:
  + Local controller
  + Control unit
  + Remote alarms
  + Remote display unit

All distribution panels are manufactured with sufficient working space, temperature suitability for Site conditions, and maximum current rating. Panels include separate cable and bus bar alleys.

Where applicable, the Contractor complies with:

* Eskom Field Instrument Installation Standard: Junction Boxes and Cable Termination (240-56355815)
* Eskom Field Instrument Installation Standard (240-56355754)

## Inverters

Inverters comply with manufacturer specifications for interconnection with other Plant components and are designed for continuous operation under extreme Site conditions.

### General Requirements

* Inverters may be central or string-type
* Earthing of the negative/positive pole is provided per PV module manufacturer requirements
* Inverters comply with Grid Code requirements, including:
  + Power factor control
  + Harmonic distortion
  + Voltage ride-through
  + Ramp rate control
* Inverters include filters to mitigate harmonic heating on MV transformers and upstream equipment
* Total Harmonic Distortion (THD): < 3%
* Reactive power compensation capability at night
* Automatic grid synchronisation
* Communication protocol compatible with PPC and SCADA systems, with timestamped I/O signals
* Display interface showing performance values and faults
* Active string monitoring for string inverters
* Earthing protection system connection
* Minimum two MPPTs per inverter
* Minimum European efficiency: 98%
* Maximum DC system voltage: 1,500 V
* IP rating:
  + Central inverters: ≥ IP54
  + String inverters: ≥ IP65
* Outdoor inverters are designed to withstand extreme conditions
* Indoor inverters are housed in stations with adequate airflow and cooling
* All conduits are sealed to prevent water and rodent ingress
* Inverters are mounted to prevent dust/water ingress and are shaded from direct sunlight
* Containerised inverter/transformer solutions include ventilation or air-conditioning to prevent derating
* Inverters are not installed under trackers when bifacial modules are used
* Inverters must have shelters to reduce sun exposure

### Manufacturer Requirements

* Inverters and manufacturers have a proven track record in commercial international projects
* All inverter types and models have been operational in at least three commercial plants totalling ≥ 200 MWac, with ≥ 99% technical availability over 12 consecutive months
* All inverters are of the same type and from a single manufacturer

### Manufacturer Certification

* Manufacturer has produced inverters for ≥ 5 years
* Cumulative installed capacity: > 1,000 MWac
* Annual production capacity: > 500 MWac
* Supplied inverters to ≥ 3 non-recourse financed projects in the past 2 years

A letter of confirmation certifying compliance with these requirements is issued by the inverter manufacturer and submitted to the Employer.

### Applicable Standards

Inverters comply with the following standards:

* SANS 60529:2013 – IP protection
* SANS 62109-1 / IEC 62109-2 – Safety of power converters
* SANS 62103 / EN 50178 – Equipment safety and protection class
* SANS 61643-11/-12 – Surge protection
* Anti-islanding protection
* CE Declaration of Conformity
* DIN VDE 0126-1-1
* SANS 61000 series – EMC guidelines
* IEC 61557 – Electrical safety
* Grid Operator protection coordination requirements

### Manufacturer Facility Certification

* ISO 9001 – Quality Management Systems
* ISO 14001 – Environmental Management Systems

# Civil Engineering and Building Works Requirements

The Contractor shall be responsible for the design, procurement, and construction of all civil works associated with the Project. Civil works include, but are not limited to, the following:

## Site Investigations and Surveys

Conduct all required investigations and surveys, including:

* Topographic survey and utility services survey;
* Geotechnical studies (field and laboratory tests);
* Hydrological and geohydrological studies, including flood risk assessment and stormwater management;
* Structural analyses and tests, including foundation, pile load, and pull-out tests (POT);
* Seismic study;

The Contractor shall review, verify, and update all surveys and studies provided by the Employer on a non-reliance basis, performing any additional investigations required to execute the Works in accordance with Good Industry Practice and Applicable Laws, Permits, Codes, and Standards. The Contractor bears full responsibility for ground and geotechnical risks within the Contract Price.

## Site Preparation and Earthworks

### General

The Contractor shall be responsible for carrying out all site preparation and earthworks required for the proper execution of the Works. These activities shall ensure suitable conditions for the installation of PV module mounting structures, substations, access roads, and other infrastructure.

When excessive differences in existing ground levels are identified in the topographical survey, the Contractor shall execute the necessary earthworks within and around the Site to achieve the required formation levels. Slopes across the Site shall comply with:

* The PV module mounting structure manufacturer’s requirements;
* The design of access and internal roads; and
* Optimised drainage and layout configurations.

Earthworks shall be minimised and cut-and-fill volumes shall be balanced as much as practicable to reduce the need for importing or disposing of material.

### Site Clearance

Prior to the commencement of construction works, the Contractor shall clear the Site of all rubbish, debris, vegetation, building rubble, and unwanted materials. All cleared materials shall be removed and disposed of in accordance with Applicable Environmental Legislation and through licensed disposal contractors approved by the local authorities.

### Excavation, Filling, and Compaction

* Excavation: All excavations shall be carried out to the lines, levels, and grades shown on the approved drawings. Excavated materials suitable for reuse shall be stockpiled and classified in accordance with the Soil/Material Management Plan.
* Filling and Compaction:
  + Filling for foundations shall be executed in layers not exceeding 250 mm, compacted to at least 98% of maximum dry density at optimum moisture content in accordance with SANS 1200 and SANS 2001 standards.
  + For general backfilling and platform formation, compaction shall not be less than 93% of maximum dry density unless specified otherwise.
* Balancing Cut and Fill: The Contractor shall strive to balance cut and fill to minimise off-site material movement. Surplus excavated material not reused shall be disposed of in compliance with Applicable Laws, Regulations, and Codes and Standards.

### Levelling, Grading, and Drainage

Levelling and grading shall be designed to facilitate free drainage of the Site while maintaining stable slopes.

* Cut and fill slopes shall be clearly indicated on drawings in H:V gradient format.
* Substation platform gradients shall comply with Eskom Distribution (MOU) requirements.
* Additional imported fill, where required to achieve proper drainage, shall be of suitable quality and verified by geotechnical testing.
* Finished surfaces shall be compacted and graded to direct surface water away from foundations, structures, and roads.

A temporary site drainage system shall be implemented during construction, including settlement or attenuation ponds and, where required under the Environmental Authorisation (EA) or Environmental Management Programme (EMPr), oil interceptors and wheel wash facilities. Contaminants in water shall be removed prior to discharge, and extracted materials shall be disposed of at a licensed facility. These requirements shall be reflected in the Stormwater Management Plan.

### Flood Protection and Finished Levels

Finished ground floor levels for all technical and non-technical buildings or enclosures shall be:

* At least 250 mm above the 1:100-year return period maximum water level, or
* At higher levels where required by the Flood Risk Assessment or Hydrological Impact Assessment.

The Contractor shall implement the recommendations of the hydrological studies and comply with SANS 10400 for finished levels and drainage design.

### Topsoil Management and Environmental Restoration

The minimum layer of topsoil, as defined in the geotechnical report, shall be stripped and stored separately for reuse in landscaping and environmental restoration within the Site perimeter.

* Topsoil shall not be used as fill material or in foundation works.
* Stored topsoil shall be protected from contamination and erosion.
* Following completion of construction, topsoil shall be respread over designated areas for re-vegetation in accordance with the Ecological Restoration Plan.

### Platform and Bearing Capacity Design

Where platforms are required due to earthworks, including access road embankments and substation pads, the Contractor shall:

* Design platforms to achieve the required bearing capacity for foundations, equipment, and vehicular loads;
* Base designs on the geo-mechanical parameters obtained from the approved Geotechnical Study; and
* Verify in-situ compaction and bearing through field density and plate load testing as necessary.

### Material Classification, Processing, and Disposal

All excavated materials (for reuse or disposal) shall be stockpiled prior to testing and classification.

* Unacceptable materials shall be processed—mechanically, chemically, or otherwise—to render them suitable for reuse, where feasible.
* Contaminated materials shall be classified and disposed of at licensed facilities, in accordance with Environmental Legislation and with the Employer’s written agreement.
* The Contractor shall provide documentation verifying the source and chemical composition of imported materials, confirming they are free of pollutants.

### Temporary Surfacing and Construction Access

During construction, the Contractor shall:

* Re-dress working areas with free-draining granular material to ensure efficient movement of personnel and vehicles;
* Maintain temporary surfacing in good condition to prevent construction delays and water accumulation; and
* Provide adequate laydown and hardstanding areas for equipment storage, maintenance, and vehicle manoeuvring.

## Roads and Hardstanding Areas

### General Requirements

The Contractor shall design and construct all internal and external access roads required for the construction, operation, and maintenance of the Plant in accordance with the following standards and requirements:

* Eskom Standard 240-170000918 – Design for Maintenance Vehicle Access in and Around Substations;
* SANS and COLTO standards for road construction and compaction; and
* Good Industry Practice applicable to utility-scale solar and substation infrastructure.

All roads shall be designed and constructed to ensure safe, reliable operation for construction and maintenance vehicles over the 25-year Plant lifetime.

### Responsibilities

The Contractor shall be responsible for the design, construction, testing, and maintenance of all roads and hardstanding areas within its scope, including:

* Permanent and temporary access roads up to the Site boundary (as applicable);
* All internal roads within the Plant;
* Parking areas and laydown zones; and
* Vehicular circulation and hardstanding areas in and around the substations.

The Contractor shall liaise with local authorities and relevant stakeholders to ensure continuous and secure access to the Site during both the construction and operation phases.

### Design Criteria

Roads shall be designed to accommodate the heaviest transportable component, being a 20 MVA transformer, and other heavy construction and maintenance equipment.

Road structural design shall be supported by a geotechnical investigation, including California Bearing Ratio (CBR) testing of subgrade and basecourse materials to evaluate mechanical strength.

The Contractor shall submit design wheel and axle loads, turning radii, and clearances for approval as part of the road design package.

The design shall consider loading capacities, restrictions, and clearances of existing services and connecting roads identified in the transportation and logistics studies.

Road pavement layers shall be defined for the most restrictive scenario, considering the heaviest anticipated loads and widest turning radii during construction.

### Road Construction Standards

Materials

* Excavated materials that meet SANS or COLTO soil classifications and are uncontaminated may be reused in road construction, subject to geotechnical approval.
* Where wet weather conditions are expected, compacted crushed rock shall be used for surface material, with a maximum rock size of 40 mm.

Compaction and Layering

* Fill and base layers shall be placed in lifts not exceeding 250 mm and compacted in accordance with SANS 1200, SANS 2001, or COLTO standards (Modified Proctor test).
* Minimum compaction requirements shall be as specified in the approved design documentation or geotechnical report.

Geometry and Dimensions

* Minimum usable road width: 4.0 m, or greater where required by component manufacturers.
* Minimum turning radius: 10 m (measured from road axis) or larger to accommodate maintenance and emergency vehicles.
* Minimum road height above adjacent ground: 0.10 m.
* Appropriate cross-falls and longitudinal gradients shall be provided to ensure free

Drainage

* Road drainage systems shall be designed to prevent erosion and structural degradation.
* Where necessary, side drains, culverts, and erosion-control measures shall be incorporated into the design.

### Access and Circulation

Internal roads shall provide uninterrupted access to all key Plant components, including but not limited to:

* String combiner boxes;
* Inverters and LV/MV power stations;
* Transformers;
* Solar and Eskom Substations;
* O&M and control buildings; and
* Tracker drives and other major infrastructure.

In PV field areas where formal roads are not provided, the layout shall include 3 m wide obstacle-free tracks or paths suitable for light all-terrain maintenance vehicles.

### Hardstanding and Parking Areas

The Contractor shall design and construct permanent and temporary hardstanding areas, including:

* Laydown zones for equipment handling and storage;
* Parking areas for vehicles and containers; and
* O&M and transformer maintenance areas capable of supporting cranes and heavy equipment.

Hardstanding areas shall be designed for long-term load-bearing stability and surface drainage to prevent rutting, erosion, or water accumulation.

### Traffic and Safety Management

The Contractor shall prepare and implement a Construction Traffic Management Plan (CTMP), which shall include:

* Defined construction access routes and procedures;
* Coordination with local authorities and affected parties;
* Safe traffic flow arrangements and signage; and
* A traffic incident response plan.

The CTMP shall be submitted to the Employer for review and shall remain active and updated for the duration of the Works.

### Testing and Quality Control

The Contractor shall conduct in-situ and laboratory testing in accordance with SANS or COLTO standards, including but not limited to:

* Compaction and density testing;
* CBR and bearing capacity testing;
* Vertical deformation tests; and
* Topographic verification surveys.

Test results shall be recorded, certified, and submitted to the Employer as part of the Quality Control documentation for acceptance prior to continuation of subsequent layers or surfacing.

### Maintenance During Construction

The Contractor shall maintain all temporary and permanent access roads in a clean, stable, and usable condition under all weather conditions throughout the construction period.

Regular grading, dust suppression, and repairs shall be performed as required.

Prior to the Date of Completion, all permanent roads and hardstanding areas within the Contractor’s scope shall be resurfaced, free of defects, and approved by the Employer.

## Drainage and Stormwater Management

* The system shall include channels, culverts, swales, berms, soakaways, stormwater retention ponds, attenuation basins, and outlet structures as required.
* Drainage courses shall be designed to preserve existing natural drainage patterns wherever possible.

Erosion Protection

* All drainage elements shall be designed to prevent erosion under design flow conditions.
* Channels, ditches, and slopes shall be stabilised or lined with concrete, rock pitching, or geotextile where flow velocity exceeds permissible limits.
* No water-induced erosion shall be permitted within the Site during or after construction.

Pollution Control

* Before any off-Site discharge, stormwater shall be treated to remove or neutralise contaminants.
* Drainage from potentially oil-contaminated areas (e.g., transformer bays, fuel storage, vehicle maintenance zones) shall be routed through an oily-water drainage system incorporating an oil separator.
* Discharge quality shall comply with applicable environmental and water-use standards.

Hydraulic Performance

* System capacity and slopes shall be verified by hydraulic calculations.
* Drainage elements shall not obstruct maintenance access or increase travel distances within the solar field.

### Construction Requirements

All excavation, backfilling, and compaction associated with the drainage works shall comply with SANS 1200 and SANS 2001 standards.

Drainage channels shall be formed to correct gradients and profiles, free from standing water.

Concrete and lining works shall be executed to approved drawings and specifications to ensure long-term durability and resistance to scour.

Temporary measures (silt traps, settlement ponds, cut-off drains) shall be implemented during construction to control runoff and sedimentation until the permanent system is complete.

### Stormwater Management Plan

The Contractor shall prepare and submit a Stormwater Management Plan (SWMP) for Employer review and approval.

The SWMP shall include, at minimum:

* Catchment delineation and flow routing;
* Design rainfall data and design return periods;
* Calculations and drawings for all drainage components;
* Construction-phase stormwater controls;
* Operation and maintenance procedures for the permanent system; and
* Inspection and cleaning schedules.

The SWMP shall demonstrate compliance with all applicable statutory and environmental requirements.

## Fencing and Gates

Design, supply, and install permanent fencing and gates for:

* Solar Substation; and
* Eskom Switching Station.

All fencing shall comply with Eskom Standard 240-100183119 (Substation Fencing Standard).

The earth mat shall extend beyond the substation perimeter fence; therefore, fencing installation shall only proceed after the earth mat is installed.

Substation layout shall ensure a 1.2 m wide perimeter barrier zone outside the substation fence remains within the Plant boundary to maintain protection against step and touch potentials.

The combined and/or separate substations (Solar Substation and Eskom Switching Station) shall be located either:

* Completely within the Plant boundaries, or
* Completely outside the Plant boundaries, ensuring full compliance with safety and access requirements.

## Trenches, Ducts and Manholes

Underground cable runs—including communication cables and earth conductors—are installed at appropriate depths in accordance with applicable Standards, the Employer’s requirements, and Good Industry Practice.

Cables are laid on a clean sand layer and covered with warning tape. Mechanical protection is provided for LV and MV trenches. For LV trenches with cables routed through suitable ducting, mechanical protection may not be required.

Backfilling materials must be free from rocks, roots, vegetation, or any elements that could damage cables or cause cavities during compaction or over the 25-year Plant design life. Bedding material is tested to align with thermal resistivity assumptions used in cable sizing calculations.

The cable trench study determines:

* Final trench design based on DC and AC collection system layout
* Final trench design based on:
  + Geotechnical study
  + Thermal resistivity measurements
  + Surrounding and soil conditions
  + Filling material
  + Existing infrastructure
  + Characteristics of DC cables, AC MV cables, fibre optic (FO) cables, and earth conductors

Earthing connections and splices directly buried in soil are permanently bonded using exothermic connections (for copper earthing) to equalize potential differences and prevent corrosion.

Physical and digital markers are placed at every direction change, cable joint, and every 100 meters along each cable run. Subject to Employer approval, physical markers for DC cabling may be waived after final layout review.

Mixed AC MV/LV trenches are avoided where possible. If necessary, higher voltage circuits are buried deeper than lower voltage circuits.

Depth of cover and trench layout comply with SANS 10198 and include:

* Cables laid on a minimum 100 mm sand layer. Reduction below 100 mm requires Employer approval and technical justification. Minimum allowable thickness is 50 mm
* MV cables laid at a minimum depth of 800 mm from ground level
* LV (DC and AC) cables laid at least 300 mm above MV cables and at a minimum depth of 600 mm
* Signal/danger tape placed at least 200 mm above cables and 300 mm below ground level. Trenches wider than 1 m include two or more warning tapes above cables. Tape must be placed above each trefoil MV cable run
* DC cables separated by at least 200 mm from AC cables (edge to edge)
* FO cables separated by at least 125 mm from LV and MV cables
* At LV and MV road crossings, cables laid in cased ducts concreted across the full road width plus 1 m on each side. Minimum depth from top of duct to surface is 0.6 m
* Conductive signal cables separated by at least 200 mm from LV cables
* Minimum separation between cables and trench walls is 50 mm
* Cables displaced horizontally across layers to allow access to deeper cables without damaging upper layers
* All cables surrounded by soft sand backfill before trench backfilling. Sand backfill thickness aligns with trench design study and thermal resistivity requirements
* Earthing conductors laid at the lowest trench layer
* LV and MV cables mechanically protected unless LV cables are routed through suitable ducting
* Trenches backfilled with clean fill material free from aggregate, debris, organic matter, and stones. Backfilling is done in layers no thicker than 150 mm and compacted to 90–93% of maximum density at optimum moisture content to prevent trench collapse due to settling. Maximum particle size in backfill is 50 mm.
* All trenching, ducting, bedding, separation, compaction and cable laying works shall comply with SANS 10198, SANS 10142-1, SANS 10299-2, SANS 1200 LB/LZ, NRS 089, and applicable Eskom construction standards.

## Foundations

Foundations are designed in accordance with relevant standards.

The Contractor assumes ground risk as defined in the Contract. Before construction, the Contractor conducts all necessary geological, hydrological, geotechnical investigations, and land surveys to fully understand ground conditions.

The Contractor’s documentation includes, at a minimum:

* Detailed foundation design documentation (type, dimensions, etc.)
* Reinforcement characteristics (rebar diameter, spacing, steel grade)
* Corrosion protection for steel structural elements
* Concrete design mix (grade, composition)
* Design basis statements and supporting calculations
* Specific construction methodology and testing criteria
* Specific bearing capacity requirements

Foundations must withstand Site conditions for at least the 25-year design life without requiring replacement.

### Piling / Mounting Structure Foundations

The Contractor takes full responsibility for the design, construction, and operability of the solar field foundations. These foundations are designed in accordance with relevant standards and the module mounting structure manufacturer’s specifications.

The mounting structure must endure Site conditions—including soil chemistry—throughout the 25-year design life without replacement. The Contractor accounts for all loads from upper structures to determine embedment depth and foundation specifications. Foundations and substructures must safely transfer all load combinations, including horizontal and uplift forces.

The Contractor selects a suitable foundation type, preferably pile foundations, but also considers alternatives such as pre-drilled piles or concrete footings, based on load testing and geotechnical studies.

The foundation calculations must state the maximum permissible foundation movement consistent with normal Project operation. The design must account for settlement in line with the manufacturer’s requirements.

The Contractor follows this step-by-step process (any deviations require Employer approval):

1. Initial foundation pre-design based on geotechnical study
2. Initial Pull-Out Tests (POTs) on Site to verify assumed loads and validate the initial design. These POTs follow the mounting structure manufacturer’s procedures and use the same materials, geometry, and installation methods. A minimum of 10 POTs per foundation type is required, covering all varying ground conditions
3. Final foundation design based on initial design and POT results
4. Design POTs before foundation works begin, covering all terrain types where each foundation type is used. Any design or execution changes must be tested with dedicated POTs up to ultimate loads Execution of foundations Validation POTs to confirm the executed design, covering all terrain types and foundation types. These POTs test up to maximum working loads
5. Pile rejection (e.g., failure to reach embedment depth) is handled per manufacturer procedures.
6. Rejection POTs are conducted on at least 20% of rejected piles to verify performance

The Contractor repairs any metal surface damage caused during ramming or mechanical interventions (e.g., cuts or drilled holes) in accordance with the designer’s and manufacturer’s specifications. Damage at the top of ramming profiles is repaired using two layers of zinc-rich paint (95% Zn content) or per the manufacturer’s post-head damage procedure.

The Contractor verifies potential zinc coating damage in the underground portion of piles during ramming. A sample of each pile type is rammed and extracted in various Plant areas to confirm the galvanised surface remains intact.

### Other Foundations

The Contractor conducts all necessary geotechnical and related studies to assess Site ground conditions and determines the appropriate foundation types and any required ground improvement techniques (e.g., soil improvement, compaction).

A detailed structural analysis is provided, demonstrating that the design complies with Site wind speeds, seismic loads, snow loads (if applicable), and relevant Standards. The design basis report(s) clearly state all load combinations, assumptions, and specifications.

Foundations must safely transfer all actual load combinations—including horizontal and uplift forces—to the supporting soil material identified in the geotechnical assessment. The Contractor specifies the maximum permissible foundation settlement in the design calculations, ensuring it aligns with normal operational requirements.

Foundation materials consist of steel-reinforced concrete. The minimum strength class for structural concrete is 25 MPa, unless otherwise specified. Where higher grades are required, the Contractor specifies them and submits designs for Employer review. All below-ground concrete structures are waterproofed adequately.

The concrete design mix is tailored to the aggressiveness and geomechanical properties of the ground and groundwater, as determined by the geotechnical report and lab analyses.

If excessive soil erosion or dune formation is identified, the Contractor implements suitable mitigation measures, subject to Employer approval.

The Contractor’s documentation includes, but is not limited to:

* Detailed foundation characteristics (type, dimensions, material specifications)
* Geotechnical design assumptions and verifications
* Specific construction requirements and testing criteria
* Climatic condition assumptions and verifications (wind, snow, humidity, temperature)
* Concrete foundation details:
  + Reinforcement characteristics (diameter, steel grade, corrosion protection)
  + Design mix requirements (grade, composition)

The Contractor is responsible for sealing cable ducts entering buildings, foundations, or other areas—both temporary sealing during construction and permanent sealing for the 25-year Plant design life.

### Excavations and Backfilling for Foundations

Foundation excavations are designed and executed to ensure stability, safe working conditions, and proper concrete placement without soil contamination. Excavated material is stored appropriately to prevent disturbance. Topsoil is stripped to avoid mixing with subsoil.

Excavation dimensions must comply with the foundation design.

The final sub-formation (excavation bottom) is inspected by the Contractor to confirm compliance with detailed design specifications for bearing capacity. Excavations are backfilled with suitable material, compacted in layers not exceeding 0.25 m, to achieve the required density for structural stability and resistance to erosion and light vehicle traffic.

If water ingress (from groundwater or surface water) occurs, the excavation is drained before foundation construction begins. The Contractor provides temporary equipment and takes necessary actions to keep excavations free of water during construction. Environmental constraints are considered when selecting outfall locations for pumped water.

