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TECHNICAL PROPOSAL

Free State Strategic Solar Project- 600 MW PV Plant in Bethulie, Free State Province



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1 Overview of the Project

1.1 Project Location

The project will develop a new 600 MW photovoltaic solar power generation facility outside the town of Bethulie, Xhariep, Free State Province, South Africa. The proposed project will be split into 3 development phases of 200 MW each.

The PV site GPS coordinates of the location is about: 30°30'34.65"S and 25°56'54.93"E. The site location is shown in Figure 1.1-1.



Figure 1.1-1 Site Location Map

1.2 Codes and Standards

PV module and electrical equipment will adopt IEC standards;

Civil work will comply with South African standards or other equivalent international standards;

The local mandatory codes and standards will be also followed in this project.

1.3 Installation Capacity

Based on the plan, there will be built one 600MWac (3 Phases, 200MWac/Phase) level Photovoltaic (PV) power plant.

The overall preliminary technical solution of the photovoltaic power plant is high efficiency low LID PERC with half-cut technology module + tracking bracket + string inverter + box transformer+ outdoor substation.

The project is divided into 3 Phases, each with a capacity of 200MWac. Each 200MWac PV power plant including one (1) 132/33kV Step-up Substation and Thirty-two (32) 6.25MWac PV Array Units. One (1) 132/33kV Step-up Substation contains 33kV MV switchgear container, 33/132kV HV step-up transformer, 132kV HV GIS container and monitoring & control container. 6.25MWac PV Array Unit contains one (1) 33/0.8kV MV Box Step-up Station, 25 sets of string inverter, 12,600 pcs of PV module and 150sets of tracking brackets.

Thus, for one phase 200MWac PV power plant, there will be One (1) 132/33kV Step-up Substation, 32 33/0.8kV MV Box Step-up Stations, 800 sets of string inverter, 403,200 pcs of PV module and 4,800 sets of tracking brackets. And the installing AC output power is 200MW.

For all three phases of PV plant, totally 600MWac PV plant will be Three (3) 132/33kV Step-up Substations, 96 33/0.8kV MV Box Step-up Stations, 2,400 sets of string inverter, 1,209,600 pcs of PV module and 14,400 sets of tracking brackets. And the installing AC output power is 600MW.

1.4 Main Meteorological Condition

According to the software of Meteonorm, meteorological information will be as follow:

	Global Radiation Horizontal kWh/m²	Average Ambient Temperature °C	Average Wind Velocity m/s
January	299	23.4	4.1
February	251	23.1	3.6
March	261	20.6	3.3
April	253	16.6	2.9
May	270	12.3	2.7
June	254	9.2	2.7
July	277	8.7	2.9
August	289	11.6	3.5
September	280	15.3	3.8
October	294	19.2	4.2
November	300	20.9	4.3
December	322	23.1	4.4
Year	3350	17.0	3.5

1.5 Geological Condition

As there is no geologic conditions data, the site conditions are assumed as follows:

(1) The site is stable and safe. Undesirable geologic process such as landslide, collapse, debris flow, ground depression, karst and travelling dune which threaten the site safety and need special treatment will not be considered at this stage.

- (2) The subsoil of the site is assumed uniform distribution and available to be directly used for nature shallow foundation. Expansive soil, liquefied soil, collapsible loess, laterite, saline soil, soft soil and the newly backfill will not be considered at this stage.
 - (3) The ground bearing capacity is assumed as no less than 150kPa with depth of 1.5m.
 - (4) Causticity of groundwater and subsoil to the foundations will not be considered at this stage.
 - (5) The embedded depth of underground water is assumed as deeper than 5m.
 - (6) Except for nature excavation and backfilling, no special treatment and/or construction method are considered, such as piling, rock excavation and explosion and so on.
- The foundations are considered as natural foundation tentatively. The exact foundation type shall be revised according to the geological survey report in the next stage.

1.6 Seismic

According to the following global seismic hazard map (Figure 1.6-1 and Figure 1.6-2), the peak ground acceleration of the site is 0~0.04g. The exact seismic information shall be confirmed according to the geological detail survey reports.



Figure1.6-1 Global seismic hazard map

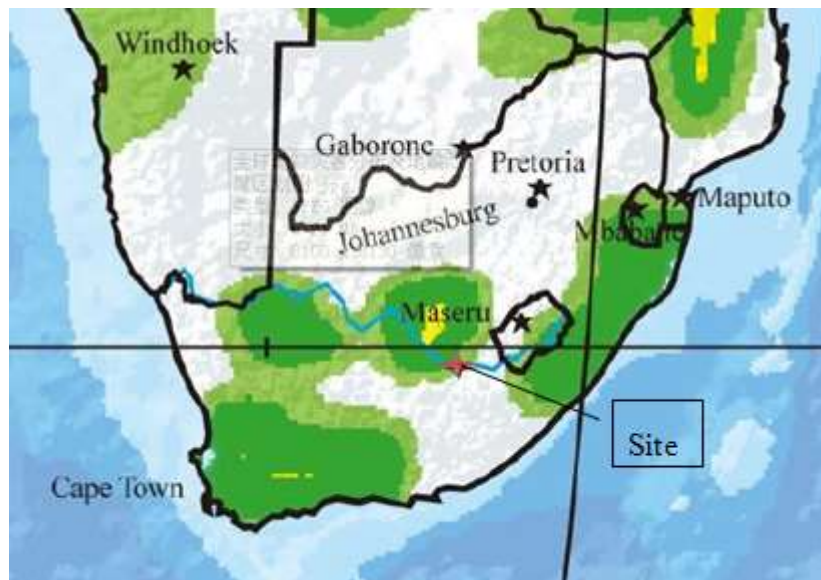


Figure 1.6-2 South Africa part of global seismic hazard map

1.7 Raw Water

The raw water resource for the PV power plant will be ground water and provided by deep water wells. It is assumed that the ground water quality can be used as potable water after simple treatment of filtration and disinfection.

1.8 Site Sensitivity

The assessment area is approximately 1400 ha.

The associated transmission will tie into the existing Eskom

substation situated approximately 1.5 km to the north of the assessment area.

1.8.1 Ecological Support Area and Formally Protected Area

The entire southern and south-eastern portions of the assessment area fall within the boundary of the Gariep Nature Reserve.

The entire Gariep Dam to the south also falls within an Important Bird Area (IBA).

Development within the nature reserve or IBA is not recommended. So the final design layout footprint of the proposed project will be placed outside the boundary of the nature reserve and IBA.

1.8.2 Water drainage lines

The majority of the assessment area forms part of the broad surface water catchment- and drainage area towards the Gariep Dam to the south while only the small portion of the assessment area located north of the hill complex, slopes towards the Bethulie Dam to the east.

Six significant first order water drainage lines/areas as well as two smaller water drainage lines traverse the majority portion of the assessment area while three significant water drainage lines also traverse the small portion of the assessment area located north of the hill complex. The majority of these drainage lines/areas have their points of origin within the localized catchments of the hill complex and are all therefore ephemeral in nature.

All of these significant drainage lines/areas flow through the grassland areas and channel and eventually discharge significant

volumes of surface water runoff into the two dams. They are therefore viewed as playing an important role in the local and regional water catchment and drainage. A minimum approximately 40 m buffer must be placed around all of these drainage lines/areas and no development is allowed to take place within the buffered zones. This must be done in order to ensure the continued flow and subsequent ecological functionality and integrity of the drainage lines/areas.

The two smaller water drainage lines possess no distinct riparian component and they both eventually dissipate into the surrounding grassland within the assessment area. They are therefore not necessarily viewed as playing an important role in the local and regional water catchment.

1.8.3 Hill Complex

A significantly sized hill complex associated with the Besemkaree Koppies Shrubland vegetation type (Gh 4), traverses the northern portion of the assessment area while another small solitary hill is also present on the western boundary of the assessment area.

This hill complex and small solitary hill possess locally unique and distinct habitat attributes within the broader grassland landscape and it is reasonably expected that these areas are utilised by a wide variety of common and specialised bird species, small antelope, reptile species (snakes and lizards) as well as burrowing and predatory mammals as refuge and for breeding, foraging and persistence purposes.