## Structural Design Principles

All structural designs shall comply with SANS 10160 and other relevant standards as required. The Contractor is fully responsible for the adequacy, safety, and durability of all structures.

All design reports, calculations, and drawings shall be prepared and signed by a professionally registered structural engineer.

Design shall account for wind speed accelerations due to terrain effects (hills, obstacles, escarpments) and dynamic loads such as vortex shedding or wake buffeting. Modal analysis and fatigue assessments shall be performed where necessary, using recognised engineering tools.

Design documentation submitted to the Employer shall include:

* Supporting structure details (type, dimensions, materials, corrosion protection);
* Design assumptions (loads, environmental data, modelling tools); and
* Results for all load combinations.

### Load Assumptions

The Contractor shall design for all applicable loads in accordance with SANS 10160, including: self-weight, wind, thermal, seismic, snow (if applicable), flood, machinery actions, construction loads, and geotechnical actions. System survivability over the 25-year design life shall be ensured.

### Wind Loads

Wind design shall comply with SANS 10160-3.

Assumptions shall be supported by site-specific wind data and verified for all relevant structures (foundations, buildings, towers, fences, etc.).

Wind effects shall be combined with other loads using appropriate safety factors.

Where required, wind tunnel or CFD studies shall substantiate design assumptions.

### Seismic Loads

Seismic design shall comply with SANS 10160-4.

The Contractor shall determine expected seismic accelerations for the Site and verify that all structural components can withstand these loads.

### Corrosion Protection

All metal structures shall be protected against corrosion according to site-specific atmospheric and soil conditions.

An independent corrosion ambient report shall be provided.

Hot-dip galvanizing shall comply with SANS 121:2011 and SANS 14713-1/2:2011 (or equivalent ASTM standards) for a 25-year design life.

Underground steel shall comply with DIN 50929-3.

Pre-galvanization (e.g., G90) is not permitted for components in contact with the ground.

All corrosionTri protection works shall be inspected by the Employer’s Representative before the Final Acceptance Certificate is issued.

## ****Civil Construction Material****

### ****Steel Materials****

Reinforcement bars comply with SANS 920:2011 and have a minimum yield strength of 450 MPa.

Steel bars are tested by the Contractor upon arrival at the Site. Testing and frequency follow ISO 15630-1:2019 or an equivalent national standard.

Materials used include hot-dip galvanised steel grades S275 and S355, with yield stresses of 275 N/mm² and 355 N/mm² respectively. S235 JR with Magnelis may be used only for auxiliary parts of the module mounting structure.

All structural elements undergo hot-dip galvanisation to a thickness that ensures the minimum design lifetime, in accordance with SANS 121:2011, SANS 14713-2:2011, or equivalent ASTM standards.

All stainless-steel products are certified according to SANS 10162-4:1997.

Hot-rolled structural steel products are certified according to EN 10025 – Hot rolled products of structural steels.

### Concrete Materials

Concrete materials comply with the following requirements:

* Cement is Portland Type unless sulphate concentrations in groundwater require stronger specifications.
* Aggregates consist of naturally occurring materials. The Contractor does not use lightweight or metallurgical furnace slag aggregates.
* Water used for mixing concrete is clean and free from substances harmful to concrete, including oil, acid, alkali, organic matter, or other deleterious components.
* Admixtures are used in accordance with the applicable Structural Code and manufacturer recommendations. The use of calcium chloride in any form is prohibited.
* Cement is sourced from a certified plant, and documentation is submitted to the Employer prior to concrete delivery, in compliance with applicable standards and building regulations.

#### Concrete Mix

Before supplying any concrete mix, the Contractor submits the following information:

* Names of all concrete component suppliers, along with datasheets
* Locations of batching plants
* Mixed concrete composition, including test results confirming compliance with specifications
* A copy of the ready-mix supplier’s certificate of accreditation (if applicable)
* Procedures from all concrete component suppliers regarding:
  + Storage and batching of materials
  + Mixing and transporting
  + Compliance testing
  + Current calibration certificates for batch weighers
  + Compliance certificates for constituent materials

#### Transport of Concrete Mix

Concrete mix is transported in truck mixers that comply with relevant norms and standards. Concrete is compacted in its final position within 2 hours of cement introduction to the aggregate.

No water is added to the concrete during transit or on Site before discharge, unless approved and supervised by the Employer’s Representatives.

Before discharging concrete at the delivery point, the supplier provides a delivery ticket for each batch, in accordance with relevant Standards. The ticket includes the following information:

* Name of the mixed concrete plant
* Serial number of the ticket
* Date and time of loading
* Truck number or vehicle ID (if applicable)
* Name of the purchaser
* Name and location of the Site
* Specification references
* Volume of concrete (in cubic meters)
* Declaration of conformity with specifications and Standards
* Certification body name or mark (if applicable)
* Specified strength class
* Specified exposure classes
* Specified chloride content class
* Specified consistence class or target value
* Limiting values of concrete composition (if specified)
* Type and strength class of cement (if specified)
* Type of admixture and additions (if specified)
* Special properties (if required)
* Maximum nominal aggregate size
* Density class or target density (if applicable)

Additional information is recorded on Site and maintained by the Contractor, including:

* Time of arrival on Site
* Time unloading begins
* Time unloading ends
* Sample references (if taken)
* Location of concrete pouring
* Slump of the mix
* Weather conditions

The Contractor submits these tickets to the Employer as the Work progresses. They form part of the quality documentation for activities involving concrete.

#### Quality Test of Concrete

Concrete mix is tested during delivery by an independent accredited laboratory to confirm conformity with specified characteristics. Testing is conducted per batch, with batch sizes defined according to applicable Standards and building regulations. As a reference, concrete is tested in batches of no more than 25 m³, with five (5) cube samples taken per batch (100 mm or 150 mm):

* Two (2) cubes tested at 7 days
* Two (2) cubes tested at 28 days
* One (1) cube tested at 56 days

All concrete is sampled on Site for slump tests and cube tests. Each cube is clearly marked to link it to the corresponding delivery ticket and the section of the Works where it is used. Cubes are tested at an independent, accredited laboratory approved by the Employer. The Employer receives copies of all cube test reports upon completion.

Slump tests are taken on Site for each concrete pour—at minimum, for the first three (3) concrete wagons, and then for every third wagon thereafter.

The Contractor maintains detailed records of all concrete tests, including:

* Date and time of cube sampling
* Cube number
* Time of mixing and duration of use
* Truck delivery number
* Mix code
* Slump and associated work section

All test specimens are cured and tested by an approved laboratory at the Contractor’s expense. Test records are submitted no later than 14 days after testing and include:

* Date of test
* Cube number
* Age of concrete (in days)
* Cube dimensions, mass, and density
* Capping details
* Crushing load
* Failure type
* Concrete strength

Concrete that does not meet the Employer’s Requirements is rejected. Rejected concrete is removed and replaced at the Contractor’s expense.

Concrete samples are stored securely by the Contractor to allow future quality checks by the Employer.

##### Concrete Works

The Contractor submits a concrete works method statement—including curing methods—for Employer review prior to any concreting activities.

A testing schedule is agreed with the Employer before work begins. This schedule includes slump tests, cube sampling, and arrangements for independent compressive strength testing.

The Contractor provides the Employer with at least two (2) working days’ notice before concrete pouring and formwork removal. Any deviations or concerns are addressed and rectified before pouring. The Contractor allocates sufficient time in the Project schedule for this process.

Concrete surface temperature at the time of placing must be between 5 °C and 30 °C, unless specific precautions are planned and implemented.

No additional water is permitted in the reinforced concrete mix during pouring.

##### Curing

Curing and protection begin immediately after concrete compaction to prevent:

* Premature drying due to solar radiation and wind
* Leaching from rain or flowing water
* Rapid cooling in early days
* High internal thermal gradients
* Extreme temperatures
* Frost or snow exposure
* Vibration and impact that may disrupt concrete or its bond to reinforcement

Curing and protection are initiated immediately after concrete placement.

### Coal Ash Waste Resource

The Employer identifies an opportunity to use coal fly ash waste from the adjacent coal power station as a construction material. Preliminary investigations explore its use in road construction, cable encasement, and pylon stabilisation.

Bid responses that incorporate ash waste are viewed favourably, but the decision to use it remains with the Bidders. The Employer acknowledges that while the ash waste is freely available, it may not be the most cost-effective option and may require extended construction time due to quality control processes. This must be evaluated against potential reductions in maintenance costs.

The Employer provides information on the physical and technical characteristics of the ash waste in the Request for Proposal (RfP) documentation to help Bidders make informed decisions about its use and cost-effectiveness.

Further detailed technical studies may be required to properly assess the suitability of coal ash waste for Project applications, beyond the internal investigations already conducted.

## ****Buildings****

### ****General Building Design and Construction****

All buildings and structures **are designed and constructed** in accordance with the requirements and recommendations of the **Structural Code** and **SANS 10400**. Final building or structure designs **are approved** by a registered structural engineer and the local authority, as required by Applicable Laws, Permits, and Codes and Standards.

Design provisions **include** features that facilitate easy offloading of relay panels and other equipment into the control room. This **includes** appropriate door dimensions and a slanted floor entrance.

Building finishes **are selected** based on each building’s function, occupancy, and operational requirements. All buildings **display** appropriate signage. As a general rule, floors **consist of** concrete slabs with either tiled or epoxy-coated finishes. Each building **includes** a one-meter-wide sidewalk around its perimeter.

Special attention **is given** to the detailing, design, and construction of reinforced concrete pitched roof systems to minimise crack widths and **ensure** long-term integrity of waterproofing membranes.

Soffit slabs above rooms housing electrical equipment **are watertight**. No drainage or water supply pipes **are allowed** to pass through these rooms.

Emergency doors **are provided** with quick exit mechanisms and/or panic bars at appropriate locations to ensure safe evacuation in case of emergency.

Cable basements **are constructed** from fully watertight reinforced concrete and **extend** at least 300 mm above surrounding ground level.

Cable, pipe, and service entries through technical floors and walls **are designed** to be completely sealed after installation, making them smokeproof and fireproof. Sealing materials **must be** fire-resistant and easily removable to allow future installations.

Lightning protection **is installed** for all buildings, structures, and shallow concrete foundations. Down conductors **are connected** to the Plant’s underground earth grid/mat, with materials and design **complying** with relevant Standards.

All buildings **incorporate** fire protection systems and alarms in accordance with Applicable Laws, Permits, and Codes and Standards.

All buildings **comply** with **ASCE 07-10** and **SANS 10160**.

### O&M Building

The Contractor designs, procures, and constructs the O&M building, including all required furniture and equipment, with characteristics suitable for Plant operation and maintenance. All building layouts and furniture specifications are submitted to the Employer for approval prior to construction and installation.

The O&M building is separate from the substation/step-up transformer building and complies with the following requirements:

* Enclosed rooms and indoor spaces are sized appropriately for their intended use and equipment
* A rainwater harvesting system is implemented where reasonably possible to supply ablution needs, or to supplement other water sources
* Internal power distribution includes sufficient switches and sockets for each area
* Adequate water supply, including drinking water, is provided
* HVAC systems are installed in all areas where personnel presence is expected
* Infrastructure for high-speed internet connectivity is included
* Flooring is constructed at a single level
* Doors are sized to allow easy installation, maintenance, and future removal of panels and equipment
* Foundations include cable entry ducts to enable cable installation and maintenance without wall perforation

The O&M building includes the following areas:

* Reception area
* Management office
* Engineer/technician room (for a minimum of 3 people)
* Employer’s office (for a minimum of 2 people)
* General-purpose office/meeting/conference room (for a minimum of 10 people)
* Kitchenette for drinks and light snacks
* Separate male and female toilets, washrooms, changing rooms, and showers (with septic tank if needed)
* Security control room
* Control room with SCADA system and control equipment (LV bay, auxiliaries, telecom, etc.)
* Server room

A designated car park area is provided, with a minimum of four (4) bays including disabled parking, adjacent to the building.

#### Control Room

All Project operation, control, and monitoring activities are conducted from the control room. Adjacent or separate rooms on the same floor house workstations, meeting rooms, printers, engineering stations, and electrical cubicles, with easy access from the control room.

#### Server Room

The server room houses SCADA, security, and UPS devices. It has no windows and maintains a temperature range of 10–20 °C at all times via HVAC.

#### Security Control Room

The security control room overlooks the Site entrance gate, if possible, and includes:

* Wall-mounted video display for all CCTV feeds
* Workstation for intruder detection system monitoring
* Workstation for trunking radio base station

The O&M building complies with ASCE 07-10, SANS 10400, and SANS 10160.

### Warehouse Building

The Contractor designs, procures, and constructs the warehouse building, which includes a storeroom and workshop sized to store spare parts, special tools (e.g., IV curve tracer, drones, thermographic cameras), and perform routine and breakdown maintenance.

The warehouse complies with the following requirements:

* Storeroom includes shelved racks for efficient spare part storage
* Handling and lifting equipment is provided for large/heavy parts
* A lockable service counter is included for spare part reception and issue
* HVAC is installed to maintain temperature per manufacturer guidelines
* Workshop is sized for typical O&M repairs and maintenance
* HVAC is included in all occupied areas
* Internal power distribution includes sufficient switches and sockets
* Adequate water supply, including drinking water, is provided
* Fire detection system is connected to the O&M building
* Hazardous materials are stored in ventilated, covered areas
* Storeroom and workshop have gates at least 4 m high for forklift and equipment access, plus pedestrian doors
* Flooring is at ground level for easy movement of lifting equipment

The warehouse building complies with ASCE 07-10, SANS 10400, and SANS 10160.

### Office Equipment

The Contractor provides all regular furniture (e.g., office LANs, computers, kitchen equipment) and special furniture (e.g., for control rooms and workshops) for all buildings.

### Substation Building

The PV plant substation houses switchgear, panel boards, bus coupler, auxiliary transformer, and battery tripping units. While secondary switchgear may be placed outdoors, DC equipment must be installed indoors in a temperature-controlled environment due to its sensitivity.

The substation building includes a switchgear room with HVAC and has minimum dimensions of:

* Length: 10 m
* Width: 8 m
* Height: 2 m

# Tracking System

This section applies primarily to tracking systems for PV module mounting structures. Sections 9.2 and 9.3 also apply to single axis tilt module mounting structures, where relevant.

## General

The tracker system consists of a single-axis tracking system with motorised drives that track the sun’s movement from east to west, with a motion range of at least ±50 degrees.

The tracker system is designed for easy operation and maintenance (O&M), and is installed to ensure reliable performance under Site environmental conditions, including wind and seismic loads, and corrosive air and soil characteristics, in accordance with IEC 62817:2014/A1:2017.

The tracker system withstands maximum sustained gust wind speeds applicable to extreme Site conditions and complies with Applicable Laws, Regulations, and Standards. To enhance compliance with CTE and South African wind loading codes, the Contractor conducts wind tunnel testing to determine wind loads on a single tracker row. The Contractor calculates mean net pressure coefficients and peak negative/positive net pressure coefficients for each tracker row at all stow and operational positions, across all wind directions, in accordance with section 8.8.

The tracker system includes a backtracking algorithm to reduce inter-row shading during early morning and late afternoon. This algorithm is optimised for Site conditions, including topographical variations. Where significant east-west slopes exist, a 3D backtracking algorithm is considered to individually adjust each tracker for optimal performance.

The tracker design and installation comply with all site-specific restrictions outlined in the EA, EIA, and GA.

The tracker system is compatible with the proposed PV modules, with special attention to bifacial modules, if applicable.

## Structure

Structure components are made from galvanised steel with adequate thickness for the 25-year Plant design life, in accordance with EN ISO 1461:2009, SANS 12944, EN 10346:2015, or equivalent. Alternatively, anodised aluminium of heavy-duty type and alloy may be used, following EN 842:1997+A1:2008, EN ISO 14171:2016, or equivalent standards for enhanced corrosion protection.

Structures are manufactured from aluminium or galvanised steel and comply with the most stringent of the following Standards or their local equivalents:

* EN 1991-1-4: Wind actions
* EN 1991-1-6: Actions during execution
* EN 1993 series: Design of steel structures (general rules, cold-formed members, plated elements, fatigue, toughness, piling)
* EN 1997 series: Geotechnical design
* EN 1994-1-1: Composite steel and concrete structures
* EN 10025: Hot rolled structural steel products

The structure design accounts for maximum imposed loads, extreme climate conditions, seismic loads (per section 8.8 ground conditions, and thermal expansion/contraction. Full design calculations are submitted to the Employer for review and approval prior to procurement.

The structure is suitable for the Site’s land profile, with special attention to east-west and north-south slopes and slope transitions.

Compatibility with the PV module frame is considered, especially regarding bi-metallic corrosion. Where necessary, insulating barriers are included. For threaded connections, insulating bushes and washers are used. No welding is permitted on Site during installation.

The structure ensures PV module alignment per manufacturer specifications and maintains the minimum spacing between modules throughout the 25-year design life, under all operating conditions and after extreme loading events. The tracker manufacturer calculates module spacing, considering applicable loads and torque tube deflection, and includes this in the structural calculation report.

All fastening connections (e.g., bolts and nuts) are made from stainless steel or other corrosion-resistant materials suitable for the application.

The structure is designed at a height that prevents shading of adjacent modules and provides adequate ventilation. The bottom edge of the modules accounts for hydrological conditions and unplanned fauna movement beneath the modules during the Project’s lifetime.

## Driving Mechanism

Tracker drive units may use hydraulic pistons or electric motors; however, electric motors are strongly preferred. If electric motors are selected, all associated control boxes installed outside of protective enclosures must be rated at least IP55, and gear drive units must be rated at least IP54.

The torque tube may be driven by wires or levers. Regardless of the technique, the system must ensure accessibility to PV modules for cleaning and maintenance.

Tracking drive units must be capable of moving all trackers to the stow position from any operational position during power outages or when wind speeds exceed the maximum operating threshold. The system automatically reverts to tracking mode once the outage or wind event has passed.

All bearings and housings in the drive units must be protected against sand ingress. Accelerated lifecycle and ingress tests are performed to demonstrate durability over the Plant’s design life. Preferred bearing materials include impregnated polyethylene or similar self-lubricated materials to minimise scheduled maintenance.

To control structural oscillations during high winds, dampers are installed at each tracker row.

Plastic parts directly exposed to UV must be evaluated for integrity over the 25-year design life, considering Site climatic conditions. Cable ties exposed to sunlight must be stainless steel, and exposed cables must be encased in UV-resistant tubing.

## Earthing

The tracker structure is earthed according to the approved earthing design, and an equipotential certificate is provided to the Employer.

The Contractor ensures electrical equipotential bonding and continuity across all tracker components, including air termination rods (if applicable). Equipotential bonds are fixed using existing holes or bolts on the metallic structure, or with self-drilling stainless steel screws.

Electrical continuity between the PV module and tracker is achieved using standard grounding points, serrated washers, or serrated clamps to remove anodised coatings from the module frame.

Tracker earthing cables are connected using existing bolts or holes, and all connections must be visible. Bare copper earth wire (BECW) is covered or painted and must not be visible.

The Contractor specifies the maximum resistance (in ohms) of the tracker’s metallic structure before connection to ground.

## Tracker Control System

The tracker control system uses an astronomical tracking algorithm that estimates the sun’s position based on time, date, and location. The system achieves a tracking accuracy of at least ±1 degree, sufficient for optimal energy yield.

The control system includes all necessary components to monitor and control tracker motion and enables full monitoring from the O&M building via the SCADA system. It manipulates module tilt and includes an emergency stow function that overrides all other signals, immediately moving trackers to the stow position during high wind events.

Drive units feature sensors and alarms to detect mechanical or electrical faults and indicate tracker position. The controller records and transmits the following alarms and parameters:

* Tracker position
* Inclinometer failure
* PLC clock drift
* Wind speed outside acceptable range
* Wind stow notification
* Anemometer signal and alarm

If hydraulic drive systems are used, pressure sensors must indicate piston pressure and oil reservoir levels.

A self-powered tracker system is preferred.

Further control system requirements are detailed in section 12.

Where applicable, the Contractor adheres to the Eskom Field Instrument Installation Standards:

* Junction Boxes and Cable Termination (240-56355815)
* General Field Instrument Installation (240-56355754)

## PV Module Installation

PV module installation avoids misalignment and stepping between modules on the same mounting structure table under all operating conditions. This prevents issues caused by differential settlement, structural flex, or vibration.

The installation ensures that the minimum spacing between PV modules, as specified by the manufacturer, is maintained at all times.

The Contractor uses specific tools and templates to guarantee correct positioning and alignment during installation.

All fasteners—including nuts, bolts, and clamps—are made from materials suitable for extreme atmospheric conditions at the Site, with adequate corrosion protection.

PV modules are installed in compliance with the manufacturer’s allowable torque specifications. Torque indicators are used to enable visual verification of torque status.

Each PV module is secured with at least two (2) anti-theft fasteners and mounted strictly according to the manufacturer’s specifications.

# Mechanical design

## Firefighting and Fire Protection System

### General

The Contractor provides a comprehensive alarm and detection system, including both passive and active fire protection measures, in full compliance with Applicable Laws, Regulations, and Standards.

The Contractor obtains all necessary compliance certifications and operating permits from relevant authorities upon completion of Plant installation.

A fire risk assessment is conducted and forms the basis of the overall fire protection strategy.

The firefighting system includes:

* Fire detection systems for reliable early warning and centralised extinguishing control
* Safe operating environments through equipment segregation and appropriate material selection
* Hazard identification and selection of suitable equipment for hazardous areas
* Tailored firefighting systems for different Plant areas and buildings based on operational characteristics

The passive and active fire protection measures throughout all the buildings, and substation in compliance with statutory requirements, local and national standards.

### Portable Fire Extinguishers

Portable and mobile fire extinguishers are installed throughout the Plant for first-response firefighting.

Quantities and locations comply with NFPA 10. All Plant areas are classified as Extra (High) Hazard Occupancy, except offices and similar accommodations, which are classified as Ordinary (Moderate) Hazard Occupancy.

Portable fire extinguishers shall be located along normal paths of travel, including exits from areas.

All extinguishers comply with:

* SANS 1910:2022
* SANS 10105-1:2021
* SANS 1475-1:2010

### Fire Detection and Alarm

An automatic and manual fire alarm system is installed to protect life and property across all buildings and MV stations. The system uses a distributed analogue addressable configuration.

A central fire alarm control panel is located in the control room/building. All fire and fault conditions are displayed on an integrated console.

All fire alarm control equipment—including gaseous extinguishing system panels—comes from the same manufacturer and is installed in accessible areas.

Automatic fire detectors provide full coverage across the Plant and are selected based on risk and environmental conditions.

Each building has its own fire extinguisher.

Cable tunnels and spreading rooms are equipped with smoke detectors, resetting linear heat detection, or both.

### Fire Safety in Building Design and Construction

All Plant buildings are designed and constructed to protect personnel and equipment in accordance with applicable Standards.

Means of egress comply with local authority requirements.

### Fire Safety During Construction and Commissioning

The Contractor is responsible for fire safety during construction and commissioning.

All fire safety measures comply with NFPA 241 and NFPA 850.

Fire safety systems are commissioned and operational before Plant commissioning begins.

## HVAC System

The Contractor installs HVAC systems in all buildings to maintain indoor conditions suitable for equipment and personnel. The design ensures proper operation and storage of equipment sensitive to dust, humidity, and temperature. Areas are positively pressurised as needed to prevent dust ingress.

The HVAC system complies with the following:

* Centralised control from the control room/building
* Separate systems for rooms with potential gaseous emissions (e.g., battery rooms)
* Alarm capability to notify SCADA of faults
* Temperature alarms in rooms with stringent climate requirements (e.g., server room)
* UPS backup for critical temperature-controlled areas, providing at least 6 hours of power
* Ventilation systems for inverters meet manufacturer specifications

# Electrical Requirements

## Scope of Work

The electrical works include the design, supply, installation, testing, and commissioning of the following systems and components:

* Generation equipment, including cabling, connections, and auxiliary systems
* Primary plant and inter-connections;
* Protection and control systems for the entire electrical system, including interlocking, intertripping, signalling, and coordination functions.
* Temporary construction power supplies
* Electrical distribution systems at appropriate voltages for the layout and power needs
* Internal and external normal and emergency lighting
* Small power systems
* Uninterruptible Power Supply (UPS) systems and associated battery systems.
* Lightning protection systems
* Plant earthing systems
* All necessary cable management systems including trays, ducts, ladders, trenches, conduits and manholes

The electrical scope covers all equipment necessary to complete the Works, whether or not explicitly listed.