It is therefore recommended that the hill complex and the small solitary hill should be adequately buffered out of the proposed

development footprint area. A minimum approximately 200 m buffer must be placed around the hill complex and the small solitary hill and no development is allowed to take place within the buffered zones.

It is further recommended that a broad ecological corridor be left undeveloped within the western portion of the assessment area which must stretch from the hill complex, through the grassland towards the Gariep Dam. This is required in order to ensure continued ecological connectivity between the different ecological components within the assessment area and broader surrounding landscape and subsequently allow for continued movement of faunal and floral species.

1.8.4 Red Data Listed and Protected Species

Clumps/individuals of the provincially protected species *Ammocharis coranica* were found to be present at three separate locations within the terrestrial grassland areas. Merely a single clump of the provincially protected species *Aloe grandidentata* and a single individual of the provincially protected species *Aloe broomii* were found to be present within the terrestrial grassland areas.

If any of these individuals fall within the final design layout footprint of the proposed development, it is recommended that they be removed and adequately relocated to a suitable and similar area as to where they were removed from. A Provincial Flora Permit has to be obtained from the Free State Department of Economic, Small Business Development, Tourism and Environmental Affairs (DESTEA) prior to the commencement of any such removal and

relocation activities.

1.8.5 Conclusion

The site sensitivity map below illustrates the recommended hill complex buffers, the slight to moderately overgrazed area, the boundary of the Gariep Nature Reserve, the locations of the various water drainage lines/areas and provincially protected species individuals. Details can refer to the EIA report.

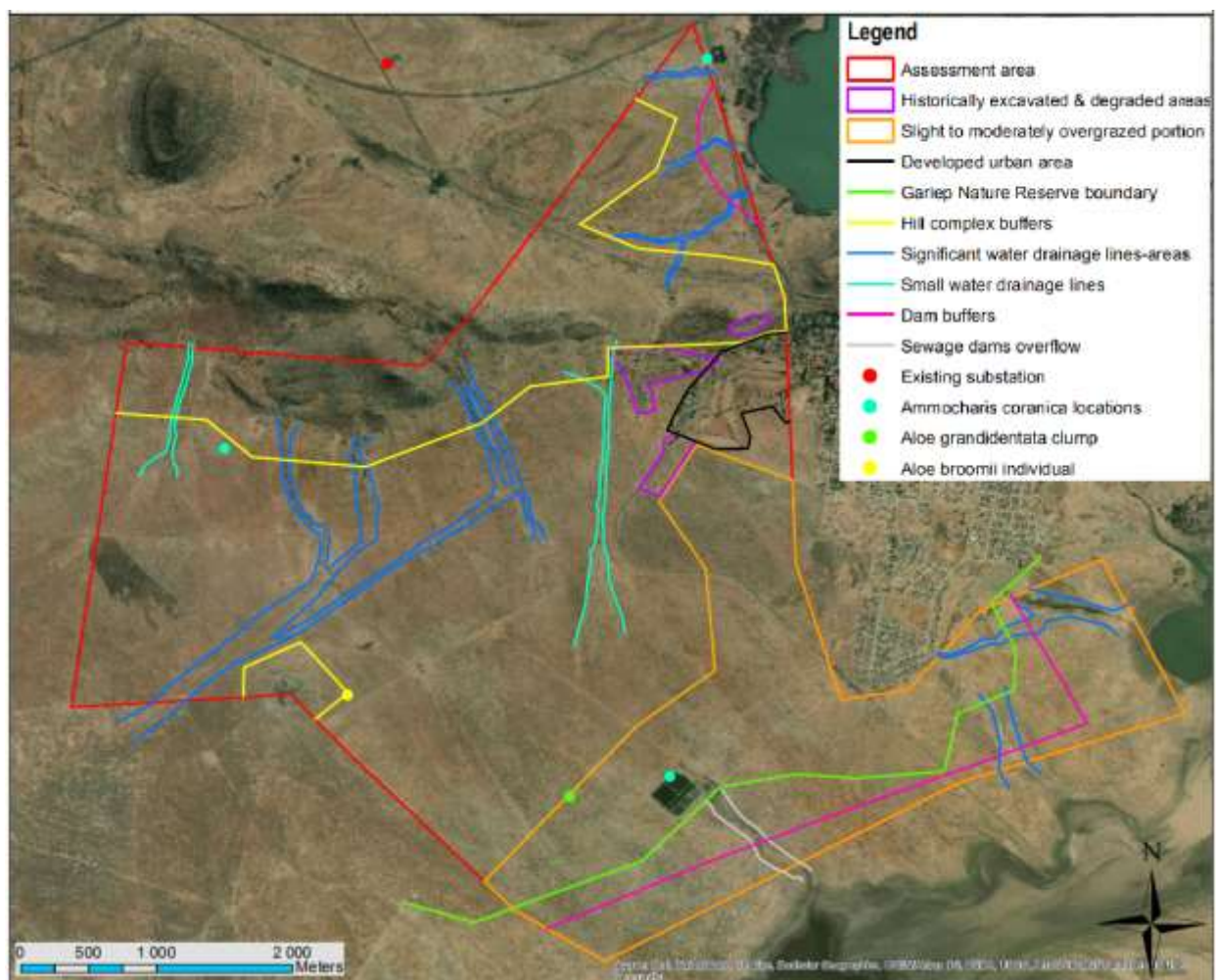


Figure 1.9-1 Site Sensitivity Map

2 Scope of Project

The scope of BPC-Ghanzi Grid Tied Solar PV Power Project includes site cleaning, access road and internal road; power generation system, protection equipment, monitor system and necessary operation & maintenance facility within the boundary wall of PV plant; as well as connection into the local Grid.

2.1 Interfaces / Terminal points

2.1.1 Grid Connection

According to the current temporary plan, each 200MWac PV power plant will be delivered to the existing substation through one 132kV overhead transmission line. The length of 132kV overhead transmission line between Phase One/Phase Two/Phase Three 132/33kV Step-up Substation and the existing substation is around 5.5km/8.5km/8.1km.

The specific point of power grid access will be determined by the local power grid after the power flow study.

The reactive power compensation device is temporarily not considered.

2.1.2 Communication

The communication interface will be at the communication device port of the Phase 1 132/33kV step-up substation, excluding the communication device in the 132/33kV step-up substation.

The interface point of telecommunication and internet system will be at the cabinet of PABX in the power station. The exchange lines from the local public telephone/internet network

to power station will be in the scope of the owner.

2.1.3 Sanitary waste water and rainwater water system

1) The sanitary wastewater after treated will be reused for the plant greening.

2) The rainwater will be collected by open trenches, and then discharged outside the booster station. The interface will be the 1.0m outside of the booster station boundary.

2.1.4 Access road

The access road and internal road of the PV power plant will be in the contractor's scope. Access road will be connected to the existing public road.

2.1.5 Site cleaning

The grass and rubbish on the site will be removed by contractor.

3 Technical Solution

3.1 PV Array

3.1.1 PV module

The use of high-power photovoltaic panels has been approved by the investors. It is **assumed** that 545W PV module is used as the preliminary technical plan.

The following parameters are for reference only.

The Si-mono/high efficiency/low LID/ PERC with half-cut technology module will adopt for this project. The peak capacity of PV module is 545Wp(Temporarily assumed). The main parameters of PV module are shown in Table 3.1.1-1.

Table 3.1.1-1 Main Parameters of 545Wp PV module

Index	Parameter
Rated power	545Wp
Open Circuit Voltage	49.75V
Short Circuit Current	13.93A
Voltage at Pmax	41.80V
Current at Pmax	13.04A
Module Efficiency	21.1%
Maximum System Voltage	1000V/1500V
Temperature Coefficient of Isc	+ 0.045% / °C
Temperature Coefficient of Voc	-0.275%/ °C
Temperature Coefficient of Pmax	-0.350%/°C
Max. series fuse rating	25A
Operating temperature range	-40°C to 85°C
Junction box (protection degree)	IP68, three diodes

Index	Parameter
Cable (cross-sectional area)	4 mm ²
Dimensions (L / W / H)	2279 x 1134 x 35 mm
Weight	28.6Kg

3.1.2 Inverter

It is **assumed** that 250kW string inverter is used as the preliminary technical plan.