The Contractor provides all electrical supplies, protection systems, communications, cabling, wiring, lighting, heating, small power, earthing, and other electrical items. All equipment is designed for maintainability and replaceability with minimal impact on adjacent systems and minimal enabling works.

Monitoring, control, sampling, and access points are made accessible without the need for specialist equipment wherever possible.

## Electrical Studies

The power distribution system is designed to maintain operational stability, current carrying capacity, and fault level performance under all operating, maintenance, and fault conditions.

The Contractor submits detailed protection grading studies, fault level calculations, and protection settings for Employer approval.

The following power system studies are conducted:

* Load flow studies (equipment ratings, voltage profiles, losses)
* Fault level studies (short circuit current levels and flows)
* Transient stability studies (system response to faults and major equipment trips)
* Harmonic studies (distortion levels and mitigation effectiveness)
* Electrical protection studies
* Equipment rating selection calculations
* Insulation coordination (per SANS 60071-1/2:2020)
* Any additional studies required to validate the design
* Earthing study
* Interlocking system study (per industrial best practices)
* Grid Code compliance study (per National Standards and Applicable Laws)
* **Arc flash hazard and incident energy analysis**, including PPE category determination and arc flash labelling requirements
* **Power quality studies** including flicker, imbalance, voltage fluctuation and rapid voltage change (RVC) analysis
* All electrical studies shall comply with SANS, NRS, IEC, Eskom standards, National Grid Code requirements and industry best practice.

## General Electrical Requirements

All equipment is designed to ensure continuous operation under all working and climatic conditions at the Site. The design facilitates inspection, maintenance, and repair, and maximises system availability through redundancy and sparing strategies.

Safety features—including isolation, locking, and interlocking—comply with Standards and Good Industry Practice.

Materials and equipment operate efficiently and reliably, with special consideration for:

* High ambient temperatures
* Fire and flood risks due to fire protection systems

Minimum enclosure classifications for non-rotating electrical equipment are as follows:

* Indoors in enclosed rooms (dust-limited): IP31
* General indoor use: IP54
* Indoor areas with water spray or condensation: IP65 or better
* Outdoor use: IP65 or better

All electrical equipment and installations comply with Standards and Good Industry Practice.

Switchgear, transformers, and other equipment operate continuously at rated current without overheating, considering temperature rise from adjacent equipment. Where forced cooling or air conditioning is required, the cooling system must be N-1 redundant.

Electrical equipment withstands maximum short circuit currents and durations without exceeding insulation temperature limits. Final temperatures must not cause permanent damage or degrade performance.

Insulation materials are finished to prevent deterioration under specified conditions.

Switchboards, panels, and cubicles include thermostatically controlled heaters to prevent condensation. Heaters switch off automatically if temperatures exceed adjustable thresholds. Control panels and kiosks include door-operated internal lighting. Power supplies for commissioning and maintenance are provided as needed.

Electrical equipment in hazardous areas is enclosed appropriately and certified for the classification of the area, in accordance with statutory regulations and codes.

## Grid Code Requirements

The Contractor ensures that the electrical design complies with the Grid Connection Code for Renewable Power Plants (RPPs) connected to the Electricity Transmission System (TS) or Distribution System (DS) in South Africa, as well as any other relevant Grid Codes.

The Contractor shall verify the suitability of voltage levels, grounding arrangements, short-circuit ratings and frequency conditions through electrical system studies and shall obtain approval from the Employer and Grid Operator prior to energisation.

## System Frequency, Voltages, Short Circuit Rating and Method of Earthing

The requirements stated in the latest edition of the Grid Code(s) shall be observed. The following voltage levels in the following Table are pre-assigned and shall be used in the Project.

Table 3 Project’s voltage levels

|  |  |  |
| --- | --- | --- |
| **Item** | **Voltage** | **Star Point/ Neutral Treatment** |
| Power Distribution  System-Medium Voltage | MV voltage +- 10 % nominal, 50 Hz, 3phase | Not earthed (to be confirmed by supplier) |
| Low Voltage system between inverters AC output and inverter transformers | As per inverter requirements (the Contractor shall be responsible for a proper coordination between the inverters and the inverter transformers design). | Not earthed (to be confirmed by supplier) |
| Power Distribution System  Low Voltage | 400/230 V +- 10 % nominal, 50 Hz, 3phase + N + PE | Solidly grounded |
| Uninterruptable Power  Supply (UPS) | 400/230 V nominal, 50Hz, 3-phase + N +  PE | Solidly grounded |
| Control DC voltage | 110 Vdc | One pole earthed |

## Grid Connection

Grid connection works are carried out by the HV Subcontractor, in accordance with the battery limits defined in Section 4.3.

Further details regarding the Grid connection scope are provided in Section 14.

## MV/LV Transformers

### General Requirements

This section defines the general requirements for all transformers that the Contractor designs, procures, installs, tests, and commissions.

All transformers comply with Applicable Laws, Consents, and Codes and Standards, particularly SANS 60076 and SANS 555 (for mineral oil transformers), as well as any other relevant standards referenced in the technical specifications and transformer planning guidelines.

Transformers are of low-loss design, and their construction, performance, and testing align with SANS 60076.

All transformers are designed for a 25-year Project design life or more. Transformers are oil-filled, except for indoor auxiliary transformers, which are dry-type and also designed for the full Project lifetime.

Transformer windings are made of copper, suitably bonded and braced for short-circuit strength. All terminal connections are copper.

Each transformer includes tap changers. On-load tap changer diverter switches are housed in a separate tank, with oil levels maintained from the main tank conservator. Tap range, impedance, and losses are selected to ensure full output under all operating conditions, including voltage extremes, without restriction across the ambient temperature range.

Tapping range calculations are submitted to the Employer for approval.

Radiators may be mounted separately or on the transformer tank. Radiators are hot-dip galvanised, while tanks, conservators, and marshalling kiosks are painted.

Protection class is at least IP65 for outdoor transformers and IP4X for indoor transformers.

Vibration and noise levels comply with best commercial practices. Transformer design and manufacturing minimise noise and vibration while ensuring safety and reliability.

Where the transformer tank bottom plate contacts the foundation, anti-vibration pads are installed. These mountings are made of oil- and weather-resistant rubber or other approved materials, suitable for operation between -10°C and +80°C. Irregularities in the tank base and plinth surface are considered. Anti-vibration mountings are not required for separately mounted equipment like coolers and pumps.

### Oil-Filled Transformers

All oil-filled transformers comply with environmental, fire safety, and local regulations and standards. No oil-filled transformer is installed indoors.

The insulating oil must be biodegradable.

Oil-filled transformers are fully sealed and require no refilling over the Project’s lifetime. They withstand three-phase short circuits on the LV side for the maximum fault current and a three-second duration. Insulation material is Class A, constructed using thermally upgraded insulation paper.

Each transformer includes:

* Oil conservator
* Oil level indicator and alarm
* Silica gel breather
* Oil temperature indicator, alarm, and trip
* Pressure relief device with alarm and trip
* Quick pressure rise relay
* Buchholz relay with gas and surge protection, alarm, and trip
* Winding temperature indicator with alarm and trip contacts

A magnetic oil level gauge is provided for each section (main tank and OLTC, if applicable), showing the full oil level range. High and low oil level alarms are connected to the Plant SCADA system, along with oil temperature monitoring.

Oil sampling devices are installed at the top and bottom of the main tank, allowing sampling while the transformer is energised. The top sampling point includes a downpipe and valve to collect oil from the bottom of the tank (no more than 1.2 m from ground level).

Cooling is either Oil Natural Air Natural (ONAN) or Oil Natural Air Forced (ONAF). If ONAF is proposed, the Contractor must justify its use.

Oil-filled transformer construction, environmental protection, fire-safety compliance, testing and accessories shall comply with SANS/IEC 60076 series, SANS 1029, applicable environmental legislation, and the Employer’s specifications.

### Dry Type Transformers

Dry type transformers comply with SANS 60076-11 and are classified as follows:

* Climatic class: C2
* Insulation class: F
* Environmental class: E2
* Fire behaviour class: F1

Only flame-retardant and self-extinguishing materials are used in their construction. No fillers are added to the cast-resin moulding material that could compromise mechanical stability.

Thermal expansion of windings (copper or aluminium) and cast-resin is considered, with sufficient space provided to accommodate thermal stresses due to differing expansion coefficients.

Dry type transformers use Air Natural (AN) cooling.

Winding temperature is monitored using two redundant sensors with pockets at each low-voltage winding of each phase. These temperatures are tracked via the Plant SCADA system in the Central Control Room.

Dry-type transformer design, testing, installation and accessories shall comply with SANS/IEC 60076-11, SANS 10142-1, SANS 10103, NEMA TR1 (noise limits) and OEM specifications.

### LV/MV Inverter Transformers

LV/MV transformers connect inverters to the MV AC collection system. These transformers step up inverter output voltage to MV, and their rating is not less than the maximum rated AC output of the associated inverter(s) at 20°C.

The transformer manufacturer confirms compatibility between the inverters and the LV/MV transformers.

The power load is designed to accommodate the full operating range of the inverters across varying temperatures.

If LV/MV inverter transformers are housed with the inverters, local protection and separation requirements are followed.

LV/MV transformers comply with the following specifications:

* Three-phase configuration
* Cooling system suitable for Site conditions
* Design, procurement, and testing in accordance with SANS 60076 and local standards
* MV voltage rating determined by the Contractor based on grid or MV/HV transformer voltage
* LV voltage rating determined by the Contractor based on inverter AC output
* Off-load tap changer with five positions: -5%, -2.5%, 0%, +2.5%, +5% (if applicable)
* Connection group designed per HV specifications and applicable regulations
* Protection against overload, short-circuit, internal faults, overtemperature, and overpressure
* Environmental suitability for the Project Site
* Reduced inrush current
* Minimised annual electrical losses
* Guaranteed transformer data, including load/no-load losses and short-circuit voltage (Ucc %)
* Condition monitoring, including oil temperature, oil level, and pressure
* Complete documentation, certificates, and test protocols
* Transformer **impedance shall be optimised** to limit fault current contribution from inverters and support grid stability
* LV/MV inverter transformers shall comply with SANS/IEC 60076 series, SANS 10142-1, applicable environmental regulations, and OEM technical specifications and shall be designed to support Grid Code performance requirements.

### Auxiliary Transformers

Auxiliary transformers are designed to operate under full Plant load with the following loading conditions:

* 80% for 1 x 100% transformer
* 40% for 2 x 100% transformers

Auxiliary transformers may be indoor or outdoor type. Indoor transformers must be flame-retardant dry cast resin type. They are located adjacent to associated switchboards in secure enclosures and connected via busbars or cables.

Connections to transformer bushings are made using flexible copper links, which can be removed for separate testing of cables and transformers.

Each auxiliary transformer includes a manually operated off-load tap changer on the high-voltage side, with 2 x ±2.5% positions and changeable terminal connections.

Auxiliary transformers shall comply with SANS/IEC 60076, SANS 10142-1, SANS 10103 (noise), environmental and fire-safety requirements, and applicable OEM specifications.

## LV/MV Substation

The Contractor considers compact LV/MV substation solutions for housing the following equipment, using shipping containers, skids, or prefabricated buildings/enclosures:

* Indoor or outdoor LV/MV transformers
* Indoor or outdoor MV Ring Main Units (RMUs)
* Indoor LV cabinets or outdoor auxiliary distribution boxes for auxiliary services and SCADA
* LV/LV auxiliary transformers
* Communication equipment
* Auxiliary equipment
* Grounding system
* Adequate **ventilation and cooling** provisions for electrical equipment (forced ventilation if required)
* LV/MV substations shall comply with SANS 10142-1, SANS 10222-1, SANS/IEC 62271, SANS 1473, local building regulations, fire codes and environmental legislation.

## Switchgear

All switchboards are industrial-grade, extensible, metal-clad, withdrawable cubicle types, arranged as freestanding units with a minimum ingress protection rating of IP54, and constructed and tested in accordance with applicable Standards.

MV switchgear is designed for nominal voltage per SANS 1019 and SANS 62271, and certified for internal arc classification IAC AFRL per SANS 62271-200:2022. It withstands short-circuit currents at least 10% higher than calculated values for three (3) seconds. RMU switchgear may be rated for a one (1) second short-circuit duration. Type test certificates are provided for all units.

Switchgear includes anti-condensation heaters and supports bottom entry for MV cables.

LV switchgear is designed for 400/230 V per SANS 1019, and withstands short-circuit currents at least 10% higher than calculated values for one (1) second.

Switchgear compartments—including busbars, circuit breakers, cable compartments, and LV compartments—are separated by barriers to prevent the spread of ionised gases.

Busbars are made from electrolytic copper and carry full current continuously without exceeding temperature limits. Busbar systems withstand thermal and dynamic effects of short-circuit faults, and accommodate thermal expansion.

Main switchboards, relay panels, and control equipment include duplicate 110 V DC power supplies for control and alarms.

Check-synchronising facilities are provided as needed. Electrical interlocks prevent paralleling of incoming supplies. MV switchgear includes interlocks to prevent incorrect operations per SANS 62271-200:2022.

Mechanical off switches are provided for emergency operation of MV feeders and LV incomers.

Withdrawable units support the following positions:

* Service
* Disconnected-test
* Disconnected
* Removed

MV switchgear is withdrawable, with air-insulated busbars, vacuum circuit breakers, and integral fault-making earth switches for circuit and busbar earthing. Circuit breakers are rated for fault making, fault breaking, and load breaking, and handle maximum fault and continuous load currents.

LV switchgear (400–690/230 V) includes air-insulated circuit breakers, MCCBs, and contactor units. Construction follows Form 4B per SANS 61439. Shutters cover stationary contacts and lock to prevent access.

LV switchboards withstand short-circuit currents of not less than 50 kA for one (1) second.

LV switchgear uses conventional hard-wired control and connects to redundant gateways or remote I/O cubicles of the Plant SCADA system.

All AC and DC LV switchgear is designed as type-tested assemblies.

## MV Ring Main Unit (RMU)

MV RMUs are compact, hermetically sealed SF₆ type, and gas-tight for life. A manometer monitors SF₆ gas pressure. A voltage presence indicator monitors cable voltage during operation and maintenance.

Each RMU includes:

* Switch disconnectors on cable feeder circuits
* Circuit breaker with IDMT, definite time overcurrent, and earth fault protection on transformer feeder circuits
* LV phase rotation meter
* Voltage presence indicator
* Cable clamping facilities
* Two incoming feeder functions for managing energy from other inverter stations
* One gas-insulated switchgear circuit breaker for MV-side transformer protection
* Modular, self-contained metallic enclosure
* Interlocking keys for safe operating/isolation sequences
* State-of-the-art relays compliant with SANS standards
* Metering devices
* Earthing switches in each cubicle
* Capacitive voltage detectors in each cubicle

Position indication of RMU switching devices is integrated into the Plant SCADA system.

Where RMUs are not used, appropriately sized separable tee connectors terminate cables to transformers, allowing safe bypass of failed transformers while maintaining radial circuit continuity. RMUs must not be close-coupled to transformers.

RMUs shall comply with SANS/IEC 62271-1/-200, SANS 10142-1, applicable environmental and safety standards, and OEM specifications.

LV auxiliary supplies follow either TN-S (separate PE and N conductors) or TN-C-S (combined PE&N from transformer to main distribution, separate PE and N in distribution and consumer connections).

## Electrical System Control, Indications, and Alarms

The Contractor provides control and alarm facilities for the Plant’s AC and DC electrical systems.

Signal interchange requirements with the Distribution Network Operator (DNO) are developed during the Project’s design phase.

AC electrical systems—including transformers, switchgear incomers, and bus-sections—are monitored and controlled from the Central Control Room (CCR) via the Plant SCADA system.

Voltage readings for each switchboard and single-phase current for all main circuits (incomers and bus-sections) are displayed locally and repeated in the CCR via SCADA.

Trips and alarms indicate and announce system warnings and faults at the CCR through SCADA.

400–800/230 V AC sub-distribution systems and DC systems are locally controlled, but alarms are transmitted to the CCR via SCADA.

Switchgear includes prominent, coloured, high-power LED status and alarm lamps. Protection relays feature LED indicators or flags.

## 400–800/230 V AC and DC Sub-Distribution Boards

Sub-distribution boards are installed throughout the Plant for local lighting, small power, and welding supplies.

Outdoor sub-distribution boards are weatherproof (IP65) and equipped with enclosed sun canopies. Indoor boards have a minimum ingress protection of IP54.

Switchgear in electrical operating rooms meets IP54 and withstands fault currents until protection activates.

DC sub-distribution boards are installed for control supplies to switchgear, control panels, and emergency lighting.

Incoming breakers on all sub-distribution boards support lock-out devices and include remote signal protection tripping relays with adjustable current and time settings.

AC sub-distribution boards may be single-phase or three-phase, with neutral and earth bars. DC boards are two-pole type. All boards are rated for full load current and equipped with incomer isolating MCCBs (4-pole for AC, 2-pole for DC) and MCBs for sub-circuit protection.

All installed equipment is designed and tested for the applicable voltage type (AC or DC).

Distribution boards reserve 10% of switchgear space unused and allocate an additional 20% for future expansion.

## Uninterruptible Power Supply Systems

UPS inverter systems are provided for essential AC supplies, including:

* SCADA and communication systems
* Security systems
* Inverters and trackers
* Safe shutdown systems

These UPS systems are normally powered from the 400–800 V system. A modular UPS is recommended.

A separate UPS for emergency lighting is provided as needed. Emergency lighting is not powered by the battery system.

Each UPS unit is rated at 120% of its load and includes:

* Automatic static transfer switch to an alternative supply
* Emergency manual bypass switch
* Local alarm lamps and remote alarms to the CCR

UPS autonomy is at least 12 hours.

UPS units are located in air-conditioned rooms (excluding battery cells) and may be housed in AC switchgear rooms.

UPS systems maintain control system power for a minimum of 12 hours after feeder supply loss.

A diesel power plant facility is considered to supplement auxiliary services. It automatically starts during outages, constraints, or loss-of-mains events, with autonomy between 24–48 hours. Diesel consumption is minimised during operations.

Power cannot be exported from the diesel facility to the grid. It connects to an alternative busbar, separate from the MV busbar linked to the step-up transformer.

The Contractor designs, fabricates, tests, and inspects the diesel power plant facility, including:

* Diesel engines and generators
* Foundations and anchor bolts
* Electrical and control systems (LV switchgear, control panels, transformers, MV switchgear)
* Power, control, and fibre optic cables
* Starting and redundant batteries with chargers
* Fuel metering and filtration systems
* Cooling water and tank
* Exhaust system with silencers
* Common base frame
* Accessories, spares, and special tools
* Installation, assembly, commissioning, and testing

Equipment is factory-assembled as much as possible for efficient field erection. Accessories are modular, with piping and wiring completed and terminated within each module.

All equipment and materials are designed and installed for environmental conditions, including freeze protection, moisture and dust control, heat tracing, and insulation. Engine air intake, enclosures, and critical systems are suitable for Site-specific conditions such as altitude and dust storms.

UPS and diesel backup systems shall comply with IEC 62040 series, ISO 8528, IEC 60034, SANS 10142-1, and all applicable fire, environmental and electrical safety regulations.

## MV (AC) Cables and Installation

MV AC cables are copper, screened, stranded single-core types, with individually screened cores. These cables comply with the following minimum requirements:

* XLPE or HEPR insulation
* Compliance with all relevant Codes and Standards
* Flame retardant properties per SANS 60332-1 and SANS 60332-3
* Capability to withstand maximum electrical voltages over the Plant’s 25-year design life
* Permanent marking and identification of all MV cables
* Maximum operating temperatures:
  + ≥ 90°C under normal conditions
  + ≥ 250°C under short-circuit conditions (max 5 seconds)

Instrument and data cables use conductors and insulation suitable for their specific duty and location.

MV cable screens are grounded at both ends to ensure safety and performance. Improper grounding can result in potential differences due to high impedance.

Cable jointing is limited per circuit, and joint specifications are reviewed by the Employer. Joints must be executed by certified personnel. Topographical documentation of MV/HV joint positions is included in As-Built records.

Derating factors for current capacity are applied per applicable standards to prevent overheating. MV cables are sized based on ampacity, voltage drop, and let-through energy.

Power cables are suitable for maximum design load and minimum voltage conditions, and withstand through-fault currents for the short-time rating of associated switchgear. Cables protected by fuses/MCCBs/MCBs must sustain maximum prospective fault let-through current/time.

Maximum voltage drop limits:

* Between main switchboards and sub-switchboards: 2%
* Between main switchboards and static load terminals: 5%
* Between sub-switchboards and lighting loads: 3%

Within buildings, cables are installed on hot-dip galvanized trays or racks, preventing damage and minimising fire spread. Power cables are clamped to prevent movement during short-circuit events.

Single-core cables are clamped in trefoil formation, with phase cable swapping every 100 m.

Duplicated circuits (e.g., emergency or high-integrity circuits) follow separate routes or are spaced apart. MV, LV, and control cables are segregated:

* MV cables at the lowest level, in single layers
* LV cables above MV, in up to two layers
* Control cables at the highest level, also in up to two layers

Segregation follows SANS 10198. From trays/racks to equipment connection boxes, cables are installed in galvanized steel conduits or metallic flexible conduits with external PVC insulation. Transitions from aerial to underground are mechanically protected, extending 2 m above floor level.

LV cables are wrapped with thermal sleeve tape for durability. Colour coding:

* Brown, Black, Grey, Blue for R, S, T, N
* Green and Yellow for earthing

Cables outside buildings are laid in galvanized steel conduits or on trays/racks within reinforced concrete trenches or pipe racks. PVC conduits are used only for cables in underground ducts.

All trays/racks/conduits are hot-dip galvanized and, if damaged, repainted with anti-corrosion coatings (e.g., cold galvanizing paint). No plastic or PVC trays/conduits are permitted. Outdoor trays/racks include covers for sun protection.

Cable trays are bonded to each other and to the Plant earthing system. Trays allow 20% spare space and limit cable layers to two per tray.

Bottom-entry power and C&I cabling is used for switchgear and other main equipment. Cable access to enclosures uses compression-type glands made of non-magnetic metal. Gland plates are metal, with sufficient rigidity to prevent distortion.

Cables and trays are clearly identified at both ends with weatherproof tags, following the KKS system. Cable ratings comply with SANS 10198.

Underground cables and those in meshed trays/ladders are designed to prevent faunal harm and maintain the Plant’s design life.

Cable tray fixation follows Good Industry Practice, including:

* Proper earthing
* Protection from structural cutting angles
* UV resistance
* Durable, regular fixation to prevent sagging
* Anchoring to both tray and ground
* Full performance assurance of the electrical system

Where applicable, the Contractor adheres to:

* Eskom Field Instrument Installation Standard: Junction Boxes and Cable Termination (240-56355815)
* Eskom Field Instrument Installation Standard (240-56355754)
* MV cable design, installation, jointing, termination, testing and commissioning shall comply with SANS 60502-2, SANS 10198, SANS 10142-1, SANS 60332 series, IEC 60287 (ampacity), IEC 60840, and Eskom standards where applicable.

## Earthing System Design, Bonding, and Lightning Protection

The earthing and lightning protection systems are designed in accordance with SANS 725, EN 50522:2010, IEC 60364, SANS 62305, SANS 61936-1, and IEEE 665 standards. All earthing connections are secured using bolts, nuts, and stop washers to ensure durability and reliability. Anticorrosion coatings are applied where necessary.