The following parameters are for reference only.

Considering both the investment and the maintenance required, the inverter should have well matched with the selected PV module and has high efficiency levels and it will be containerized type. The general parameters are in Table 3.1.2-1.

Table 3.1.2-1 General Inverter Parameters

Index	Parameter
Max input voltage	1500Vdc
MPPT voltage range	600~1500Vdc
Max input current	26A*12
Rated output power	225kVA(40°C)250kVA(30°C)
AC output voltage	680-880V
Rated frequency	50Hz/45-55Hz,60Hz/55-65Hz
Power factor, adjustable	>0.99,0.8 leading-0.8 lagging
Max efficiency	99.0%
European efficiency	98.8%
Protection rating	IP 66
operating ambient temperature	-30~+60°C

Index	Parameter
Humidity	0~100%, non-condensing
Max altitude	4000m(> 3000 m derating)
Dimensions	1051x660x363 mm
Weight	95kg

The rated output of the inverter is related to the temperature of the working environment. The highest local temperature is around 35°C, and usually no more than 30°C (according to Meteorological data). Therefore, this project's inverter rated output is decided based on the rated output of 250kVA(30°C).

3.1.3 Number of PV modules in the String

The voltage of modules in the string will meet the following requirements:

- 1) The open circuit voltage (Voc) should not exceed the allowable maximum Voc of the inverter under the circumstance of extremely low temperature conditions, 1000W/m² of irradiance and 1m/s of wind speed.
- 2) The operational voltage should be in the range of the MPPT voltage of the inverter under extremely high temperature conditions, 1000W/m² of irradiance and 1m/s of wind speed.
- 3) The operational voltage should be in the range of the MPPT voltage of the inverter under the circumstance of extremely low temperature conditions, 1000W/m² of irradiance and 1m/s of wind speed.

Definition of the above indicated parameters are as follows:

Extremely Low temperature conditions: +0°C

Extremely high temperature conditions: +35°C

The formula for calculating the temperature of the PV module is shown below:

$$T_{cell} = G/800 \cdot (NOCT - 20) + T_{amb} \quad (3.1.3-1)$$

The formula for calculating the open circuit voltage of the PV module is shown below:

$$V'_{oc} = V_{oc} \cdot (1 + K_1 \cdot (T_{cell} - T_s)) \quad (3.1.3-2)$$

The formula for calculating the MPPT voltage of the PV module is shown below:

$$V'_{mppt} = V_{mppt} \cdot (1 + K_2 \cdot (T_{cell} - T_s)) \quad (3.1.3-3)$$

Where,

G irradiance, 1000W/m²

T_{amb} the temperature of ambient

NOCT the rated temperature of PV module, 45°C

T_s standard test temperature, 25°C

K₁ temperature coefficients of V_{oc}

K₂ temperature coefficients of V_{mppt}

The calculated operational voltage also can be seen in Table 3.1.3-1.

Table 3.1.3-1 Operational Voltage

numbers of modules in the string	23	24	25	26	27	28	29
V _{oc} (V)	1223	1276	1329	1382	1436	1489	1542
operational voltage under extremely maximum temperature (V)	928	968	1008	1049	1089	1129	1170
operational voltage under extremely minimum temperature (V)	1046	1091	1136	1182	1227	1273	1318

The range of MPPT voltage of the inverter is 600Vdc ~ 1500Vdc

and the allowable maximum Voc is 1500Vdc. The optimal number range of modules in a string is 23~28, which meets the project requirements. In order to get the high efficient, the number of modules in a string is chosen 28.

3.1.4 Axis Azimuth Selection

Axis Azimuth: 0°

The azimuth of axis is 0°, means that the axis is north-south, and the tracking direction from east to west.

3.1.5 Tracking type for PV Array

Distributed single axis will be used to install PV module.

The distributed single axis trackers are the attractive solutions in terms of profitability and reliability. It is a solution to high return on investment and make solar projects economically profitable under cost pressure. The distributed single axis trackers are all steel structure & hot dip galvanized with strong & high anti-corrosion.

The following parameters are for reference only.

Table 3.1.5-1 General Parameters of tracking device

Structural Features	
Tracking Type	Distributed single axis
Axis Azimuth	0°, N-S horizontal single-axis
Tracking Range of Motion	±55° (For reference only at this stage)
Tracking Accuracy	±2°
Maximum row size	90 Modules (1x90, 2x45, 3x30)
Drive	Linear Drive
Materials	HDG steel/ Aluminum components

Electronic controller features	
Motor power consumption	24V DC Motor
Control system	Single chip microcomputer
Solar tracking Method	Astronomical algorithm + closed loop control
Communication	Wire or wireless (Zigbee)
Backtracking	Yes
System feature	
Maximum ground sloping	North-south 10%, East-west no limits
Allowable Wind Load	Tailor to project
Operating Temperature range	-30°C to +60°C



Figure 3.1.5-1 General view of Distributed Single-axis Tracker

Single axis tracking system has only one degree of freedom and they are able to track the sun in one axis. The maximum of rotating degree is 55° to -55° .

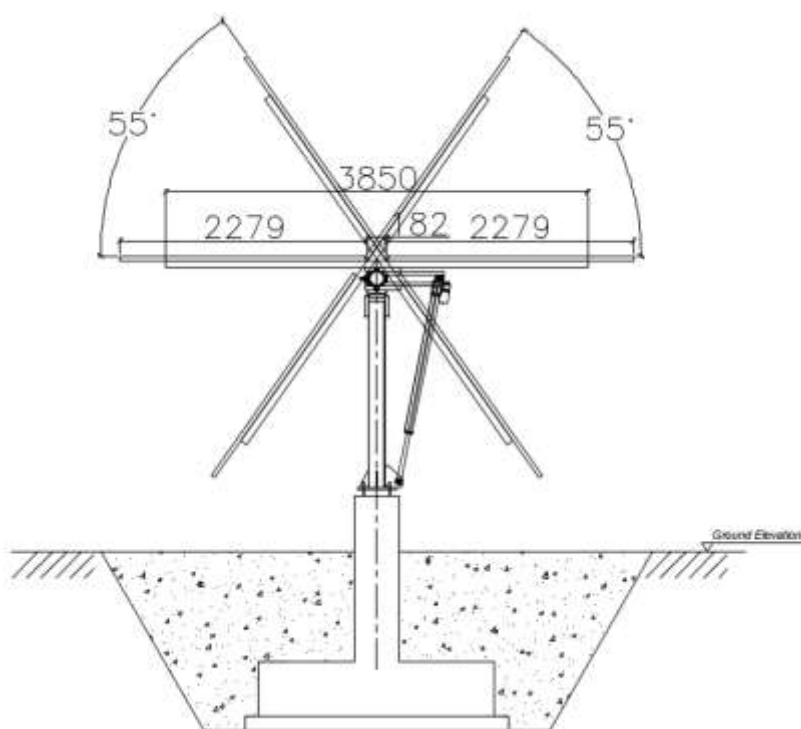


Figure 3.1.5-2 Axial side view of Tracker

The solar modules should be placed on a metal structure with sufficient mechanical strength to form a steering unit:

- 1) Number of rows: 2
- 2) Number of modules per row: 42
- 3) Total modules in each steering unit: 28x3
- 4) Table size: 50032mmx4740mm (LxD).

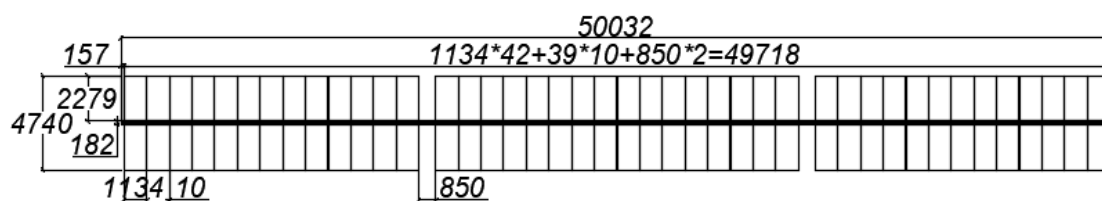


Figure 3.1.5-3 Distributed Single-axis Tracker PV array

There are 84 PV modules and 3 PV strings on each distributed single-axis.