Special attention is given to:

* Lightning ground potential rise and difference
* Step and touch voltages
* Electromagnetic zoning
* Soil resistivity variation across the Site
* Earth electrode resistance (low-frequency parameter)
* Large earth electrodes (e.g., solar PV field)
* Lightning electromagnetic pulse (LEMP) effects
* Structural steel piles are not used as underground earthing electrodes; instead, an independent buried earthing grid is installed, with steel structures connected to it

The Contractor designs, installs, and tests a single earth grid/mat for the entire Project. This grid serves all Plant equipment, including PV module structures, LV/MV power stations, transformers, switchgear, buildings, and fences. The grid consists of bare earth copper wire (BECW) along LV/MV cable trenches and additional dedicated earth trenches, as required by the earthing study.

Final specifications of the buried copper earth electrode comply with SANS 60479, EN 50522:2010, IEEE 80, and Good Industry Practice. The earthing system achieves safe step and touch potentials per applicable standards.

Each inverter has a perimeter earthing grid made of BECW and copper rods, as defined in the earthing study. The earthing system’s short-time current withstand rating matches the system fault current and backup protection time. Loop impedance ensures protective devices operate within short-time ratings and prevents unsafe step/touch potentials.

All underground joints are cad-welded.

All electrical equipment, metallic frames, structural steel, fences, and cable trays/racks are bonded to the earthing system. Transformers and switchboards include at least two earth terminals, each connected to the secondary earthing system.

A copper strip is used, sized for maximum system earth current (1 second) and mechanical rigidity. Earthing cable sizes are designed per applicable standards.

The Contractor provides a lightning protection system for the PV Plant, compliant with SANS 62305, including risk assessment and electromagnetic zoning (EM Zones per SANS 61000-2-5, SANS 61000-4-5, and SANS 61000-4-9). Each lightning protection system is bonded to the main Plant earthing system. Equipment in different EM zones is rated accordingly.

A qualified third party conducts a lightning risk assessment to inform the protection system design and minimise repair costs due to lightning damage.

The earthing and lightning protection systems shall be designed, modelled, installed, tested and certified in accordance with SANS 10142-1, SANS 10199, EN 50522, IEEE 80, SANS 62305, IEC 60364, and Eskom standards where applicable.

## Protection and Control

### Plant Step-Up (PSU) Transformer Protection

MV transformers are equipped with the following protection functions, per ANSI/IEEE Standard C37.2-2008:

* Restricted earth fault (64REF)
* Overcurrent (50/51UAT)
* Buchholz relay for transformer tank (96BT)
* Pressure relief device (63PT)
* Oil temperature alarm and trip (49Q)
* Winding temperature alarm and trip (49W)
* Oil level monitoring (71Q)

All protection functions, integration logic and coordination studies shall comply with ANSI/IEEE C37.2-2008, IEC 60255, the South African Grid Code and applicable NRS standards (including NRS 048 and NRS 097).

### Protection of Electrical Auxiliary Systems

All electrical circuits are protected by relays and appropriate current interruption devices. Minimum protection includes:

* Overcurrent and earth fault protection for feeders
* Auxiliary transformers installed in controlled, naturally ventilated enclosures
* Winding temperature indicators with alarm and trip contacts
* MV standby earth fault (voltage displacement supervision), Buchholz relay, winding and oil temperature monitoring, rate-of-rise pressure protection, and low oil level detection

Protection is implemented using electronic digital relays with built-in testing capabilities that do not interfere with other active protection functions. Relays communicate with the SCADA system for alarm and trip visibility.

MV switchgear protection relays are electronic digital type with continuous self-supervision and SCADA integration.

LV protection relays use conventional relays/releases. Trip and alarm signals are hardwired to SCADA. Feeders up to 25 A use MCBs; feeders from 25 A to 630 A use MCCBs.

Breaker failure protection (50BF) shall be implemented where applicable to prevent backup faults. Monitoring of control supply integrity, including DC undervoltage, earth leakage detection and battery monitoring and Arc flash protection shall be implemented in MV and LV switchboards, including fault detection and rapid tripping capability.

Auxiliary protection systems shall comply with SANS 10142-1, IEC 60255, ANSI/IEEE C37.2, IEC 60947 series (LV switchgear), IEC 62271 series (MV switchgear), and Eskom NRS standards.

# Control, Instrumentation, and Communication Requirements

## Plant Monitoring and Control System Design Philosophy

The control, monitoring, protection, and information management functions for the Plant are managed through the Power Plant Controller (PPC) system, which is located in the control room/building.

The Supervisory Control and Data Acquisition (SCADA) system interfaces with the PPC to enable real-time monitoring and control of all Plant operations. The interface architecture between SCADA and PPC is defined in the system design and ensures seamless communication and data exchange between the two platforms.

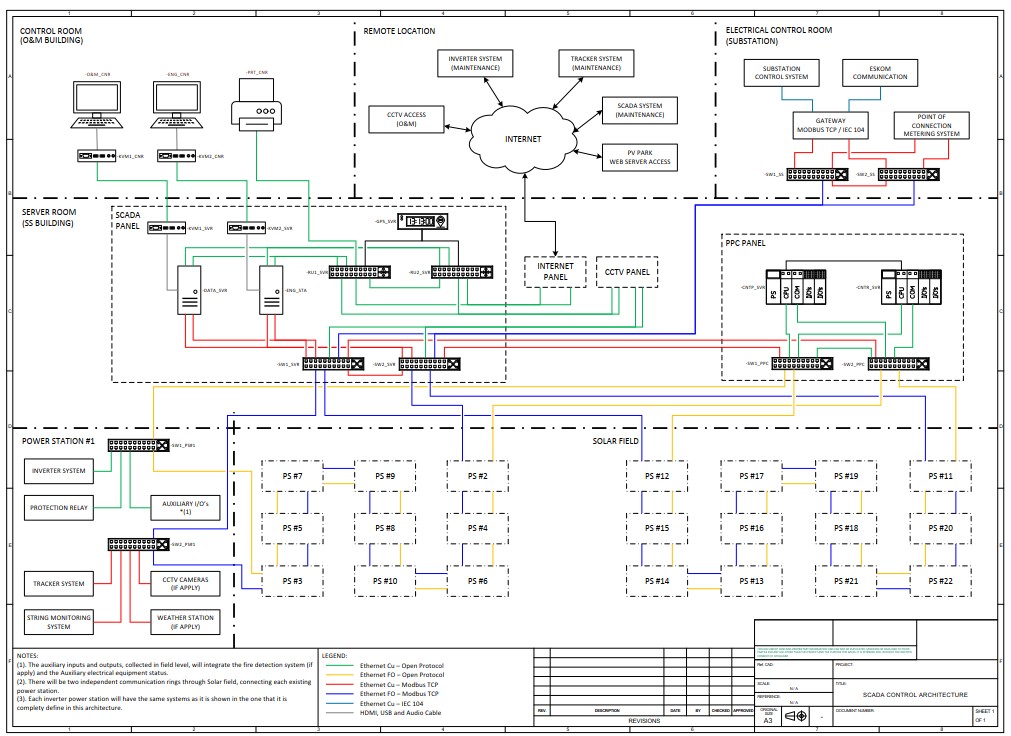


Figure 1 SCADA & PPC Interface Architecture

The monitoring and control system for the Plant is designed to ensure safe, efficient, and reliable operation. The system is managed from the Power Plant Controller (PPC) located in the control room/building and interfaces with the SCADA system.

The design complies with the following minimum guidelines:

* Supports safe and efficient operation of the Plant
* Enables communication with field devices including measuring elements, inverters, string combiner boxes, tracking controllers, protection systems, meteorological stations, field testing equipment, metering systems, and the Plant substation
* Allows remote access and interfaces with the Grid Operator to maintain grid compliance
* Generates comprehensive Plant status summaries to support monitoring, corrective actions, maintenance, and self-diagnosis
* Includes local servers hosting software applications and data storage, with workstations featuring dual 32” monitors, keyboards, and mice for up to six (6) operational staff, and routers for remote internet/web access
* Provides large display screens (minimum 80”) in each control room/building
* Uses MODBUS TCP or RTU for communication with measuring devices, inverters, weather stations, and other control devices. If required, other protocols such as DNP3.0 or SANS 61850-7-420 are implemented via hardware gateways or software drivers
* Employs a distributed node architecture, with LV/MV power stations as communication nodes. Internal communication uses UTP 5e/6 cables or RS-485 cables, as determined by the lightning risk and zoning assessment
* Connects nodes using redundant multimode/single-mode fibre optic (FO) cables
* Collects and stores performance data, including:
* DC string-level current, voltage, instantaneous power, and energy
* AC inverter-level current, voltage, power, energy, and frequency
* Fiscal meter readings and total energy generated
* MPPT parameters, voltage/frequency set points, active/reactive power, and power factor
* Inverter status and alarms
* Meteorological data (temperature, irradiation, humidity, wind speed/direction)
* Alarms from Plant switchgear and transformers

All control and instrumentation (C&I) equipment meets enclosure classifications:

* IP54 for enclosed buildings (per SANS 60529:2013)
* IP65 for outdoor installations
* IP42 for control cubicles in air-conditioned rooms

The system complies with the following Eskom standards:

* Interconnection of Embedded Generation (240–61268576)
* Field Instrument Installation Standard: Junction Boxes and Cable Termination (240-56355815)
* Field Instrument Installation Standard (240-56355754)

## Hardware

### Control Room / Building

The Plant includes a control room designed to accommodate at least two full-time operators per day shift. These operators monitor Plant parameters via integrated graphical displays and respond to alarms or abnormal conditions. Under normal conditions, the Plant operates automatically with minimal intervention.

Inside the control room/building, a 19” rack hosts the monitoring and control system server, long-term data server (RAID), PLC, UPS, and PPC. The console includes:

* Operator workstation
* Desks
* Large display screen
* Printer
* Control, operation, and protection panels

The control system server is fully redundant. Any hardware component that could cause system unavailability upon failure is duplicated.

Communication with solar field circuits and third-party control/monitoring equipment is handled by an industrial manageable switch with sufficient fibre optic (FO) and Ethernet ports, maintaining at least 20% spare capacity for future expansion.

The control room/building is equipped with secure HVAC systems that maintain temperature and humidity within acceptable limits, as required by equipment manufacturers.

The network is arranged in one or more managed closed fibre loops (redundant ring topology). The fibre loop starts at the control room/building, connects each LV/MV power station in sequence, and returns to the control room. Fibre type (multimode or single mode) depends on segment length.

Separate fibre cables—not just separate cores within the same cable—are used to create redundancy. The network operates at Gigabit speed to support monitoring, control, and security data flows without congestion.

### LV/MV Power Stations

Each LV/MV power station includes a monitoring cabinet that houses:

* Power sources
* Electrical protections
* Communication equipment
* Gateways and routers
* FO patch panels and pigtails
* Auxiliary devices as needed
* The cabinet is metallic and rated IP66 if installed outdoors.

Minimum equipment inside the cabinet includes:

* One industrial manageable Ethernet switch
* One FO patch panel
* One RTU/TCP gateway (if required)
* One PLC for data gathering and control (CPU and memory usage not exceeding 60%)
* One power supply

From this cabinet, the following components are monitored:

* Inverters
* Meteorological stations (if applicable)
* Soiling stations
* String combiner boxes (if applicable)
* Trackers (if applicable)
* Transformers and auxiliary equipment
* MV line status
* MV switchgear status

LV/MV power station monitoring and communication systems shall comply with IEC 61439, IEC 61850, IEC 60255, IEC 62305, IEC 62443 (cybersecurity), SANS 10142-1 and Eskom communication requirements.

### Wiring

Wiring specifications are as follows:

* RS-485 cable: 24 AWG, 7-strand tinned copper, 2 twisted pairs, foil and braid shield, chrome grey PVC jacket, AWM Style 2919; EIA-485; CM/CL2
* Fibre optic cable: Used for communication links; Ethernet cable (Cat 5e or Cat 6) used only indoors for distances <100 m
* Data communications cable: Stranded copper AWG 18–22, twisted pair, shielded (e.g., Belden 1120 A or equivalent)
* Outdoor cables are UV-rated, anti-hygroscopic, and vermin-resistant; armoured cable used for direct burial
* Sun-exposed cables are encased in UV-resistant trunking or tubing
* Fiber Optic cable must be loose tube construction
* Fibre Optic cables in trenches are installed in subducts with 100% waterproof joins, suitable for high groundwater areas
* Manufacturer specifications (e.g., minimum bend radius, tensile strength, temperature limits) are followed
* Each cable is visibly marked at both ends
* Wiring materials, routing, segregation, termination and testing shall comply with SANS 10142-1, IEC 60364, SANS 1574, TIA/EIA-568, IEC 61754 (FO connectors), IEC 60794 (FO cables), and applicable OEM requirements.

### Shielding and Grounding System

The shielding and grounding system adheres to and complies with SANS 101421:2021 and the Eskom Standard for Earthing and Lightning Protection (240-56356396).

Grounding, shielding, and treatment of the common reference form a uniform system for the entire C&I system and DC supply throughout the Plant.

To avoid double earthing of cable shields due to earth faults or erroneous connections, a systematic shielding network with easy checking capability is implemented, with only one side of the cable earthed. All applicable standards are considered.

Grounding of all cable shields is done systematically at the relevant terminals on an isolated bar with detachable connections. All isolated shielding bars of individual cubicles connect to a central earthing bar located in the respective Plant’s control room/building, which remains easily accessible for maintenance.

Shielding and grounding systems shall comply with SANS 10142-1:2021, Eskom Standard 240-56356396, IEC 61000 EMC series, IEC 60364-5-54, IEC 60204-1, and applicable SCADA and communication standards.

## SCADA Software

### General Description

The SCADA consists of a software application that collects data from equipment installed in the PV Plant.

The Contractor requests and receives the Employer’s acceptance before using any proprietary software.

The system includes a web-based interface that allows users to operate, monitor, and control the system with appropriate authority levels for ‘viewers’, ‘administrators’, and ‘operators’.

Web-clients are remote users with authorised access to monitor the plant in near real-time via a web browser.

Information displays through graphs, tables, tree-schemes, and drawings. Data exports as text or .xls files for further analysis when needed.

The database is organised in tables. The most important tables include the production table (energy, power, performance, time of operation, and availability of each inverter unit) and the events table (equipment status, diagnosis, and alarms).

A daily report of the previous day’s production is automatically generated and sent via email to authorised users.

The SCADA allows users to perform personalised queries.

The Contractor must designate a contact person for the Employer who will take responsibility for every request about the SCADA system and be the person in charge for every security event relevant to the Employer as well.

### Software Architecture

The SCADA enables communication between field equipment (inverters, meteorological stations, transformers, trackers, and string combiner boxes) and supervisory equipment in the respective Plant’s PPC room/building, and further with soft clients via a web server.

### Network Topology

Network topology refers to the arrangement of devices (nodes such as switches, computers, or PLCs) physically connected in a network.

Four common types of topologies exist: star, bus, ring, and mesh. A hybrid topology combining two or more types is also possible.

The chosen SCADA network topology considers both technical and financial benefits.

* Ring topology connects nodes in a loop. Data transmits from one node to the next until it reaches its destination, traveling in one direction using a control signal called a ‘token’.

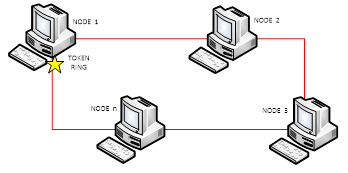


Figure 2 Ring network topology

* Bus topology uses a single cable connecting all nodes. Each end of the bus includes a ‘terminator’ to prevent signal reflection.

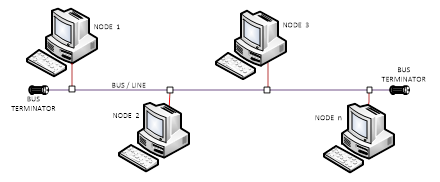


Figure 3 Bus network topology

Although the final topology depends on the Contractor’s design, the preferred solution is to implement a ring topology as the core SCADA LAN. This topology is commonly used in utility-scale solar and wind power plants due to the large distances between network nodes.

The ring topology employs redundancy management protocols that allow logical single fault tolerance over a physical loop using managed Ethernet switches. Its loop architecture results in shorter cable lengths compared to a star topology, reducing cabling costs.

This recommendation is optional and not mandatory.

The bus topology is preferred for communication with field devices such as inverters, string combiner boxes, and weather stations. The widely used data communication standard for this setup is RS-485.

### Internet Connection

The Employer requires a permanent connection to the SCADA via a Virtual Private Network (VPN).

The Contractor provides all necessary devices in compliance with relevant Eskom, national, and international cyber security standards to prevent unauthorised internet access to the SCADA. This includes firewalls, Intrusion Detection Systems (IDS), and Intrusion Prevention Systems (IPS).

The SCADA remains compatible with modern communication technologies for internet access. The web server supports Google Chrome and Mozilla Firefox browsers.

### Network Communication Medium

The data communication medium refers to the physical material through which data transfers.

The data communication networks are configured to eliminate single points of failure within the core SCADA network and optimise traffic flow between devices.

* Fibre optic cables create the core SCADA LAN using managed Ethernet switches and VLANs.
* STP Ethernet cables connect devices within close proximity, with a maximum cable length of 100 m between devices.
* STP cables are also used on RS-485 networks to communicate with field equipment.
* Surge protection equipment is installed on each RS-485 bus network. RS-485 cable segments are limited to 1000 m.

The recommended interface solution for SCADA and BMS connections to external networks for remote signal monitoring depends on the selected solution in the next project baseline.

The current design bases its C&I architecture on a radio link interface solution, as it presents a more complex technical challenge compared to a fibre optic solution.

### Network Diagram

The optical fibre ring serves as the recommended LAN for the reference design. The LAN communicates using the Ethernet standard. The ring network maintains single fault tolerance by employing redundancy management protocols. It forms part of the core SCADA network, enabling data communication between field equipment, SCADA servers, and the Human Machine Interface (HMI). Any fault in a single segment of the ring does not cause data communication failure between the control room and the plant. The core network supports full duplex communication.

Each PV block (i.e., 1 MVA capacity) in the PV plant contains a SCADA network panel that connects the block’s sub-systems to the SCADA network. These sub-systems include:

* Central inverters
* Auxiliary power (LV) and generator transformers (MV)
* Switchgear MCCBs and status indication relays
* String combiner boxes
* Weather stations

The SCADA network panel is installed inside a well-ventilated section of the inverter cabin. The PV plant substation and the Point of Connection (POC) substation each include a SCADA network panel that connects to the SCADA ring network. These panels interface with:

* Switchgear MCCBs and status indication relays
* Energy meters
* Protection systems
* BTUs
* HVAC panel (at the switchgear room)

According to the AC and DC Single Line Diagrams (SLDs) developed for the reference design, the SCADA ring network contains 16 nodes distributed across the following plant areas:

* PV field (10 nodes)
* PV plant substation room (2 nodes)
* O&M building server room (2 nodes)
* POC substation (2 nodes)

One pair (2) of redundantly configured SCADA servers and one pair (2) of redundantly configured network switches are installed in the server room to store plant data, process it, and present information to plant operators via the HMI. A master-slave redundant configuration is used for the dual SCADA servers. Each server includes a plant information server (i.e., database server) that stores all plant production data for the plant’s lifespan.

The plant operates with two operators, requiring two operator systems comprising thin client PCs in the control room. The SCADA software application is installed on the SCADA servers for control and monitoring of all plant equipment.

Operational redundancy ensures that failure of a server, thin client, or network switch does not result in loss of operations or monitoring of the PV plant.

A common network switch is installed in the SCADA network cabinet of the server room to interface with:

* SCADA servers and thin clients
* GPS-based network time synchronisation system
* Programmable Logic Controller (PLC) for data exchange between SCADA and the Distributed Control System (DCS) at Arnot power station
* Eskom IM plant data system at Arnot PS computer room
* SCADA UPS at the PV plant server room
* SCADA network printer

The SCADA firewall, webserver, and VPN gateway ensure highly secure and stable internet connectivity for remote monitoring of the PV plant.

### Design Criteria

The system is developed using the following criteria:

* Availability: Designed to ensure high availability, i.e., greater than 99.9%
* Safe data storage: Prevents data loss by storing data locally and externally, with periodic backups to external hard drives kept in a secure location
* Quick internet access: Provides fast access via web with robust cyber security safeguards
* Scalability: Supports horizontal scalability (expansion of the power plant without major architectural changes) and vertical scalability (addition of new functionalities without major changes)
* Modularity: Built in independent modules to support evolving maintenance and upgrades
* Simplicity: Designed in the simplest way that meets the Employer’s Requirements
* Redundancy: Equipped with redundant configurations for the SCADA, communication network, and field control system to achieve maximum availability
* Open data exchange: Interfaces allow the Employer’s centralized control and monitoring system to exchange real-time and historical data with the Plant SCADA system
* Automatic operation: Supports automatic start-up and shutdown of the Plant
* Resilient field control: Ensures normal operation even if the software communication link is lost
* Compliance: Adheres to the Grid Code, System Operator dispatch requirements, and the Eskom Standard for the Interconnection of Embedded Generation (240-61268576)
* Longevity: Designed for a 25-year operational lifespan from the Plant’s Commercial Operations Date (COD), with adaptability to software updates. The Contractor provides a lifecycle management plan for SCADA hardware and software
* PPC functions: Included in SCADA if required by System Operator Technical Requirements
* User licenses: Provides a minimum of ten user licenses to the Employer, with access restrictions to protect system integrity and prevent unsafe configuration changes
* Technical support: Vendor offers technical support for the system’s operational life. The Contractor provides a lifecycle management plan
* Access rights: Employer receives licenses and access to modify SCADA/PLC and all programmable devices as needed

### SCADA Servers

One pair (2) of redundantly configured SCADA servers operates in a primary-standby configuration. The standby server continues full operation if the primary server fails. A high-speed watchdog interface interconnects both servers to establish a dual redundant configuration.

Each server in the redundant pair includes the following hardware:

* Redundant CPU
* RAID configuration
* Redundant power supplies with dual power input ports
* 19” rack-mountable type enclosure
* On-board memory to continuously process and store all real-time plant data for the plant’s lifespan
* Removable media such as a DVD writer and front-accessible USB ports

The dual redundant SCADA servers perform multiple functions, including:

* Hosting the latest Windows operating system
* Hosting a single SCADA application for operating and monitoring all equipment
* Hosting anti-virus software
* Storing all engineering logic and SCADA network configuration settings
* Processing plant data via redundant information servers and storing it in the CPU database for the plant’s lifespan
* Communicating with thin clients for plant operation and network configuration
* Managing network configuration, logic development, mimic development, antivirus, and software updates
* Running OPC protocol software to enable communication between multi-vendor systems and remote data transmission to Eskom PDS in MWP via the PDS network at Arnot power station
* Automatically copying data from the CPU’s built-in historian to removable media at preconfigured intervals
* Saving information, backing up data to removable media, closing all running applications, and shutting down the CPU in an automatic sequence upon detecting loss of input power to the UPS system

The operating system and application software versions are confirmed during tender clarifications.

### Operator System Thin Clients

Two (2) thin client machines serve as the operator HMI for the SCADA network. Each thin client is configured to operate and monitor the entire plant with full functionality. Both machines run simultaneously, providing 100% operational redundancy.

Thin clients 1 and 2 connect to the following HMI peripherals, respectively:

* 3 × 24” LCD monitors
* 1 × 50” LCD monitor
* Built-in DVD writer
* 1 × USB keyboard
* 1 × USB mouse

### Installation of Thin Clients

Thin clients are installed in the server room. They may be tower type or 19” rack type, mounted in the network cabinet. KVM (Keyboard, Video, Mouse) extenders are used to extend peripheral access between the thin clients in the server room and the HMI peripherals in the control room.

Using KVM extenders allows installation of thin clients in a controlled environment, maintaining a fixed operating temperature. This ensures equipment longevity and allows the control room temperature to be adjusted for operator comfort. The trade-off is the additional cost of the KVM extenders.

### Network Switches

Industrial Ethernet network switches are installed to facilitate communication between multiple network nodes. Each switch includes, at minimum:

* Managed type with Redundancy Management (RM) capability
* Configuration via SCADA servers and thin clients
* Monitoring of port connections, communication link status, bandwidth, and device health, with alarms and fault indications sent to the server and remote users
* Compatibility with SNMP v3 and IPv6 or other acceptable protocols
* Power supply from dual redundant sources (230 Vac or 24 Vdc)
* Dual power input ports
* DIN rail mounting in SCADA network panels (see Section 12.3.4), or 19” cabinet mounting for switches in the server room
* Minimum IP20 ingress protection rating
* 20% spare network ports (rounded up)
* Wide operating temperature range for outdoor installations
* Optical fibre and Ethernet ports
* Auto negotiation
* Auto crossover (MDIX)

### SCADA Network Panels

The SCADA network panel will be installed inside each inverter cabin and the switchgear rooms of the Project. The network panel will be IP54 rated. The following equipment should be considered for installation inside each SCADA network panel:

* A managed type network switch with Ethernet and optical fibre ports;
* Network protocol or medium convertors (e.g., RS485 to Ethernet);
* Digital or analogue input or output (I/O-Ethernet modules) to measure signals from the ambient air temperature and relative humidity sensors inside each SCADA network panel;
* An optional PLC with on-board I/O cards and protocol converters;
* Splice trays for fibre optic cables (located in a separate compartment of the network panel);
* Cable channels, terminal strips; and,
* 24 V DC DIN rail mount power supplies.

All electronic equipment installed inside SCADA network panels will be suitable for continuous operations in an uncontrolled environment subjected to wide temperature ranges (i.e., between 40˚C to +65˚C).

The PLC will replace the dedicated I/O-Ethernet modules and protocol convertors. Each PLC will include an OPC client-server application to allow connectivity to multi-vendor systems.

The panel will be designed such that the following equipment is physically segregated from each other within the panel:

* Electronic network equipment (switches, protocol or media convertors, I/O cards, PLCs, internal temperature sensors, etc.);
* Power supply and associated equipment (MCBs, SPDs, etc.); and,
* Splice trays and patch panels for optical fibre cabling.

### Server Room Network Cabinets

The SCADA servers, thin clients, redundant network switches, and UPSs will be installed in 19” racktype network cabinets. It is preferred that patch panels be mounted in separate network cabinets from the servers. The server room network cabinets will have the following characteristics:

* Network and power cabling will be bottom entry;
* Grommets will be installed where panels are cut for communication and power cable entry;
* Internal cable channels or traces to neatly route cables inside the cabinet;
* Removable blanking panels on all unused slots or sections;
* Free space of approximately 200 mm to allow air circulation around cables in the rear;
* Perforated front and rear door panels and side panels to allow circulation of air;
* Flexible brushes to be used to prevent air leakage via cable entries or cut-out;
* Include 19” racks and DIN rails to mount equipment;
* Removable front and rear door panels;
* Doors with manual locking mechanism and automatic open/close detection;
* Internal lights for illumination;
* IP 20 rating;
* 20% uninstalled space on the racks and DIN slots to install spare equipment;
* Internal air temperature and relative humidity sensors monitored and alarmed on the network cabinet (local) and at the BMS HMI. Internal temperature to be controlled at 22 ˚C ± 2 ˚C; and,
* Suction and extraction fans for forced air circulation.

As far as possible, all connectors on rack mounted components must be rear facing in the cabinet for easier cable management.

### SCADA functions

The main SCADA functions shall include the following:

* Monitor and control of every local electrical equipment;
* Interface with PPC;
* Ancillary services and Automatic Generation Control (if required);
* HMI interface;
* Central historical logging;
* Open Data Exchange (including full remote access);
* Interface with Grid Operator system for remote monitoring and load dispatch;
* The local data acquisition and controls (SCADA) system uses standard and open protocols: Modbus, DNP3, SANS 61850-7, IEC 60870-5-101/104, and OPC;
* The SCADA system must provide open port, e.g., Modbus TCP/IP, for collecting site data from third party data-loggers;
* All licenses required to operate the system for the duration of the 25 years Plant lifetime;
* Easy WEB access to the entire SCADA system from any PC, Mac, smartphone, or tablet;
* Safe connection at least via https;
* SANS 61724-1:2019 compliant (Photovoltaic system performance – Part 1: Monitoring);
* Utility integration: the system acquires and makes available the data required by the local utility (i.e., System Operator) and is compliant to the local grid interconnection requirements.
* Asset Management systems integration (cloud platforms): the system can exchange data virtually and on any Cloud platform, Employer’s Central SCADA or DIST Control Centre without extra costs;
* Situational awareness: the system provides an easy overview of the main KPIs and the status of all the elements of the Plant;
* Automatic report generation: the system generates automatic production reports avoiding repetitive tasks;
* Remote desktop control software, such as Teamviewer or Anydesk, installed on a local computer;
* Dedicated software accessible from the WAN;
* Dedicated VPN; and,
* SCADA server & workstations to run on the latest Microsoft Windows Operating system.

### Commands Requirements

The SCADA system shall allow central and remote automatic and manual control.

Remote control shall only be through the DIST NSP interface gateway for specific remote-control functions as required by the Grid Code.

To ensure safe working conditions in the Plant, it must be possible to set, by a selector in the SCADA HMI, the equipment in ‘service mode’ in case of maintenance activities in the Plant or in the electrical substations. This action shall disable the remote controlling of the electrical equipment in the power plant. (This service shall not replace a Permit-to-Work or trapped key interlock system).

The SCADA system shall be able to set the tracker tilt angle to predefined set points (if a tracker mounting structure is used). Rejection of invalid commands and set points must be communicated clearly to the operator.

All commands and set points activation must be stored in the event log with information on the operator who activated the command and set point.

Remote control function shall be protected by a password in the SCADA central monitoring system.

The system shall be equipped with a PA system.

The SCADA and PPC shall allow for automatic start-up of the PV Plant after a grid failure or downtime. This is performed by internal functionality and backup power sources.

Every command will be tested during the implementation and the commissioning of the SCADA system.

The following commands shall be checked and respected by the system:

* It must not be possible to exceed min/max limits when entering new parameters;
* When commanding, interlocking (local/remote switch) functions must be respected;
* When the PPC is in local mode, remote commands must be rejected;
* The following commands and set points must be available for the entire Plant:

− Set points according to the Grid Code;

* The following commands and set points must be available for the Plant’s controller:

− Points for active power, reactive power, power factor, voltage, frequency, and ramp control; and,

− Close circuit-breakers and disconnectors of the electrical substation.

* All commands and set points require confirmation from the operator (both remote and local) before activation;
* The SCADA shall provide at least the following control capabilities:

|  |  |
| --- | --- |
| − | Enable/disable inverter operation of any individual unit or of all units; |
| − | Set inverter real power limit; |
| − | Set Plant active / reactive power control; |
| − | Set Plant power factor; |
| − | Set Plant ramp control; |
| − | Set Plant frequency control; |
| − | Set Plant voltage control; |
| − | Emergency disconnection; |
| − | Ancillary services; and, |
| − | Automatic Generation Control. |

### Monitoring System

#### Data Acquisition

The system shall acquire data from:

* Meteorological station;
* Soiling station;
* Inverters;
* Trackers (if applicable);
* String combiner boxes (if applicable);
* Transformers;
* MV switchgear;
* Fiscal meters and accredited meters;
* Contacts from auxiliary equipment;
* Plant substation SCADA;
* Plant protection and control system; and,
* Security system.

Data shall be acquired and recorded at least with the following time steps as minimum requirement and the record time interval shall be adjustable and shall be decided during the project detail engineering stage:

* The main AC meter data shall be recorded at one (1) minute intervals;
* DC meter data shall be recorded at one (1) minute intervals;
* Inverter data and fault codes shall be recorded at one (1) minute intervals; and,
* Environmental data shall be recorded at one (1) minute intervals.

The parameters to be monitored shall be agreed at a later stage during the detail engineering phase. As a minimum the signals included in the list below shall be gathered by the monitoring system:

* Fiscal meters and accredited meters

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| − | Active energy; |  |  |  |  |  | kWh |
| − | Reactive energy; |  |  |  |  |  | kVArh |
| − | Active Power; |  |  |  |  |  | kW |
| − | Reactive Power; |  |  |  |  |  | kVAr |
| − | Voltage L1, L2, L3; |  |  |  |  |  | V |
| − | Voltage L12, L23, L31; |  |  |  |  |  | V |
| − | Current phase L1, L2, L3; |  |  |  |  |  | A |
| − | Frequency; |  |  |  |  |  | Hz |
| − | THD-R current L1, L2, L3; |  |  |  |  |  | % |
| − | THD-R voltage L1, L2, L3; and, | |  |  |  |  | % |
| − | Power factor. | |  |  |  |  | Lag/Lead |

* Plant protection and control system

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| − | Active energy; | |  |  | kWh |
| − | Reactive energy; | |  |  | kVArh |
| − | Active Power; | |  |  | kW |
| − | Reactive Power; | |  |  | kVAr |
| − | Grid voltage L1, L2, L3; | |  |  | V |
| − | Grid voltage L12, L23, L31; | |  |  | V |
| − | Current phase L1, L2, L3 at the POC to the grid; | |  |  | A |
| − | Grid frequency (Hz); |  |  |  | Hz |
| − | Over/Under Voltage trip; |  |  |  |  |
| − | Over/Under Frequency trip; |  |  |  |  |
| − | Voltage unbalance trip; |  |  |  |  |
| − | Vector shift protection trip; |  |  |  |  |
| − | Rate of change of frequency protection trip; |  |  |  |  |
| − | Trip due to directional overcurrent limit; |  |  |  |  |
| − | Neutral voltage displacement trip; |  |  |  |  |
| − | Earth fault current limit trip; |  |  |  |  |
| − | Ground surge time-overcurrent protection trip; |  |  |  |  |
| − | Overcurrent limit trip; |  |  |  |  |
| − | Time-overcurrent protection trip; |  |  |  |  |
| − | Current unbalance trip; |  |  |  |  |
| − | Capacitive/Inductive PF limit protection trip; |  |  |  |  |
| − | Trip due to reaching the No AC Reclose limit; |  |  |  |  |
| − | Low Backup battery; |  |  |  |  |
| − | Over or undervoltage of the power supply; |  |  |  |  |
| − | Phase sequence is correct/opposite with antiphase; and, | |  |  |  |
| − | Remote / manual opening of CB. | |  |  |  |

* Inverters

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| − | DC Current (total and per phase per inverter module); |  |  | A |
| − | DC Voltage; |  |  | V |
| − | DC Power; |  |  | kW |
| − | DC Power (1m); |  |  | kW |
| − | AC Current; |  |  | A |
| − | AC Current L1, L2, L3; |  |  | A | |
| − | AC Voltage; |  |  | V | |
| − | AC Voltage L1, L2, L3; |  |  | V | |
| − | AC Voltage L12, L23, L31; |  |  | V | |
| − | AC Power; |  |  | kW | |
| − | AC Power (1m); |  |  | kW | |
| − | AC Power L1, L2, L3; |  |  | kW | |
| − | AC Reactive Power; |  |  | kVAr | |
| − | AC Apparent Power; |  |  | kVA | |
| − | AC Frequency; |  |  | Hz | |
| − | AC Power factor; |  |  |  | |
| − | Operating hours; |  |  | h | |
| − | Insulation Resistance DC; |  |  | Ohm | |
| − | Inverter internal and main component temperature; |  |  | °C | |
| − | Inverter Status / Alarms; |  |  |  | |
| − | Temperature protection activation; |  |  |  | |
| − | Inverters On/Off switch indication and activation; |  |  |  | |
| − | DC/AC fuse status, if possible; |  |  |  | |
| − | Inverter internal failure – error code; |  |  |  | |
| − | Ground fault protection; |  |  |  | |
| − | Humidity control; |  |  |  | |
| − | Emergency stop; |  |  |  | |
| − | General AC & DC protection & disconnection; |  |  |  | |
| − | Module AC & DC protection & disconnection; |  |  |  | |
| − | Overvoltage protection; and, |  |  |  | |
| − | Lightning protection. |  |  |  | |

* DC String Combiner Boxes (if applicable)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| − | String Current (per string) ; |  |  |  | A |
| − | Total output current; |  |  |  | A |
| − | Total output voltage; |  |  |  | V |
| − | Total output power at the boxes; |  |  |  | kW |
| − | Internal enclosure Temperature (if available); |  |  |  | °C |
| − | DC fuses status, if available; and, |  |  |  |  |
| − | SPD status, if available. |  |  |  |  |

* Weather Station

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| − | Global horizontal Irradiance; |  |  |  |  | W/m2 |
| − | Plane of Array Irradiance; |  |  |  |  | W/m2 |
| − | Ambient temperature; |  |  |  |  | °C |
| − | Photovoltaic module temperature | ; |  |  |  | °C |
| − | Wind speed; |  |  |  |  | m/s |
| − | Wind direction; |  |  |  |  | grades |
| − | Humidity; |  |  |  |  | % |
| − | Precipitation quantity; |  |  |  |  | mm |
| − | Precipitation type; |  |  |  |  | Rain/Snow |
| − | Hailstorm sizes; |  |  |  |  | mm |
| − | Ambient air pressure; |  |  |  |  | hPa |
| − | Maximum power of soiled and cleaned reference module; | | | |  | W |
| − | Short-circuit of soiled and cleaned reference module; and, | | | |  | A |
| − | Temperatures of soiled and cleaned reference module, if available. | | | | | °C |

* Transformers

|  |  |  |  |
| --- | --- | --- | --- |
| − | Winding temperature; |  | °C |
| − | Oil temperature; |  | °C |
| − | Internal enclosure temperature (above transformer), if available; |  | °C |
| − | Buchholz relay status; |  |  |
| − | Over oil temperature (1st set); |  | °C |
| − | Trip max. oil temperature (2nd set); |  | °C |
| − | Oil level; |  |  |
| − | Winding temperature; |  | °C |
| − | Gas pressure; and, |  | Pa |
| − | Pressure relief valve. |  |  |

* Switchgears / RMU

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| − | Internal enclosure temperature, if available; |  |  |  | °C |
| − | Circuit Breaker status – OPEN/CLOSED; |  |  |  |  |
| − | SF6 Gas level low alarm; |  |  |  |  |
| − | External trip signal from transformer; and, |  |  |  |  |
| − | Spring fail-to-charge alarms. |  |  |  |  |

* UPS system

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| − | Battery level; |  |  |  |  | V / Ah |
| − | Battery temperature; |  |  |  |  | °C |
| − | Battery level status; |  |  |  |  |  |
| − | Battery temperature status; and, |  |  |  |  |  |
| − | Failure alarms. |  |  |  |  |  |

* Electrical components and other signals and parameters

|  |  |
| --- | --- |
| − | Emergency stop status; |
| − | Surge arrester status; |
| − | Circuit breaker status; |
| − | Switch status; |
| − | SPD status; |
| − | Enclosure dehumidifier station status; |
| − | Enclosure heater station status; and, |
| − | Enclosure fan station status. |

SCADA shall be able to periodically send these files to an external system. In case of hyper vision, the period of sending can be once a day.

* At least one FTP server for Employer services (external system);
* An e-mail with standardized subject and content and an attached file; and,
* SFTP server

#### Calculated Points

The system shall generate calculated data points that show new values based on the values of any monitored or calculated data points. Calculated data points shall be available for alarming and trending.

#### Real-Time Supervision

The system shall allow the user to monitor and supervise the equipment of the Plant by the means of diagrams or graphs in real time.

Alarms shall arise when they happen in order to allow for corrective actions.

The system should include tools to allow for queries and to generate reports that help the Operator to evaluate the performance of the Plant.

The system shall manage all alarms generated by field equipment, sort them by sequence of events with a time stamp and alarm severity, and show them to the Operator.

The CPU and memory loading of the system shall not be greater than 60% of its capacity.

The card slots in the SCADA data server cabinets shall be in accordance with the total number of I/O signals required, plus 20% of the installed spare signals accommodated, plus 15% of the slots for additional cards.

#### Historians

The system shall allow data storing by means of the long-term data servers via the RAID station installed in the SCADA monitoring and control system server rack. The servers shall be capable of storing and reporting data points at intervals of one (1) minute for the first three (3) years, every five (5) minutes subsequently up to the first 10 years and every 15 minutes for the remaining duration until the end of Plant operation.

#### SCADA HMI

The SCADA shall have at least the following views and screens:

* Overview based on the Plant layout;
* SLD;
* Device detail: the Operator shall be able to access every device (inverter, tracker, weather station, etc.) on a separate screen. Every device’s screen shall show alarms, operating parameters, control functions, status, etc.;
* Inverter summary: it shall include operating status, operating parameters, power factor, alarms, alerts, AC voltage and current, DC voltage and current, etc.;
* Communication status: it shall indicate the communication status of every device;
* Alarms: it shall provide an alarm list showing status and acknowledgment;
* Performance: it shall show the available solar resource, project output, and comparison of actual to expected output. The performance screens shall allow viewing for a single day, past week, past month, month to date, past 24 months, and year to date performance summaries;
* Trending: The user shall be able to configure and graph all monitored data over relevant time frames at a minimum of five (5) second interval. The SCADA system shall allow users to save trend screens for future re-use;
* Alarm configuration. The Operator shall be able to set thresholds for alarms on any monitored data point, alarm level, and notification options;
* System view: only accessible via administrator role to allow programming or any other system modification; and,
* Customized development of the HMI GUI will be conducted through a minimum of five (5) full-day workshop engagement sessions between the Contractor and the Employer prior to acceptance of the GUI.

The HMI GUI will conform to proven and best industry practices for utility scale PV plant SCADA systems.

The Eskom 240-56355728 HMI Design Requirements Standard shall be adhered to for:

* Alphanumeric characters;
* Numeric data;
* Abbreviations and acronyms;
* Labels;
* Icons and symbols;
* Colours for HMI graphics;
* Cursors;
* HMI graphics;
* Menus;
* Windows; and,
* Errors.

The GUI will display the following information as a minimum:

* Main Overview Window:

|  |  |
| --- | --- |
| − | Plant map window showing all PV blocks, and summary information of each block; |
| − | Plant control window (i.e., voltage, current, frequency, setpoints, etc.), Automatic/Manual control mode, Local (Plant Operator) or Remote (SO) Control selection, and status; |
| − | Status of main MV/HV breakers/isolators; |
| − | Summary alarm list showing high priority and rationalised alarms; |
| − | Trend with irradiation and power values of the Plant; |
| − | Radar indicating power, irradiation, and availability of each PV block; |
| − | Plant meteorological values; |
| − | Plant Performance Ratio; |
| − | Redundant hardware status; and, |
| − | Selection of any graphic on the Main Overview Window will take the User to a more |

detailed graphic of information for the selected window.

* Plant Map Window:

− Displays the geographical and physical arrangement of all the PV blocks on the Plant; and,

− Any fault or alarm on a specific PV block will cause the block to indicate so in a different colour on the block.

* Plant Control Window:

− Monitoring and control parameters for control functions as required by the SAGC for RPP and the Eskom Standard for the Interconnection of Embedded Generation (24061268576);

− Remote/Local control mode selection and indication; and, − Automatic or manual mode selection and indication.

* Plant Blocks Windows:

− Displays greater detail of information pertaining to each PV block based on the PV block layout; and,

− Clicking on a sub-system within the PV block will open the Field Device Window displaying information relating to the Field Device (e.g., Inverter detail, Combiner box detail, tracker system detail, etc.).

* Plant Electrical Line Diagram Window:

− Displays the entire electrical reticulation of the Plant; and,

− Clicking on a specific switchgear, transformer, meter, etc., shall open the Field Device Window displaying information relating to the specific device.

* SCADA Network Line Diagram Window:

− Displays the entire SCADA network of the Plant; and,

− Clicking on a specific network device (e.g., network switches, Server, Control Systems) will open the Device Window displaying information relating to the devices, etc.

* Meteorological System Windows:

− Displays all the Plant meteorological parameters.

* Solar Tracker Systems Windows:

− Displays the angular position of all trackers, faults, etc.; and,

− Selection of a tracker provides a Window to manually operate the tracker. Operator selected setpoints can be inserted and the position feedback displayed.

* String Combiner Box Windows:

− Displays the individual string input values;

− Displays the total output values;

− Displays any other status indications of the string combiner box; and, − Bar graph representation of string values.

* Auxiliary and Ancillary Services Windows:

− Displays the indications of the UPS;

− Displays the indications of the Auxiliary power distribution boards;

− Displays the indications of the equipment environmental condition monitoring systems;

− Displays the indications of the Potable Water and Sewage Treatments systems; − Displays the indications of the Fire Detection and Alarm system; and, − Displays the indications of the HVAC systems.

* Alarms Window:

− Displays all alarms that require operator intervention;

− Alarms shall automatically be ordered according to their priority; and, − Clicking on an alarm will provide an Alarm Response Window.

* Individual Alarm Response Window:

− Displays the possible causes of the alarms;

− Displays the mitigation actions to attend to the alarm;

− Includes a facility to supress or disable a nuisance alarm for a temporary period; and, − Historical alarms over a defined calendar period must be available for display.

* Trend Window:

− Includes real time trending of user selectable parameters;

− Includes historical trends of user selectable parameters over a defined calendar period; and,

− Each parameter must be dearly distinguishable in colour from the other parameters.

#### Cyber Security

The cyber security system must adhere to, and be in compliance with, the Eskom Cyber Security Standard for Operation Technology (240-55410927).

The system shall be protected from undesired and malicious access by means of a firewall in accordance with the Eskom governance documents for OT/IT systems, antivirus, and a complete role management. Remote control function shall be protected by a hard key or dongle in the Plant SCADA. Adequate interlocks shall be provided to prevent unsafe operation of Plant while personnel are working on the equipment.

Parameterization and configuration modification can only be done by authorized users, accessed using passwords.

### Reports

The SCADA system shall record and report all necessary operational details obtained and process data into information for the warranty agreements.

The software provided shall be capable of undertaking the warranty calculations and providing daily/monthly/yearly operations and management reports to an agreed format.

The SCADA shall be capable of producing reports for evaluation of Availability and analysis of the Performance Ratio. It shall be capable of providing supporting data as required for O&M reporting. The Performance Ratio shall be calculated and created for any user selectable date range, irradiance range and active power range. The Availability calculation shall be done according to the contractual formula as defined in the Contract. Additionally, calculations shall be made on definitions that are generic, transparent, unambiguous, and based on realistic measurements. All records of inverters in the historical data (5 minutes data) shall be recorded and assigned to the required categories as defined in the contracts. The Availability shall be calculated over any time period (although typically one (1) year).

The SCADA HMI must provide a tool for generating the Performance Ratio for the inverters and Plant.

Summary analysis reports for daily/monthly/yearly or other defined time periods shall be automatically produced in an agreed format. They should be produced on demand or automatically at set times. They should provide extensive analysis and viewing functions for statistical and event data.

### Documentation

The SCADA shall be supplied with comprehensive, complete, and up-to-date documentation relevant to all the hardware and software supplied (documents in PDF format, in modifiable format, and USB flash drive for software installed).

This will include at a minimum:

* A comprehensive user manual explaining the operation and use of all hardware and functions (installation, operation, and maintenance manual);
* A complete electrical wiring diagram showing connections to the controller and the communications links;
* System architecture layout, detailing the port used in each device, colour topology according to the protocol of each network communication, types of protocols used, IP address of the machines, type of connector in the end of the connections, and model of each;
* Functional drawing for every panel;
* Location of all the accessories;
* Data sheet of each equipment and device;
* Lists of signals for each communication channel (variables of the Plant and of electrical substation, list of signals available for the Control Centre of the Employer);
* Quality control, installation, and commissioning documentation including detailed test procedures;
* List of licences provided by the Contractor; and,
* List of passwords issued to the Employer.

Manuals regarding the maintenance of equipment shall be supplied in English.

### Incident Handling

The Contractor must implement an incident handling policy to determine:

* What actions to take when an incident is detected;
* Whom to alert;
* Who should coordinate crisis management actions; and,
* What initial steps should be taken.

The Contractor must also complete a post-incident analysis to determine the source of the incident, whether it can spread to other parts of the system, and how to improve the SCADA system’s overall (cyber)security.