Considering the topography conditions and the repairing and cleaning factors in plant maintenance and required passage

width, the recommended distance (E-W) between the PV module rows is 8m.

3.2 Electrical System

3.2.1 Electrical System of PV Array Unit

One 6.867MWp/6.25MWac PV Array Unit will be composed of one (1) 33/0.8kV MV Box Step-up Station, 25 sets of string inverter, 12,600 pcs of PV module and 150sets of tracking brackets.

Each inverter is connected with 18 PV strings, and each string is made up of 28 PV modules. The PV modules are connected in series to PV string, and then connected to the string inverter directly through a special PV DC cable.

The string inverter will be connected to the LV cubicle of the 33/0.8kV MV Box Step-up Station which contains one box transformer. The inverter converts the DC power into AC power and then collects it into the box transformer through the AC LV cable.

PV array unit electrical system connection please see Fig.3.2.1-1.

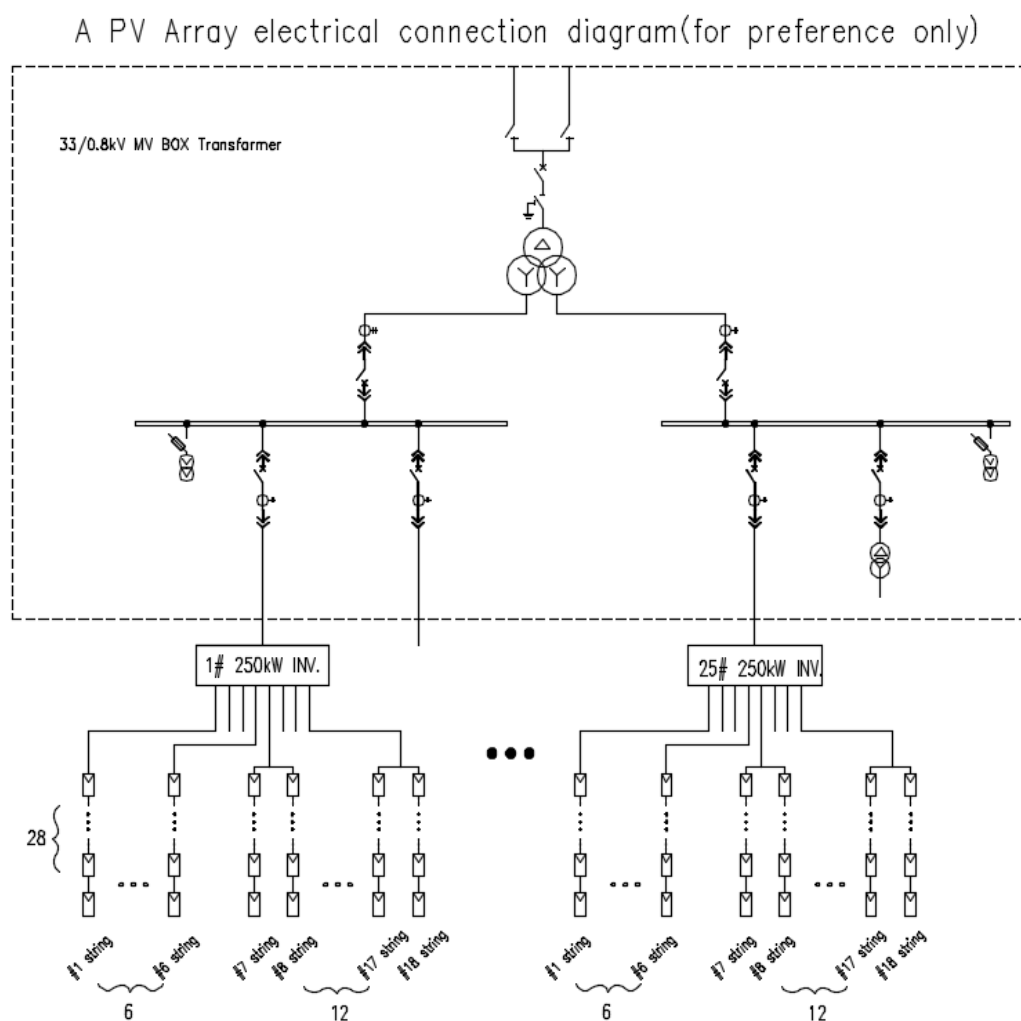


Figure 3.2.1-1 Diagram of PV array unit electrical system

The inverter's input interface number is 12. In order to ensure the output power, each inverter connected with 18 strings, some PV strings are connected to the interface by two strings in parallel. There are 25 inverters with totally 18. PV strings connected (6 strings are connected by one string; 12 strings are connected by two strings in parallel)

33/0.8kV MV Box Step-up Station is an integrated system set in preset cabin that contains box step-up transformer, LV cubicle and MV (middle voltage) RMU (Ring Main Unit) , which will collect the power form inverters and transform this from 0.8kV

low voltage to 33kV MV (middle voltage). The MV power will be send to the 132/33kV Step-up Substation through 33kV underground cable.

3.2.2 33kV collector line

The 33kV collector line is underground cable. To reduce the number of MV cables and simplify the wiring, the RMU on the high voltage side of the MV Box transformer of every 3 PV Array Units are connected in series through 33kV cables, so there is a total of 11 collection lines Access to the 132/33kV Step-up Substation.

3.2.3 132/33kV Step-up Substation.

132/33kV Step-up Substation contains 33kV MV switchgear container, 33/132kV HV step-up transformer, 132kV HV GIS container and monitoring & control container.

3.2.4 The existing substation