### Hardening Workstations

SCADA workstations must be hardened to reduce the scope for attack:

* Unnecessary or unused physical ports (hardware) (debugging interfaces, USB ports, Ethernet interfaces, etc.) shall be deactivated;
* Unnecessary or unused services, functionality, and software (Telnet, FTP, service discovery, network services, development tools, etc.) must be deactivated and, if possible, uninstalled;
* All access must be protected by, at a minimum, a hardened password (as applicable) and must be restricted to the authorized persons;
* Anti-virus software must be installed; frequent updates shall be done in a controlled manner without direct access to the internet. Centralized monitoring and logging are required;
* The security flaws which are discovered and available security corrections must be provided to the Employer through the dedicated contact person;
* The services and applications must be executed with the minimum necessary privileges (for example, not under an administrator account); and,
* Compliance shall be in accordance with the Eskom cyber security Standards and an assessment report after the installation shall be provided.

The Contractor must create white lists of authorized applications to prevent the use of unauthorized software. If not, it must specify what other steps it will take to detect unauthorized software use.

### Data Backup

Full data back-up facilities shall be provided. To eliminate the impact of a physical incident (theft, fire, etc.), the backup system must be stored off-site which shall be approved by Eskom’s IT Department.

An automatic backup system shall be provided with the SCADA system. Files and directories to be saved shall be listed and documented. A clear separation between database and the executable programs would be advantageous.

A procedure for a manual backup and to modify the configuration of the backup shall be provided by the Contractor to the Employer.

A recovery procedure shall be provided to fix the SCADA database in case of corruption.

The copies of backup must be retained at minimum for a period of five (5) years.

### Response Times

All hardware and software will be specified to achieve the following response times:

* The response time for Command outputs (running time command from the HMI up to signal change at the Field Device) must not exceed 2 s;
* The response time for updating of variables in HMI displays (running time of signal from signal change on the Field Device up to change of the appropriate variables on the video display) must not exceed 2 s;
* The maximum time taken to completely populate an HMI graphic with dynamic data shall not exceed 2 s;
* The average time taken to completely populate any HMI graphic with dynamic data shall be less than 1 s;
* The maximum time taken to completely populate a trend with dynamic data shall not exceed 3 s; and,
* The average time taken to completely populate any trend with dynamic data shall be less than 1.5 s.

## Monitoring and Control System External Interfaces

The monitoring and control system shall allow the interfaces with the third parties as necessary via redundant links. Some third-party system as envisaged is listed below; however, it is the Contractor’s responsibility to ensure the interfaces satisfy the specific requirements for this project:

* Interface to the Plant substation control and monitoring system;
* Interface with the electricity metering system; and,
* Interface Plant office LAN system and other control and surveillance systems (such as fire detection system and security system) (CCTV surveillance to be on separate network to the Plant SCADA system).

The system shall be secure such that security breaches of the Plant’s monitoring and control system do not influence the Grid Operator’s system and the Employer’s existing systems to which the PV Plant interfaces.

### Inverters

Inverters include their own built-in control and protection system. The on-site SCADA will interface to the inverter control system to monitor data in real time. Open/close commands will be sent from the SCADA thin clients to start/stop the central inverters from the control room.

Inverters shall comply with IEC 62109, IEC 62116, IEC 61000, NRS 097-2-1/-2-3, the South African Grid Code, and OEM specifications, and shall support full SCADA visibility and control.

### DC String Combiner Boxes

DC SCB used in solar PV plants combine multiple parallel strings from the PV array. The combined DC power is supplied over a single DC cable to an inverter, or a second combiner box. Intelligent DC combiner boxes are installed with measurement and data communication capabilities to monitor individual string current, average DC voltage, isolation switch status, and the internal temperature of the box.

DC string combiner boxes shall comply with IEC 61439, IEC 60269 (fuses), IEC 60364-7-712, IEC 61000 series (EMC), SANS 10142-1-2, NRS 097-2-3, and OEM specifications.

### Switchgear

MV switchgear panels at the inverter cabins, the PV plant switchgear room, and at the Point of Utility Connection (PUC) will be controlled using Motorised Controlled Circuit Breakers (MCCB). The plant SCADA will interface to the switchgear panel to monitor the status of the MCCBs. Command to open/close each MCCB will be initiated via the plant SCADA at the control room. The switchgear panel will include 24 V DC interposing relays to allow the SCADA to interface using digital I/O cards with potential free terminals. This method is commonly known as hardwiring.

Emergency or protection stop/trip signals will be hardwired from the push button switch directly to the switchgear breaker. No emergency or protection trip/stop commands will be communicated to the switchgear via the SCADA network.

Switchgear design, installation, interlocking and control systems shall comply with SANS 10142-1, IEC 62271-200, IEC 61439-2, IEC 60255, IEC 61850, and Eskom standards for protection and control systems.

### Energy Meters

Energy meters installed at the PV plant substation and the POC are required to communicate data to the on-site SCADA. The energy meters at the POC are required to include at least two (2) spare Ethernet ports for direct connection to a laptop and for future integration to the Power Station.

One energy meter, main and check meters, and a power quality meter are required for energy measurements at the POC. The metering and measurement requirements will be as per Eskom Standard, 240-56359083, Metering and Measurement Systems for Power Stations in Generation.

The meter shall provide tariff metering, bi-directional energy measurements, and power quality measurements. The meters procured must be listed in the Eskom standard 240-56227589 list of approved electronic devices to be used on Eskom Power stations. The scope for the PV Project is therefore to cater for meters and Ethernet cables that meet the above requirements inclusive of the referenced standards. For standardization, same type meters should be used at the POC and at the PV plant.

There is a project aimed at installing a dedicated stand-alone Energy Management and Data Acquisition System (EMDAS) at Eskom’s generating plants. This will be applicable to Arnot Power Station. The energy meters that the PV project must cater for should allow for the interface to EMDAS and the PV plant SCADA. The purpose of EMDAS is to ensure that accurate, reliable and auditable metering data is stored, archived, and provided to the power station and Eskom as a whole. The energy meters must have bus interface capabilities using open published communication protocols such as Modbus, DLMS COSEM, or DP. To access EMDAS, the meters will be connected to the nearest secure network point through an Ethernet cable.

Energy metering and power quality monitoring shall comply with IEC 62053-22/-23, IEC 61000-4-30 Class A, IEC 61869, IEC 62351, Eskom Standard 240-56359083, approved device list 240-56227589, and all applicable Grid Code requirements.

### Building Management System (BMS)

As part of the C&I scope of work, the BMS is a standalone network system that monitors and controls the balance of plant services such as fire detection and HVAC systems. The BMS network will be made up of the following equipment:

1. BMS server

The BMS server will comply with the requirements as specified in section 12.3.8 SCADA Servers

1. BMS network switch

The BMS network switch will comply with requirements as specified in section 12.3.11 Network switches

1. BMS network cabinet

The BMS network cabinet to comply with the requirements as specified in section 12.3.13 Server room network cabinet

1. BMS thin client

The BMS thin client to comply with the requirements as specified in section 12.3.9 Operator system thin client. The BMS thin client will include 2 x 24” LCD monitors.

1. Datalogger/IO/PLC

The datalogger will be used to monitor the temperature sensors of the network cabinets and the level sensors of the potable water and sewage tanks.

The PV plant BMS network will connect to the following systems:

#### Fire Detection System

A Fire Detection System (FDS) will be installed as part of the Project. The PV plant FDS is required to be monitored at the PV plant control room.

A detailed fire risk assessment will be conducted by the Contractor to determine the type and number of sensors, warning indicators, and fire panels that will be required prior to the design.

The PV plant O&M building, substation, and all inverter cabins require monitoring and alarming as part of the FDS. Real time data and alarms of the FDS will be monitored and stored.

The number of fire panels used will be dependent on the design layout of the plant. The master fire panel will be installed inside the PV plant server room. Communication between fire panels will be via optical fibre if multiple fire panels are required to be installed on the PV plant. The fire panel is required to have an on-board display and siren for local monitoring and alarms. The fire panel is required to be monitored at the PV plant control room via a local BMS HMI. The fire panels will be powered from a highly available auxiliary power source. The fire panels will include an internal backup power supply with a battery.

The design and installation of the FDS will be carried out by a company that is registered by SAQCC and the FDIA.

Due to the plant operators not working on a 24 h basis, an interface is required to enable the Arnot Power Station first response to react in the event of a fire.

#### Heating, Ventilation, and air-conditioning (HVAC) system

The indoor conditions and areas to be provided with HVAC systems include the following (Table 6):

Table 4 Indoor conditions and areas to be provided with HVAC system

|  |  |  |
| --- | --- | --- |
| **Area/Building** | **Indoor Temperatures** | **Relative Humidity** |
| 1. O&M Control room | 22°C±2°C | Not Controlled |
| 2. O&M Server Room | 21°C±2°C | 50% ± 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 |

The HVAC control system is required to be monitored at the PV plant control room via a dedicated BMS HMI. Data and alarms of the HVAC control system will be monitored and stored. Typical parameters include:

* System fault;
* Air flow;
* Pressure;
* Temperature; and
* Humidity.

In the event of a fire, the PV plant BMS will command the HVAC control system to close the fire dampers to contain the fire and smoke.

The master HVAC panel will be installed inside the PV plant server room and interface with the other HVAC panels and the BMS server.

System Description:

The O&M Control room is to be serviced by two (2) off-dedicated direct expansion split units complete with an evaporator and matching air-cooled condensing units. The cooling and heating plant is based on air-cooled outdoor units which are connected to an indoor unit via a single refrigerant circuit, comprising suction, and liquid refrigerant pipework. Both the indoor and outdoor units are inverter type units which provide space cooling or heating depending on the individual space requirements.

The O&M Server Room will be equipped with running and standby under ceiling type indoor units together with air-cooled outdoor units. The HVAC equipment will 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 will be supplied complete with cooling and pressurisation functions. The filtration system will 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 will 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 will have a cooling-only mode of operation and will provide cooling 24 hours a day, seven days a week throughout the year.

The HVAC units will 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 will be sensed at a wall-mounted thermostat which will automatically adjust its cooling or heating to maintain the room set point. The switchgear room and O&M Server Room HVAC system will be programmed such that the controller automatically starts the standby unit, should the temperatures within the respective rooms rise above 26 °C, or should a fault occur on the running unit.

Outdoor filtered air is to be provided by means of fresh units which are connected to an external insulated galvanized sheet metal ductwork. Air is to be introduced into the space by means of Constant Air Volume (CAV) diffusers/grilles.

Ablution and O&M Spare Parts - Workshop ventilation is to be provided by a ducted extraction system and window extractor fans. This discharges contaminated air to the outside and supplies make-up air from the surrounding areas via door grilles.

#### Potable Water and Sewage Tanks

The potable water supply for the O&M building shall consist of a holding tank of at least 5 000 litres capacity. As a minimum, the tank’s design should meet the following requirements:

* The tank must be constructed and designed in accordance with the information contained within SANS 10400-P:2010 standard;
* The tank must be designed such that all requirements of the Occupational Health and Safety Act (Act No. 85 of 1993) and its regulations are adhered to;
* The tank must be watertight at all times and must not allow for any storm water inflow. The tank must be constructed of materials which are not susceptible to excessive corrosion. The interior must be plastered with a waterproof material;
* The tank must have a level sensor to monitor the water level inside the tank;
* Adequate water supply must always be available for use with a water connection point available within the vicinity of the tank;

A separate non-potable water supply will be used for the washing of the PV modules. This supply will be fed from a borehole and storage tank, which shall have a minimum capacity of 5 000 L. A meter will be installed to record the water usage.

Sewage disposal and its reticulation system is to consist of a sewage conservancy tank of at least 5000 litres capacity that is embedded in the ground and sized for at least one month retention time for 15 staff working a 12-hour shift on site. As a minimum, the tank’s design should meet the following requirements:

* The tank must be constructed and designed in accordance with the information contained within SANS 10400-P:2010 standard;
* The tank must be designed such that all requirements of the Occupational Health and Safety Act (Act No. 85 of 1993) and its regulations are adhered to;
* The inlet must be designed such that blockage by the scum layer is prevented;
* The depth of the tank must be designed in line with acceptable standards;
* The tank must be designed with two compartments to allow for periodic desludging. The tank must be easily accessible;
* The tank must be watertight at all times and must not allow for any storm water inflow. The tank must be constructed of materials which are not susceptible to excessive corrosion. The interior must be plastered with a waterproof material;
* Adequate water supply must always be available for use with a water connection point available within the vicinity of the tank; Monitoring:

The sewage conservancy tank should include appropriate monitoring mechanisms, such as continuous level sensors monitored at the PV plant BMS. The level sensors should interface to a PLC / I/O installed inside the BMS network cabinet. Weekly scheduled level checks of the conservancy tank should be conducted to monitor the capacity level. If water is used from a local water infrastructure supply point, a meter will need to be installed to measure the water usage.

A warning system with an audible alarm must be installed in order to prevent the discharge of raw sewage to the environment and protect the public health by preventing backup of sewage and subsequent discharge. This alarm must be triggered at 80% capacity in order to give sufficient warning to the onsite personnel. This will give sufficient time to arrange for removal by the Contractor.

Reticulation:

The sewage conservancy tank must be linked with pipes from the kitchen and toilets in the O&M building. The kitchen waste must pass through a grease trap before entering the drain. This grease trap requires regular cleaning and maintenance that must not be neglected.

Location and accessibility:

The sewage conservancy tank must be situated where it is accessible to vacuum tankers for sludge and scum removal, noting that no erection of building is permitted over the tank.

## Power Supply

The monitoring and control system power supply shall be fed from a redundant UPS system with backup battery banks designed to maintain power supplies to the control systems for a minimum of 12 hours following the loss of its feeder supplies.

UPS system shall follow the standard IEC 62619:2017 and/or UL 1973 or any similar standard for other technologies than Li-ion cells. Any other standard compliance of the battery cells or battery system shall be indicated. All certificates and tests completion results shall be provided.

Particular attention shall be given to the thermal management of the battery enclosure. The Contractor shall provide all technical notes justifying its design choices, notably the sizing of the cooling units.

The design must include prudent provisions for technology improvement. Battery modules shall allow for upgrade or replacement with higher performance cells to the extent practical. Where such changes are made to a battery module, all modules in that battery string must also be upgraded before the upgraded modules are placed into service.

UPS and battery systems shall comply with IEC 62040, IEC 62619, IEC 62485, IEC 61000 EMC standards, UL 1973 (where applicable), SANS 10142-1/-2, and Eskom design and SCADA communication requirements.

## Labels, Tags, Plates, and Inscriptions

The Contractor shall supply and install for every piece of C&I equipment all labels, tags, name, ratings, instructions, and warning plates necessary for the identification of the works, to allow safe and correct operation, easy testing, and efficient maintenance.

The material and size of all label-, tag-, plate-, and inscription categories shall be according to the specification in this Employer’s Requirements.

## Meteorological Station

The Contractor shall design, supply, install, and commission at least three (3) complete meteorological stations for the Plant. The meteorological stations shall be located near the PV module arrays and distributed across the Plant boundaries. Their specification, installation, and operation and maintenance shall comply with the manufacturer’s guidelines and that set forth in the World Meteorological Organisation best practices, as well as SANS 61724-1:2019.

The minimum equipment specification for the meteorological station is shown in Table 5 Minimum Technical Requirements of the Meteorological station.

Table 5 Minimum Technical Requirements of the Meteorological station

**Irradiance Sensors**

|  |  |
| --- | --- |
| Quantity | One pyranometer on the horizontal plane to measure the Global Horizontal Irradiance (GHI).  One Plane-of-array (PoA) pyranometer to measure the PoA irradiance.  For bifacial modules:  One horizontally mounted albedometer installed away from the solar array in an unobstructed area to measure the horizontal albedo and optionally diffuse irradiance, and use an optical model, such as a view-factor or ray-tracing model, to estimate rear-side irradiance; or  Three in-plane rear-side irradiance or, optionally, spectrally matched in-plane rearside irradiance albedometers |
| Type | Spectrally flat Class A (secondary standard) pyranometers conforming to international standards ISO 9060:2018 and SANS 61724-1:2019 |
| Accuracy | ± 2% |
| Location | The horizontal pyranometers shall be installed in a flat horizontal surface.  The plane of the array pyranometers shall be installed in the plane of the array with the same tilt and azimuth as the PV modules and shall be adequately located across the site to provide an average measured irradiance that is representative for the site.  The albedometer shall be installed at the same location as, but in the opposite direction to, the plane of array pyranometers. The Contractor shall provide the respective specifications for Employer’s review and approval.  All pyranometers/albedometers to be mounted a minimum of 1m from the ground. |
| **Temperature Sensors** |  |
| Type | PT1000 with minimum IP54 protection class.  Implementation of the module temperature sensor following the SANS 617241:2019 |
| Quantity | 1 to measure cell temperature (back of the module) and 1 to measure ambient temperature (shielded ventilated). |
| Range | -40 to +100 °C |
| Accuracy | ±1 °C |
| Location | Module temperature sensor shall be adequately bonded to the module and in the middle of a cell at the centre of the module, and the ambient temperature sensor shall be installed out of the shade, in direct sunlight. |
| **Anemometer** |  |
| Operational temperature | -20 to 70 °C |
| Speed range | 0 to 70 m/s |
| Accuracy Threshold | The higher between 0.5 m/s or 5% |
| Location | At a height of the top row of modules representative of the PV array conditions. |
|  | Tracker: At a height and a location in accordance to stow position requirement from tracker manufacturer. |
| Wind speed measurement  uncertainty | ≤ 0.5 m/s for wind speeds ≤ 5 m/s  ≤ 10% for wind speeds > 5 m/s |
| Direction | 0 to 360° |
| Wind direction accuracy | ±5° |
| **Relative Humidity** |  |
| Range | 0 to 100% RH |
| Overall accuracy | ±2% |
| Response time | 20 s (T90) or less |
| **Soiling sensor** |  |
| Type | Dust IQ (or other equipment subject to Employer’s approval). |

The meteorological station must be powered by UPS with at least 12 hours of uninterrupted power supply capacity. The status of the UPS devices (like battery level, UPS temperature etc.) must be monitored at all times by the monitoring system, and alarms must be triggered in case of values exceeding specific ranges.

Further meteorological stations requirements are as follows:

* The design of the meteorological stations shall be such that 100% of all maintenance work can be accomplished while the equipment remains in operation;
* The measurement equipment shall be provided with the necessary protection against ambient conditions on Site. However, it must be easily accessible for maintenance and inspection purposes;
* The stations shall be connected to the Plant monitoring and control system; and,
* Location of the stations should be placed so that they are not shaded. The final location of the meteorological stations shall be reviewed by the Employer prior to construction.

All instruments and equipment shall be supplied with calibration certificates not older than six (6) months. All sensors shall be calibrated and recalibrated in accordance with the manufacturer’s specifications and as a minimum on a yearly basis. The Contractor shall be responsible for all the calibration processes and costs according to manufacturer requirement up to the date of issuance of the Performance Certificate. Calibration frequency shall not be less than two (2) years.

The pyranometers shall be placed where no shadows are received at any time during the day. In case this it is not possible to mount them within the trackers, an independent installation will be required following the same inclinations as the PV arrays. The position of the pyranometers must be agreed with the Employer before fixing their position.

## Soiling Station

The Contractor shall supply, install and commission at least four (4) soiling stations for the Plant, preferably Dust IQ type. Each of the soiling stations shall include at least two (2) PV modules in the plane of the array, one of which will be cleaned on a weekly basis and the second one will be cleaned with the same cleaning interval of the PV modules of the Plant.

## Station Clock

A GPS synchronized station master clock system shall be provided complete with all necessary hardware, software, and firmware to achieve an integrated Plant-wide system capable of communicating with and synchronising the monitoring and control system. The station master clock system shall be provided with all necessary interfaces for synchronising the Plant SCADA and other control and monitoring systems.

## Security System

The site perimeter serves as an enclosure for all key areas of the site comprising of PV modules, copper cables, inverter cabinets with step up transformers, a control room/switching station with the required switchgears, rooms, and a small store. 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. The Contractor shall provide an integrated and complete operational security system for the Plant.

Double gate configuration for the main gate to control access and egress of all vehicles required on site so that free access into the core security area is not possible at any time. All gates must have capability of being remotely managed.

The access control system shall be provided for the Plant gate, building, and dedicated rooms. The access security system shall be fully automated and shall provide for secure access to the specified locations including time attendance record. In order to prevent the unauthorised access of individuals and vehicles to the PV Solar Plant, or to prevent the unauthorised removal of assets and information, the area shall be secured with access being strictly subject to formal authorisation.

All the Plant’s substations and buildings shall be secured by the security system in compliance with the Applicable Laws, Permits, and Codes and Standards.

Site planning and landscaping:

* All-weather roads/paved surfaces and walkways shall be provided as necessary to facilitate the required surveillance of and response to security threats within secured areas; and,
* The ground cover and landscaping shall not introduce barriers that will have a negative impact on surveillance of the area and perimeter.

Buildings and facility design:

* Openings into buildings and structures protecting equipment shall be kept to a minimum, consistent with operational requirements, and emergency evacuation plans; and,
* Consideration shall be given to ensure that the construction of the physical barriers (walls, doors, ceilings, etc.), and openings into core and production areas, shall offer the same protection against intrusion.

Patrol roads or paths:

Patrol roads must be on the inside or outside of the internal perimeter barrier throughout the entire perimeter.

* Where other entry points enter or pass under or through the site perimeter such as emergency gates, storm water drains, and culverts; vents, ducts, and similar openings shall be hardened and protected to give the same protection as the rest of the boundary and monitoring capability; and,
* All openings in the core security area barriers shall be protected to ensure that the integrity of the barrier is not decreased.

Security control facility:

The site management shall ensure that:

* The Arnot Power Station Security control room monitor all access to and alarms at the site;
* Arnot Power Station Security respond to all alarms at the site;
* The facility must have continuous communication with Arnot Power Station Security;
* It must be fully independent with redundant wire and wireless communication with local law enforcement agencies;
* The design of the communication system shall ensure that all non-portable communication is provided with an independent source of emergency power when the normal power supply is not available;
* The design of the security communications system shall ensure that there are no areas where communication is not possible; and,
* The security communication system shall be protected, and tamper protected.

Alarm systems:

* All alarms shall annunciate at the Arnot security control room;
* Alarm annunciation, audible, and visible intrusion alarm indication shall also be provided in all access control points; and,
* The design of the system shall provide for the installation of duress alarms at the entrances to the site.

Security guard and response force:

* An armed security response force is required 24/7 and must be deployed from Arnot Power Station Security; and,
* The response force capability must be capable of responding to a security breach or incident with a response time less than the delay time of the physical security measures.

### CCTV Cameras

The surveillance system shall cover the points of entry to the respective Plant and the following critical areas as a minimum:

* Site entrance gate;
* Plant’s substation, all Plant’s building and MV stations, control room/building, and spare parts housing;
* Security fence;
* CCTV and thermal IR cameras covering the whole PV plant perimeter;
* Pan, tilt and zoom (PTZ) cameras shall be placed at key areas of the Plant, such as the main access gate, control building, and MV stations. The final locations shall be subject to Employer’s review and approval; and,
* CCTV surveillance shall consider providing an overall view of the solar field in order to detect a potential fire event during daytime operation.

CCTV / thermal IR cameras shall be suitably weatherproofed and include remote control facilities. These CCTV / thermal IR cameras shall be able to monitor the whole Plant perimeter without dead areas. Purpose-built poles must be provided to achieve suitable viewing positions for the cameras where necessary. The cameras shall be with video analytics, with suitable lens focal length and minimum resolution in order to ensure effective detection of movements of people and vehicles for the entire designed field of coverage of the PV Plant. They shall have an embedded web interface for settings and video view. The codec is either H.264 or H.265 to minimize network traffic. In case of IR cameras, they shall be equipped with infrared lights able to illuminate the entire designed field of coverage.

Cabling for the perimeter fence cameras must be buried along the perimeter fence at a depth of no less than 60 cm. Cabling to each camera must be routed vertically from the cable trench along the fence line and up the fence post in a steel conduit to prevent tampering.

The following system design requirements shall be met:

* Night vision capability;
* PTZ capability;
* Secure power supply;
* Provision of sufficient cameras for full coverage;
* Image recording, playback system and video-analysis system;
* Automatic tracking;
* POE capability; and,
* Remote control or central control of all images, either during normal operation, or during emergency situations to clarify security conflicts. This includes the control room/building, the gate house, and third parties alarm monitoring station.

Illumination:

* Area lighting shall provide sufficient illumination to isolation zones and exterior areas to enable the response force to accurately assess intrusion detections and alarm annunciations;
* Illumination shall be designed in co-ordination with the CCTV design and the placement of lights shall ensure enhanced surveillance;
* The illumination design shall make use of two independent electricity supply systems to ensure that at least 50% of the lights continue to function when a loss of power is experienced; and,
* Extensive use shall be made of LED technology to ensure low energy usage, low maintenance requirements and prolonged reliability.

### Network Video Recorder

The signal from the individual cameras must be connected to a Network Video Recorder (NVR). The NVR shall be installed in the O&M control room / building of the Plant.

Any storage should be either a flash card or a solid-state disk with redundancy (RAID system). It can be remotely monitored and operated via a web interface or similar. It shall be able to record from all PV arrays’ cameras simultaneously with at least 12 frames per second. The data from the cameras installed should be available for at least 28 days before being overwritten.

NVR shall include for the following functions:

* Search function in the recorded videos; and,
* Video copy and export in one of the common formats, .avi or .wmv.

All CCTV outputs shall be displayed on a video wall in the security room / O&M control room / building with control of the PTZ cameras. All surveillance system outputs must all be accessible through a web interface.

CCTV analytics must be integrated with the intruder detection as described in following sections of this document.

### Intruder Detection System

Video-analytics surveillance system shall be the main intruder detection system of the PV Plant.

Additional technology for an intruder detection system can be proposed by the Contractor; however, IR and microwave barriers shall be avoided. The IDS shall be designed for multiple zones around the perimeter and shall include gate magnetic detectors at all gate locations, entrance to the O&M control room / building, storage room / building, and all the fence mounted outdoor enclosures. This system shall be integrated with the CCTV system of the Plant.

Intruder detection and surveillance equipment suitable for day and night, including thermal IR cameras, shall be provided for the Site to deter unauthorised access to the Site while permitting ease of access to authorised staff and visitors. All security measures shall be fully integrated to initiate incident response by the security personnel and to allow continuous operator surveillance. It is the responsibility of the Contractor to ensure that the security systems comply with local regulations.

The intruder detection system shall allow for identification of the specific location or fence section on Site where intrusion has occurred.

## Telecommunications

The Contractor shall provide a dedicated telecom system for voice, data, LAN, and fax communication with the Grid Operator. The Contractor shall provide a hotline facility at the Plant. Integration of the telecommunication system with the Grid shall be carried out in consultation with the Grid Operator.

### PV Modules Site Acceptance Tests

All PV modules containers and pallets delivered to the Plant Site shall be visually inspected for any damages.

Upon delivery of the PV modules on Site, the Contractor shall submit the post-production flash test reports for each PV module at STC in electronic format (Excel files) to the Employer. As part of the As-Built documents, the Contractor shall provide a summary spreadsheet containing all the documentation on the PV modules.

PV module testing and acceptance shall comply with IEC 61215, IEC 61730, IEC 60891 (I-V measurement), IEC 62716 (ammonia resistance), IEC 61701 (salt mist), and applicable Eskom requirements.

#### Visual Inspection of Each Container Before Unloading

The containers must be in good condition (no water ingress, debris, or damage). There shall be no indication of pallets or packaging being damaged.

The Contractor must include shock sensors/indicator labels within the PV modules pallet (one sensor per pallet). Furthermore, visual, flash electroluminescence (EL) testing shall be carried out in case the shock sensor of the pallet is activated.

#### Sample-based Inspection of Modules

The Contractor shall perform the following on Site tests by use of an accredited PV module testing mobile laboratory on samples as defined as follows:

* Visual inspection – two (2) modules per container;
* Maximum Power determination (Flash test) – two (2) modules per container; and,
* EL testing – two (2) modules per container.

The description of the tests shall be reviewed by the Employer before performing the tests. The specific PV modules to be tested shall be selected by the Employer.

If the first test fails, the Contractor shall have the right to perform a re-test on the same PV modules in a mutually agreed independent third party accredited mobile testing laboratory. If the re-test fails, the Contractor shall perform a whole inspection on the related containers in which the nonconformant PV modules were transported and replace the unqualified modules at the Contractor’s own cost.

Any delays to scheduled installation dates caused by rejected PV modules, the provision of replacement PV modules and the inspection and testing of replacement modules are the responsibility of the Contractor.

The Employer, at its sole discretion, may perform additional testing on samples of PV modules delivered on Site. These additional tests shall be for the account of the Employer unless such test results indicate additional issues, in which case the cost shall be borne by the Contractor.

### Mounting structure

The thickness of the galvanization of mounting structures and its compliance with structure shop drawings and the soil corrosion results of the geotechnical assessment reports shall be verified on Site. A report verifying the thickness of galvanising shall be provided for all hot dip galvanised components. A report verifying the thickness of anodising shall be provided for all anodised components. Welding reports shall be provided for any welded material. No welding is permitted to take place on Site. The tightness of all module clamps and fasteners shall be verified. The proper alignment of the array frame, module rows and the inclination of the modules shall be confirmed. The Contractor shall provide the Employer with survey reports of the pile which shall meet the requirements of the manufacturer’s installation manual.

# Performance Guarantees

## General Requirements

The Contractor shall provide guarantees and warranties as defined in the Contract.

The Contractor shall undertake all tests that are required to demonstrate that the Plant meets the defined performance guarantees as required by the Contract and the Employer’s Requirements.

The Contractor shall guarantee that the Plant and equipment shall be completely new, advanced in technology, superior in quality, free from any defect in design, material and workmanship, suitable for the use, and purpose specified in the Employer’s Requirements.

The Contractor shall warrant the Plant against defects for two (2) years from Date of Completion.

## Performance Guarantees

### AC Capacity Guarantee

The Contractor shall guarantee a Maximum Export Capacity as set out in section 3.1.2 at the inverter level with a power factor of one (1) and 50 ºC of operational temperature.

### Installed DC Capacity Guarantee

The Contractor shall guarantee the installed capacity (DC peak power) of the Plant as set out in the Contract.

The sum of the peak power of all installed PV modules as stated in the factory flash test list (to be provided by Contractor in electronic format to the Employer) shall be equal to or greater than the guaranteed installed capacity. The Employer shall retain the right to verify the correctness of the PV module peak power by requesting sample PV modules to be tested at independent laboratories (as agreed by both Parties).

If the Contractor breaches this obligation, the Contractor shall either provide and install additional PV modules to achieve the guaranteed capacity or the Contract Price shall be reduced to reflect the actual installed capacity as determined from the flash test list.

All PV modules shall be traceable through unique serial numbers linked to their physical installation location and included in the as-built documentation and digital module mapping system. Flash-test data shall include measurement uncertainty, testing equipment calibration certificates, test date, and Standard Test Conditions reference conditions. PV modules shall comply with positive-only power tolerance, and no negative tolerance will be accepted. Any module identified as defective, damaged, or underperforming relative to the guaranteed tolerance shall be replaced by the Contractor at no additional cost. The Contractor shall ensure that all modules are free from PID, LID and LeTID degradation risks through certified anti-PID measures and manufacturer warranties and shall provide long-term performance warranties.

### Guaranteed Plant Performance Ratio during Tests on Completion

The Contractor shall guarantee that the Performance Ratio of the Plant as measured at the fiscal meter during the Provisional Acceptance Tests shall be equal to or greater than the guaranteed value set out in the Contract.

The Contractor shall provide the guaranteed Performance Ratio data for the Provisional Acceptance Tests in the monthly breakdown format for the monthly Guaranteed Performance Ratio, as well as the monthly Contractor’s expected average PV module temperature with which the Guaranteed Performance Ratio values were calculated by the Contractor. These guaranteed Performance Ratio values for the Provisional Acceptance Tests shall be included in the Contract.

The Plant Guaranteed Performance Ratio shall be tested as part of the Provisional Acceptance Tests as described in section. If the Contractor breaches this obligation, it shall be liable for liquidated damages for performance shortfall as described in the Contract.

### Guaranteed Annual Performance Ratio

The Contractor shall guarantee that the annual Performance Ratio (as described in section 13.2.1) for the first and second operational years from the Date of Completion shall be equal to or greater than the guaranteed value set out in the Contract. If the Contractor breaches this obligation, it shall be liable for liquidated damages as described in the Contract.

### Guaranteed Annual Availability

The Contractor shall guarantee that the annual availability (as described in section 13.2.2) for the first and second operational years from the Date of Completion shall be equal to or greater than 99 %. If the Contractor breaches this obligation, it shall be liable for liquidated damages as described in the Contract.

## Extended Defect Liability Period

In addition (and without prejudice to the Defects Liability Period), the Contractor shall provide a warranty on the equipment (including but not limited to strategic part warranty) that shall be back-to-back with the OEM warranties under the respective supply agreements between the Contractor and the OEM.

The equipment warranties continue for all the periods set forth in Table 6. No equipment warranty shall limit another warranty or vice versa.

Table 6 Minimum Warranty Period of Main Components

**Equipment Minimum Warranty**

|  |  |
| --- | --- |
| **PV modules** | Product warranty of 12 years. Power warranty of 25 years |
| **Inverters** | 5 years with option to secure an extended warranty (10 to 20 years) |
| **MV transformers** | 5 years |
| **String Combiner boxes** | 5 years |
| **MV switchgears** | 5 years |
| **HV switchgears** | 5 years |
| **Mounting Structure** | 10-year product warranty for the steel structure components;  20-year product warranty against corrosion;  5-year product warranty for the tracker motors and gears (if applicable); and  2-year product warranty for the communication and control system (if applicable) |
| **Civil works** | **10-year latent defect warranty.** |

The Contractor shall also provide a serial defect warranty (with the same duration as the product warranty) and a latent defect warranty of five (5) years for all Plant equipment and 10 years on all Civil works for the Plant. The serial defect failure threshold shall be as follows:

* PV modules: 5 %;
* Inverters: 10 %;
* Transformers: 10 %; and, • Mounting structure: 10 %.

## PV Modules Warranty Terms

The PV Module Supplier shall provide warranties commencing at the earliest six (6) months from the delivery of the PV modules to the Project Site and minimum warranty terms under the supply contract.

PV module defects covered under the warranty terms shall include, without limitation, one or more of the following criteria for any individual PV module:

* SANS 61215:2015 (IEC 61215-1/1-1:2021) non-compliance;
* Glass fracture, crack, or break;
* Chips in the edge of glass that impair structural stability, sealing, or deeper than 2 mm;
* Foreign material, except tin/strip residues larger than 10 mm inside the laminate, or conductor foreign material connected with the live part;
* Delamination of the laminate;
* Cord plate (junction box) damages that impair proper functioning or sealing;
* Lead wire or connector damage that impairs proper function;
* No serial number;
* Damage to the frame that impairs structural stability or function;
* Gaps or damage to the edge seal;
* Failure of the bypass diode;
* Improper or damaged cell connections;
* Any cracks, pinholes, broken cells, discoloration, or edge “V” chips exceeding either 0.1 mm in length or 20 % of wafer thickness;
* More than six instances of cells in a given module with edge breakages or cracks affecting

10 % or more of a cell area; or any instances of dark cells; and,

* At EL testing, any instances of dark cells.

The power measurement uncertainty which is considered for the determination of the actual power of a module shall not exceed 3 %.

If a PV module fails to exhibit the guaranteed power output in any given warranty year, the PV module supplier will either:

* deliver additional PV module(s) to replace the loss of power output with no change in module dimensions; or
* compensate the Employer with an amount equivalent to the loss of revenue which shall be calculated on the Net Present Value of the amount of loss of revenues from such a year.

Responsibility of costs for removal of suspected defective PV modules, laboratory testing in support of a claim, PV module supplier personnel and transportation costs, and shipment of additional PV modules will be borne by the PV module supplier in case of a valid claim.

The PV module supply contract shall include the following response times:

* Ticket opening and claim receipt acknowledgement: one (1) business day;
* Response on the validity of the claim: two (2) weeks from ticket opening date;
* PV module replacement and delivery to Site: five (5) weeks from claim validity date; and,
* Defective PV module removal: five (5) weeks from claim validity date.

As stated in this section, the PV module serial defect warranty shall be 12 years. In the event of disagreement on serial defect claim validity between Employer and PV module supplier, a third party consultant to be agreed between the Employer and the Contractor shall be engaged and paid for by the party losing the claim. The third party consultant shall be granted access by the PV module supplier to all the PV module manufacturing and delivery data, including BOM, raw material supplier, production lines, manufacturing equipment, testing equipment, factory indoor environment, involved labour in each operation, quality records, etc. The study result outcomes of the third party consultant shall be binding on both Parties.

# Grid Connection Works

## Scope of Grid Connection Works

Eskom has entered, or is in the process of entering, a self-build agreement with Eskom Distribution for the connection of a solar farm to the Eskom Distribution Grid. The contractor will be responsible for all works required in connection with the grid connection works to enable a fully functional system on completion of the project.

The Grid Connection Works consists of the following main parts:

* New 22 kV Arnot Solar Plant Substation, to be taken over, owned, operated, and maintained by Eskom Generation. References to Solar Substation in the context of the Grid Connection Works refers to this substation. The substation name must be agreed upon within Eskom (between Eskom Generation and Eskom Distribution) so as to ensure there are no conflicting or duplicating names, e.g., Arnot Solar Plant Substation.
* New 22 kV 2-bay Arnot Solar Switching Station, to be taken over, owned, operated, and maintained by Eskom Distribution’s Mpumalanga Operating Unit (MOU). References to Eskom Switching Station refers to this substation. The substation name must be agreed upon within Eskom (between Eskom Generation and Eskom Distribution) so as to ensure there are no conflicting or duplicating names, e.g., Arnot Solar Switching Station.
* A new ±1.9 km, 22 kV single-circuit Chickadee overhead line (OHL) is to be constructed and commissioned for integration into the existing Eskom Distribution network. Upon successful completion, testing, and compliance verification, the line shall be handed over to Eskom Distribution for ownership, operation, and maintenance in accordance with the approved Memorandum of Understanding (MOU), Customer-Electrification Letter (CEL) requirements, and Eskom Distribution Standards and policies.
* 1x additional 22 kV bay extension, inclusive of busbar extension, VT installation, and control plant extension at the Rietkuil Substation, to be taken over, owned, operated, and maintained by Eskom Distribution (MOU). References to this substation will read as Rietkuil Substation.

The Contractor shall ensure full compliance with the Eskom Standard for the Interconnection of Embedded Generation (240-61268576), the Grid Connection Code for Renewable Power Plants (RPPs), all applicable NRS, IEC and SANS standards, and Eskom Distribution design and construction standards. All protection, control and SCADA interfaces required for safe grid integration—including fibre communication, tele-protection schemes, intertripping, interlocking, and metering systems—shall be included in the Contractor’s scope. The Contractor is responsible for coordinating and obtaining all required approvals, permits, wayleaves, and outages, and for arranging witness testing with the Grid Operator for energisation and final take-over.

The Project SLD is depicted in Figure 4 (for more detail, refer to Annexure).

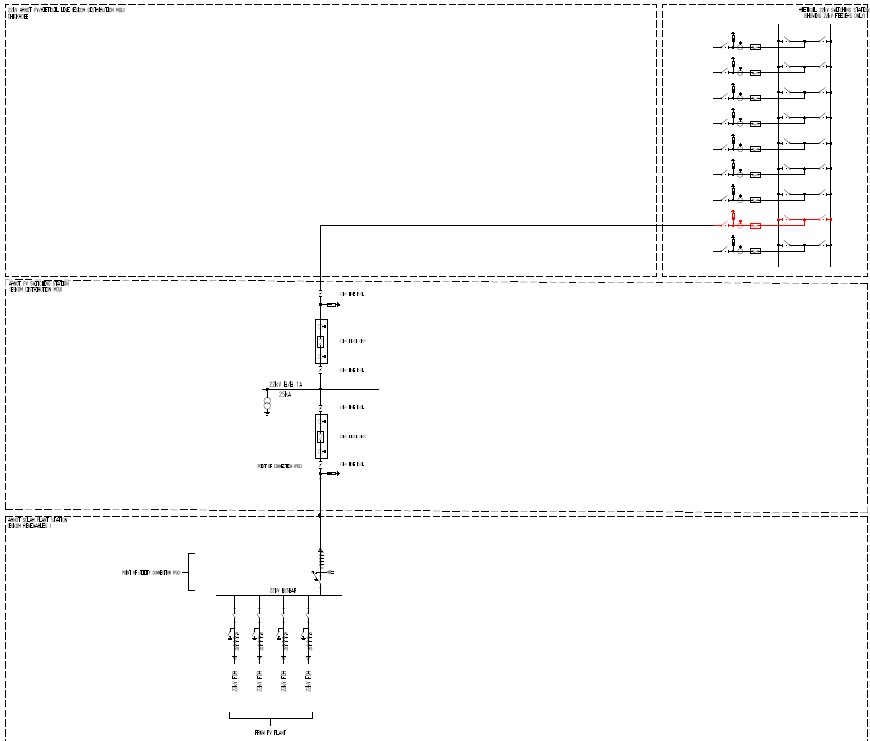


Figure 4 Eskom Arnot Solar PV Facility SLD (VT at Eskom Rietkuil Substation not shown – bay in red colour indicates the existing bay utilised connection)

The detailed scope for the above works is as follows, but not limited to:

### 22 kV Eskom Arnot Solar Switching Station

#### Primary Plant Scope of work:

* Establish a two-bay outdoor 22 kV switching station at the solar plant’s connection point (POC), comprising a line feeder bay at Eskom Switching Station (feeding to Rietkuil substation) and a line feeder bay feeding to the Arnot Solar Plant Substation, with 22 kV busbar, including isolators, earth switches, surge arrestors, circuit breakers, CT’s, VT’s and junction boxes;
* Supply and install 2 × 1-phase 22 kV power VTs, including junction boxes
* Supply and install 1 × 3-phase 22 kV busbar VT set, including junction boxes
* Supply and install 22 kV surge arrestors
* Supply and install 22 kV isolators and earthing switches
* Supply and install 22 kV motorised circuit breakers suitable for remote operation (control room)

#### Control Plant Scope of Work:

The Contractor will be responsible for materials and designs. Eskom CPM will commission the 22 kV Eskom Switching Station and Eskom PC & C to provide the 22 kV control and protection equipment settings.

##### Protection:

* Supply & Install 2x Line Feeder protection schemes. The Solar Plant Substation feeder to have full unit protection; and,
* Pre-commission and commission all protection schemes, including primary and secondary injection testing, logic testing, interlocking checks, end-to-end testing and SCADA signal checks.
* Ensure full compliance with IEC 60255, SANS standards and Eskom Protection Settings and Configuration requirements.

##### Metering:

* Supply and install a full four-quadrant tariff metering scheme, including main, check and power quality metering.
* Only Eskom approved meter types shall be used;
* The Tariff metering installation shall be in accordance with Eskom specification no. 24056364444 - Standard minimum requirements for the metering of electrical energy and demand. This includes, but is not limited to, the requirements around the accuracy class of the meters, CTs and VTs; and,
* Pre-commission and commission all metering systems, including calibration certification and SCADA signal verification.

##### AC / DC Supplies:

* Supply & Install AC and DC panels, Nicad standby battery banks and chargers;
* The above AC/DC boards to comply with Eskom Standard no.240-75658628, Distribution
* Group’s specific requirements for AC/DC Distribution Units; and,
* Pre-commission and commission all AC and DC supply systems, including autonomy tests and alarm check

##### SCADA:

* Supply & Install a SCADA RTU panel; and,
* Pre-commission and commission all Scada installations.
* The system needs to be integrated as a whole.

##### Telecoms:

* Supply & Install a MSAP telecommunication panel;
* Supply & Install 1 x 48-Core fibre optic patch panel (with 1300nm single core patch leads); and,
* Pre-commission and commission all Telecoms equipment installation.

### 22 kV Arnot Solar Plant Substation:

#### Primary plant

* Supply & Install 3x 22 kV outdoor or indoor switchgear bays with 22 kV busbar (1x Eskom inter-connector bay and 2x Solar PV MV feeders), including isolators, earth switches, surge arrestors, circuit breakers, CT’s, VT’s and junction boxes, or alternatively establish an indoor

22kV substations with three 22kv circuit breakers, complete with VT’s and CT’s;

* Supply & Install MV cable termination structure(s), MV cabling, cable trenches;
* Supply & Install all civil engineering and structural works including, but not limited to, foundations, fencing, storm water management, drainage etc., complete;
* Supply & Install substation earth mat; and,
* Build substation building consisting of switch room, control room, and battery room.

#### Control Plant

Generator protection must cater for the below requirements according to Eskom Standard No. 240-61268576 (Standard for the Interconnection of Embedded Generation).

##### Protection

* Supply & install 1 x ‘Eskom’ feeder protection scheme - design same as used by Eskom, with 1 x new line current differential feeder protection scheme and panels. The scheme must feature directional back-up overcurrent and earth fault protection;
* Supply & install 2x 22 kV MV PV feeder protection panels;
* Settings configuration to incorporate synchronism check, loss of grid protection and other relevant configurations required to attain full functionality;
* Complete settings revision on adjacent substations to suit; and,
* Pre-commission and commission all control and protection systems

##### Metering

* Supply & install 1x tariff metering scheme for 22 kV (generation) supply to Eskom;
* Supply & install generator feeder metering schemes;
* Supply & install Power Quality Metering at the PUC; and,
* Pre-commission and commission all metering schemes.

##### Telecommunication

* Supply & Install 1 x FO patch panel (with 1300 nm single core patch leads);
* Supply & Install a MSAP telecommunication panel;
* Install 1300nm optic fibre link between the Eskom Switching Station and the Solar Substation; and,
* Pre-commission and commission all telecommunication schemes.

### MV Line

* Construct approximately 1.9 km of 22 kV three-phase single-circuit overhead line (Chickadee), using self-supporting steel monopole or wooden pole structures, from the 22 kV Eskom Switching Station to Rietkuil Substation, including installation and termination of ADSS fibre optic conductor. The line shall be constructed to Eskom Distribution standards to enable takeover, ownership, operation and maintenance by Eskom Distribution in accordance with the MOU.
* A servitude alignment is proposed, and the Contractor and his design team shall confirm the servitude and design and install the line within the servitude.
* There are existing 22, 275kV and 400 kV lines to be crossed *en route*.

### Rietkuil substation:

#### Primary Plant Scope of Work:

* Utilize and existing 1 x 22kV line feeder Bay at Rietkuil substation, including isolators, earth switches, surge arrestors, circuit breakers, CT’s, VT’s and junction boxes, busbar extension and line termination structures. The bay may require a re-built.

#### Control Plant Scope of Work:

##### Protection:

* Install a line current differential feeder protection scheme on the new feeder bay at Rietkuil Substation;
* Replace the existing non-standard AC/DC panel to accommodate the new installation;
* Install 1 x CT JB on the new 22 kV CTs;
* Pre-commission and commission all protection systems, including primary and secondary injection tests, end-to-end differential tests and interlocking verification

##### Metering:

* Install statistical metering equipment on the new 22 kV feeder bay at Rietkuil Substation;
* Install a standard 19” rack metering panel; and,
* Pre-commission and commission all new metering schemes.

##### Scada/RTU / Telecommunication:

* Expand I/O module to accommodate the new installation;
* Pre-commission and commission Telecoms equipment;
* Install FO ADSS conductor on the new 22 kV Rietkuil substation – Eskom Switching Station line; and,
* Pre-commission and commission new fibre optic link and SCADA/RTU functionality, including remote control, status, alarms and SOE data integration

## Engineering Design

It is a requirement by Eskom Distribution (MOU) that the Engineering Design performed under the self-build agreement by the Contractor, be performed by a consulting engineer accredited by Eskom Distribution (MOU) for Substations, Control Plant and MV lines. The same consultant shall also design the Solar Substation as both the Solar Substation and the Eskom Switching Station will share a common platform and adjacent earth mats.

The Contractor shall appoint such an Eskom accredited consultant who shall be responsible for the design as well as the submission for approval to Eskom in terms of Eskom Distribution (MOU) processes.

In terms of the self-build agreement requirements by Eskom Distribution (MOU), the Eskom accredited Engineering Consultant shall remain involved during the construction process to oversee that the design is correctly implemented. The Engineering Consultant shall also provide an Eskom approved Clerk of Works with suitable Medium and High Voltage Regulations (ORHVS) certification to act as Clerk of Works on behalf of the Contractor, and who shall carry out all inspections prior to, during and after all visits by Eskom Distribution (MOU)’s Clerk of Works. The Contractor’s Engineering Consultant’s Clerk of Works shall maintain the hand-over file for handing over to Eskom at the end of the Project. The Hand-over file shall contain all test certificates, copies of inspections sheets, test reports, and eventually, the As-Built drawings. The Eskom accredited Engineering Consultant or his appointed Clerk of Works shall maintain a full-time presence during factory acceptance tests, site acceptance tests and commissioning, to witness the tests performed.

The design of the Grid Connection Works (balance, not taken over by Eskom Distribution) will be reviewed by Eskom Generation.

## Grid Connection Works Sub-Contractor

It is a requirement by Eskom Distribution (MOU) that the construction works performed under the self-build agreement be performed by a contractor accredited by Eskom Distribution (MOU) for Substations, Control Plant, and MV lines.

It is advisable that the Contractor appoints the same sub-contractor to construct both the Solar Substation as well as the Eskom Distribution’s part of the Grid Connection Works.

## Electrical Requirements

### MV Switchgear

All switchboards shall be of the industrial, extendible, metal-clad, withdrawable, cubicle type arranged as freestanding units with minimum ingress protection of at least IP54 class and constructed and tested in accordance with the appropriate Standards.

All MV switchgear shall be designed for a nominal voltage according to SANS 1019 and SANS 62271, to be internal arc certified IAC AFRL according to SANS 62271-200:2022 Standard and to withstand a short-circuit current of minimum 10% higher than required by calculations, for a duration of three (3) seconds. A type test certificate compliant with SANS shall be supplied for the unit(s) offered.

The switchgear shall be equipped with suitable anti-condensation heaters and shall be designed for bottom entry MV cables.

The LV switchgear shall be designed for a nominal voltage of 400/230 V (according to SANS 1019) and to withstand a short-circuit current of minimum 10% higher than required by calculations for a duration of one (1) second.

Switchgear busbars, circuit breakers, cable compartments, and LV compartments shall all be contained in separate compartments. Barriers shall be provided between the compartments to prevent the spread of ionised gases.

Busbars shall be manufactured from electrolytic copper and shall be capable of carrying full current continuously along the entire length of the busbar without exceeding maximum allowable standard temperatures. Busbars, busbar connections, and insulation materials shall be capable of withstanding without damage the thermal and dynamic effects of short-circuit fault current according to the outcomes of the fault level studies, equivalent to the short time rating of the associated switchgear. Facilities shall be provided to accommodate thermal expansion of the busbars and associated components.

All main switchboards, relay panels, and control equipment shall be provided with duplicate 110 V DC standby power supplies for control and alarm purposes.

Check-synchronising facilities shall be provided as required. The switchgear main incomers, interconnectors, and bus-section circuits shall be interlocked electrically or via the SCADA to prevent the paralleling of two incoming supplies to a switchboard. MV switchgear shall have the interlocks to avoid incorrect manoeuvres according to SANS 62271-200:2022 Standard.

For emergency operation of MV feeders and LV incomers, mechanical off/trip switches shall be provided.

All the withdrawable units of the assemblies shall have the following positions:

* Service;
* Disconnected test;
* Disconnected; and,
* Removed.

The MV switchgear design shall incorporate draw-out type circuit breakers using air-insulated busbar with vacuum circuit breaker as the breaking medium and shall include integral fault making earth switches for circuit and busbar earthing. The circuit breaker shall be of the fault making, fault breaking, and load breaking type rated for the associated system maximum fault current and capable of carrying the maximum continuous load current.

### Substation Conductor, Hardware & Clamps

Aluminium conductors and clamps shall be used for connections between equipment as well as for connections between equipment and busbars. Tubular aluminium busbars shall be used for all outdoor busbars and cable end supports.

The following conductors shall/may be used:

* Centipede AAC Conductor;
* Bull AAC Conductor;
* Hornet AAC Conductor; and,
* 120 x 4 mm Tubular Aluminium Busbars (Minimum size).

The conductor used shall be suitably rated for the specific bay, busbar, or connection in terms of current rating, fault current rating, material, and corrosion.

Substation clamps shall be used to connect conductors to equipment and busbars. Clamps shall be suitably rated for current rating, mechanical strength, and corrosion. Clamp ratings shall not be less than the specific conductor rating used. For all main current carrying conductors and equipment, such as isolators, circuit breakers, current transformers, compression type clamps shall be used on the conductor side. All voltage type equipment, such as VTs and surge arresters, may have bolted type clamps on the conductor side.

All conductors, clamps and hardware shall be as per the various Eskom specifications and D-DT drawings.

## Medium Voltage Overhead Line

### General

A new 22 kV Overhead Line will be constructed between the 22 kV Eskom Switching Station and the Rietkuil Substation. The line shall be designed at 22 kV standard. The line shall further be designed according to SANS 10280:2017 which deals with the design of overhead power lines for conditions prevailing in South Africa. The line shall further be designed using the PLS CADD software which shall be set up with the correct criteria files.

### Structures And Foundations

Steel monopole or Wooden pole structures may be used. The structures shall be as per the Eskom requirements in terms of material, electrical clearances, hardware connections, strength requirements etc. All Steel structures shall be manufactured from steel with a grade of S355JR. All steel structures shall be hot dip galvanized.

Structures shall generally be planted and stayed. Where necessary, steel poles can be self-supporting structures which can either be planted or base plate mounted onto a concrete foundation which can either be a pad- type or piled foundation.

Steel poles shall be manufactured by a reputable company and shall be manufactured strictly in accordance with Eskom standards 240-75883378 and 240-75883830. The manufacturer shall further provide detailed shop drawings for each structure type, which have been designed and signed off by a professional structural engineer.

Foundations shall be designed according to the geotechnical report that was done for the site. Test holes shall be done along the line route. Foundations shall be designed by a professional structural engineer for the typical soil types (Types 1 to 4 as per the Eskom soil type classification). Each hole shall be classified by the structural engineer according to the soil type for which the applicable foundation as per the soil type shall be used. Foundation designs shall also take the pole bending moment for each pole into consideration.

Stays shall be as per the Eskom standards for stay assemblies such as D-DT 7323.

### Conductors And Shield Wires

The main phase conductor to be used shall be Chickadee ACSR conductor. The Chickadee conductor shall be as per D-DT 3136. The ADSS

conductor to be used shall be the single mode 48Core.

### Labelling

The overhead line shall be labelled as per the Eskom standard 240-120804300 – Standard for the Labelling of Electrical Equipment within Eskom Wires Networks.

### Insulation And Hardware

All insulators and hardware shall be as per Eskom standards. Strain assemblies shall be as per DDT 7311 and D-DT 7321 for jumpers on strain poles. Intermediate poles shall have long rod suspension assemblies. Only crimp dead ends shall be used. Tests crimps shall be provided by the Contractor. Assemblies shall generally further be as per the Eskom standard 240-60777474.

OPGW strain and suspension assemblies shall be as per the recommendation of the OPGW supplier. Only Eskom approved OPGW suppliers may be considered.

Shield wire strain and suspension assemblies shall be as per the Eskom standards D-DT 7324 and D-DT 7326.

OPGW and Shield wire assemblies shall be insulated or non-insulated and shall be as per the Eskom standard 240-75880946 – Earthing Standard.

Stockbridge type vibration dampers shall be used for the phase conductors and spiral type vibration dampers shall be used for the OPGW/Shield wire. Vibration dampers shall be as per the Eskom standard 240-98155879.

### Line Templating and Profiling

The phase conductors shall be templated at 70 °C Hot. The

conductors shall be templated at 15 °C EDT. The correct catenary constant shall be used for both the phase conductor and ADSS conductors. For the phase conductors the catenary constant is generally 1800 at 15 °C EDT and 2100 for the ADSS conductors at 15 °C EDT.

Clearances between phases, other power lines, ground, other structures, roads etc., shall be adhered to as per the Eskom standard 240-125383428 – Building Line Restrictions, Servitude Widths, Line Separations and Clearances from Power Lines. These clearances must be adhered to under all defined weather conditions and design criteria.

Staking Tables, Construction Staking Tables and Stringing Charts shall be provided for the line. Wind and Weight Span reports shall also be provided for the construction of the line and the manufacturing of the steel poles.

All relevant construction drawings shall be provided.

## Electrical System Control, Indications and Alarms

Control and alarm facilities for the Plant’s (Solar Substation and Eskom Switching Station) electrical AC and DC systems shall be provided.

Details of the required signal interchange with the DNO shall be developed during the design phase of the project.

AC electrical systems shall be monitored and controlled from the Central Control Room, including for all transformers, switchgear incomers, and bus-section via the plant SCADA system.

The voltage of each switchboard and single-phase current magnitude of all main circuits (incomers and bus-sections) shall be displayed locally at each switchboard. This information shall be repeated in the CCR via the plant SCADA system.

Trips and alarms signalling shall be provided to indicate and annunciate all system warnings and faults at the CCR via the plant SCADA system.

400/230 V AC sub-distribution systems and the DC systems shall be locally controlled only, but alarms shall be transmitted to the CCR via the plant SCADA system.

The switchgear shall include all related circuit prominent coloured high-power LED type status and alarm indication lamps. The associated protection relays shall also include LED status/alarm indicators or flags.

### 400/230V AC And 110V DC Sub-Distribution Boards

Sub-distribution boards shall be provided throughout the Plant for local lighting, small power, and welding supplies.

Outdoor sub-distribution boards shall be of the weatherproof enclosure type and IP65 rating; indoor boards shall be IP54 rating. Additionally, all outdoor installed sub-distribution boards must be equipped with totally enclosed sun canopies.

Switchgear installed in electrical operating rooms shall be provided with a minimum ingress protection of IP54 rating. They shall be capable of withstanding the associated fault current until the related protection operates.

DC supply sub-distribution boards shall be provided throughout the Plant for control supplies to switchgear, control panel and emergency lighting as required.

The incoming breaker of all sub distribution boards shall be able to accommodate a lock-out device and be equipped with a remote signal protection tripping relay with adjustable current and time scales.

The AC supply sub-distribution boards shall be either single phase or three phase with a neutral and earth bar. The DC sub distribution boards shall be equipped with two-pole type miniature circuit breakers. All distribution boards shall be rated for the full load current of the incoming supply and equipped with an incomer isolating MCCB (4-pole for AC ad 2-pole for DC) and with MCBs to provide over current protection to each sub circuit. All equipment installed inside the sub-distribution boards shall be designed, rated, and tested/certified for the applicable voltage rating (AC or DC).

All the space in the distribution boards shall not be fully utilised and shall contain 10% unused but equipped switchgear circuits and an additional 20% space for future switchgear circuitry to be installed.

### Batteries and Battery Chargers

Substation control rooms shall be equipped with suitably rated batteries and batteries charging units in accordance with Eskom Distribution’s Design Standard for Tele Protection Systems (24090353855). The same standards and principles shall apply to the Solar Substation and Eskom Switching Station.

Battery systems shall be nickel-cadmium (Ni-Cd) type or equivalent Eskom-approved technology, designed to supply uninterrupted power to control, protection, SCADA and telecommunication systems for the required autonomy period in accordance with Eskom standards. Battery chargers shall include automatic and manual modes with alarms and remote indication for AC supply loss, DC earth fault, charger fault and low/high battery voltage. The Contractor shall perform full autonomy discharge tests and functional commissioning to verify capacity, performance and compliance prior to energisation. Ventilation, segregation, spill containment and safety provisions shall comply with statutory requirements and Eskom SHEQ standards.

No Valve-regulated Lead-acid batteries will be accepted.

### AC Cables and Installation

Where three (3) single-core MV cable designs are used, the MV cables shall be screened, stranded copper or aluminium single-core cables. Where three-core cables are used, the individual cable cores shall be individually screened stranded copper or aluminium cores. MV Cables shall comply with the following minimum criteria:

* XLPE insulation cables shall be used;
* MV cables shall comply with the corresponding codes and standards such as SANS 10198;
* MV cables shall be flame retardant as per SANS 60332-1 and SANS 60332-3;
* MV cables shall withstand the expected maximum electrical voltages during the lifetime of the Plant;
* All MV cables shall be permanently marked and properly identified;
* Colour code Red, White (or yellow), Blue, Black for (ABC+N), or Brown, Black, Grey and Blue

(R, S, T, N) for LV cables. Colouring systems shall not be mixed;

* For earthing: Green, or green/yellow combination coloured;
* AC cables shall be designed with a maximum operation core temperature of:

o ≤ 90 ºC under normal operation; and, o ≤ 250 ºC under short circuit circumstances (five second maximum).

Instrument and data cables shall have conductors and insulation appropriate for their duty/location.

MV cable screen will be connected in both sides for three-core cables, and at the source side for single-core cables (transformer interconnection cables).

Suitable derating factors for current capacity of the cables shall be applied according to the applicable standards to prevent overheating under design conditions. MV and LV cables shall be sized based on current ampacity, voltage drop, and let through passing energy capacity.

All power cables shall be suitable for service at maximum design load and minimum voltage conditions for the Site conditions and shall be capable of sustaining maximum through fault current without damage for the short time rating of the associated switchgear. Power cables with fuse/MCCB/MCB protection shall be capable of sustaining maximum prospective fault let-through current/time duty.

The following maximum regulation (voltage drop) limits shall apply:

* Between main switchboards (i.e., supplied by a transformer) and sub switchboards: 2%;
* Between main switchboards (i.e., supplied by a transformer) and static load terminals: 5%; and,
* Between sub switchboards and lighting loads: 3%.

Within buildings, cables shall be installed on hot dip galvanized cable trays or racking in a manner that shall prevent the cable being damaged and minimise the risk of occurrence and spread of fire.

Power cables shall be adequately clamped to prevent movement under short-circuit conditions.

Single-core cables shall be clamped in trefoil formation considering phase cable (phase) transposing every 100m.

Duplicated circuits, such as cables that service main distribution switchboards and those cables forming part of emergency/high integrity circuits, shall follow different routes or be separated as far as is practicable.

Cables between the substation yard and the control room shall run in cable trenches. MV and LV control cables shall run in separate trenches. MV cables may be installed in sleeves and not necessarily in a constructed cable trench. Rating of cables shall take the sleeve / duct / trench environment into consideration for when considering derating factors as per SANS 10198.

Control cables inside the substation buildings between switchgear and control panels may be run on cable racks mounted above the panels and switchgear.

In all areas hot dip galvanized trays/racks or conduits shall be used and, where any damage may occur, they shall be further protected with additional anti-corrosion painting (such as cold galvanizing paint). No plastic, PVC, or similar trays and conduits shall be used. Trays/racks installed outdoors shall be provided with covers for protection of the cables against solar radiation.

All cable racking/trays shall be bonded to each other as well as to the Plant’s earthing system. The cables trays shall be designed to allow for 20% spare space for future cables and shall have no more than 2 layers of cables in each cable tray.

Cable access to enclosures shall be by compression type cable glands. Cable glands shall be of non-magnetic metal construction. Gland plates shall be of metal construction and shall be designed with sufficient inherent rigidity and strength to ensure no distortion with cables installed. Where necessary, gland plates associated with termination of single core cables above a certain current rating shall be made of non-magnetic material.

Cables and cable trays shall be clearly identified at both ends with a robust and weatherproof permanently indelible cable identification tag that carries the cable/tray number as per the agreed identification system. Numbers shall be unique across the Plant and follow the AKZ system for the Solar Substation taken over by Eskom Generation, and in accordance with Eskom Standard 24062629353 (Substation labelling standard) as may be required for the substations taken over by Eskom Distribution (MOU) (Eskom Switching Station).

Cable tray fixation shall be in accordance with Good Industry Practice, such as earthing, protection from the cutting angle of the structures, protection from UV radiation, durable, regular fixation to prevent sagging, and anchoring of the cable tray support to both cable tray and ground conductor such that the installation maintains the full performance of the electrical system.

All cable installations shall comply with minimum bending radius requirements per manufacturer specifications, and fire-stop sealing shall be provided where cables traverse building walls, floors or fire-rated zones to maintain fire compartmentalisation. Cables shall be segregated by function to avoid electromagnetic interference (EMI) between power, control, metering and communication circuits. All cable routes shall be inspected, megger-tested, and recorded before termination and before backfilling of trenches. Installation, testing and commissioning shall comply with SANS 10142-1, SANS 10198 and IEC 60364 requirements.

### Earthing System Design, Bonding and Lightning Protection

The earthing and lightning systems shall be designed according to SANS 725, EN 50522:2010, IEC 60364, SANS 62305, SANS 61936-1, and IEEE 665 Standards. All earthing connections shall be secure and provided with bolt, nut, and stop washer for a reliable and durable connection. Also, anticorrosion coating will be applied where applicable particular attention shall be paid to the following:

* Lightning ground potential rise in the context of wire-line technology;
* Lightning ground potential difference;
* Step and touch voltages;
* Electro-magnetic Zoning;
* Soil resistivity variation across the site;
* Earth electrode resistance - resistance is a low frequency parameter, whilst the assessment and analysis called for shall consider lightning induced phenomena with higher frequencies involved; and,
* LEMP (All electromagnetic effects of lightning current via resistive, inductive, and capacitive coupling, which create surges and electromagnetic fields.).

The Contractor shall be responsible for the design, installation, and testing of a single (common) earthing grid for the two adjoining substations which will act as an earthing grid for the LV and MV equipment, in line with Eskom Distribution Substation standards. The earthing grid will consist of BECW (or other suitable material as demonstrated by relevant studies and reviewed by the Employer and Eskom Distribution) cable all along the electrical cable trenches and, if necessary, along the perimeter fence of the Site. The final specification of the buried copper earth electrode will be according to SANS 60479, EN 50522:2010/IEEE 80, and recognised Good Industry Practice and the System Operator’s approved design requirements. The earthing system shall ensure safe step and touch potentials are maintained according to the applicable international standard. The substation earthing grid design shall further comply with the Eskom standard 240-134369472 – Substation Earth Grid Design standard.

The short time current withstand rating of the total earthing installation shall be at least equal to the system rated fault current and backup protection operation time. The loop impedance of the earthing system shall be such as to ensure that all protective devices operate within the short time rating of the system, and such that prospective values of step and touch potential do not approach unsafe values. All underground earthing conductor joints shall be exothermic cad welded type.

All electrical equipment, metallic frames and supports, structural steel and in general all major metallic structures, fences, cable trays/racks shall be bonded to the earthing system.

Transformers, Switchyard equipment and switchboards or assemblies containing switchgear equipment shall be provided with two (2) or more earth terminals (preferably at diagonally opposite ends) and each shall be connected to the earthing system.

The copper strip sized to withstand the maximum system earth current for one (1) second and to provide suitable mechanical rigidity shall be used. Earthing cable sizes shall be designed according to the respective standards.

The Contractor shall also provide a lightning protection system for the PV plant which shall comply with SANS 62305, including the risk assessment and EM zoning as per the standard (EM Zones: SANS 61000-2-5, SANS 61000-4-5, and SANS 61000-4-9). Each lightning protection system shall be bonded to the Plant’s earthing system. The Contractor shall ensure that equipment used in the different zones shall be suitably rated for these EM zones.

Lightning Protection shall generally be done using the “Rolling Sphere” method and shall be in accordance with the Eskom standard 240-109589380 – Direct Lightning Stroke Protection of Substations. Lightning protection layout drawings shall be provided to prove that each substation is adequately protected against lightning.

The Contractor shall carry out full earthing grid validation tests including fall-of-potential earth resistance tests, off-frequency current injection tests, step and touch potential measurements, and continuity testing of all earthing conductors prior to energisation. Down conductors shall be routed to minimise inductive loops and separated from control, communication and fibre-optic cables to reduce electromagnetic interference. Corrosion risks due to soil chemistry, stray currents and dissimilar metal connections shall be assessed and mitigated. All metallic services entering substations (pipes, ducts, cable sheaths) shall be bonded at the point of entry to maintain equipotential zones.

### Substation Lighting

Substation lighting shall be provided by installing LED lamps at a height of 10 m onto the lightning/lighting masts. Lighting shall be as per the Eskom standard 240-113163905 – LED Floodlights for Distribution Substation Applications.

Proper lighting simulations shall be provided.

### Protection of Electrical Auxiliary Systems

All electrical circuits shall be adequately protected by relays and a suitably rated means of current interruption. The following electrical protection shall be provided as a minimum:

* Feeders shall be provided with Overcurrent Protection and Earth Fault (GFT) Protection;
* Auxiliary transformers shall be installed in controlled environments and encased in naturally air ventilated enclosures;
* A winding temperature indicator shall be provided having auxiliary contacts for temperature high alarm and trip functions; and,
* MV standby earth fault, (voltage displacement supervision) transformer Buchholz, transformer winding temperature, transformer oil temperature, transformer rate of rise of pressure and low insulation (liquid) level.

The above protection shall be realised with relays of the electronic digital/numeric type with facilities to enable testing of all functions during normal operation without imposing operational restrictions (i.e., leaving other protection functions active). The relays shall be capable of communicating with the SCADA so that alarms and trip conditions can be seen.

MV switchgear protection relays shall be of the electronic digital type with continuous self

supervision. Relays shall be capable of communicating with the SCADA so that alarms and trip conditions can be displayed.

LV protection relays shall have conventional relays/releases. Trip and alarm signals shall be hardwired to the SCADA system. Uncontrolled feeders up to 25 A rating shall be provided with a MCB rated to suit, 25 A and up to 630 A. MCCBs shall be provided.

The Contractor shall perform full protection grading, discrimination and coordination studies for MV and LV networks to ensure selectivity between upstream and downstream protection devices and prevent nuisance tripping. Trip curves, CT/VT sizing, relay settings and time/current characteristic coordination shall be verified against system short-circuit levels and earthing philosophy. All protection settings shall be approved by Eskom Protection, Engineering, and SCADA teams prior to energisation and uploading of final settings. Protection systems shall record disturbance events and be integrated into a central SOE / event recorder in accordance with Eskom requirements.

# Acceptance

This document has been seen and accepted by:

| Name | Designation |
| --- | --- |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |

# Revisions

| Date | Rev. | Compiler | Remarks |
| --- | --- | --- | --- |
| November 2025 | 1 | VM Erasmus | Eskom template and update to align with new strategy. |
| December 2022 | 0 | MPAMOT PTY LTD | New Document. |

# Development team

* MPAMOT
* Cameron Govender
* Johannes Senoamadi
* Tebatso Menziwa
* Onkgopotse Leeuw
* Vernon Erasmus

# Acknowledgements

* Bhekisigcino Mlangeni
* Yvonne Mazibuko
* Grace Olukune
* Viren Heera

# Annexure A - DC WIRING DIAGRAM- STRING COMBINER BOX (SCB)

# Annexure B - DC-AC INVERTER SINGLE LINE DIAGRAM

# Annexure C - AC WIRING DIAGRAM TRANSFORMER TO SUBSTATION

# Annexure D - Arnot PV Plant Indicative Site Location Drawings

# Annexure E - Arnot PV Plant Topographical Survey

# Annexure F - Arnot PV Plant Geotechnical Assessment

# Annexure G - Arnot PV Plant Hydrological Impact Assessment