The newly built three phases PV plants will be connected to the existing substation on voltage level 132kV. The 600MWac project has totally three 132kV overhead lines connected to the substation, with lengths of 5.5km/8.5km/8.1km respectively, two of which adopt the same tower double circuit while one of which adopts single tower single circuit.

3.2.5 PV station Monitoring & Control System

The solar PV plant monitoring & control system will be provided to monitor and control PV panel, inverter, 132kV step-up transformers, 33kV switchgear, 132kV switchgear and

accompanying device. Solar PV plant monitoring & control system will consist of electrical part and PV part, so two sets of monitoring and operation stations for the Solar PV plant will be installed in the control room.

3.2.5.1 Electrical Monitoring & Control System

Electrical monitoring & control system will monitor and control 33kV electrical switchgear, 33/132kV step-up transformers, 132kV bus, 132kV PT, 132kV switchgear, 132kV transmission line of the PV plant substation.

The following parameters will be monitored and controlled by electrical monitoring & control system.

- Current, voltage, power and the circuit breaker state of the 33kV switchboard
- Isolator switch position, protection trip signals of 33kV switchboard
- Close/Trip the circuit breaker of 33kV switchboard
- Electrical energy production or consumption of each 33kV circuit
- Current, voltage, power and the circuit breaker state of the 132kV line
- Close/Trip the circuit breaker of 132kV Step-up transformer
- The tap position of 132kV Step-up transformer
- DC and UPS operation state
- Fire alarm signals
- CCTV Image signals

The important signals for 132kV switchgear protection and alarm will be transmitted to the monitoring & control system

through hardware. The electrical monitoring & control system will be with anti-misoperation logic lockout and feature, it can be prevented wrong operation.

Additionally, a GPS time synchronization system will be incorporated into this project.

The electrical monitoring & control system can provide hardware/software interface for the dispatch central to satisfy the requirements of network communication technology and communication protocol. Remote measurements needed by the dispatch system will be collected by the local control unit of the electrical monitoring & control system, then they are transmitted to a remote terminal station and delivered to the dispatch central.

3.2.5.2 PV array Monitoring & Control System

The PV array monitoring & control system can continuously record operational data and failure data such as:

- 1) Real-time display of the PV station's operational parameters including,
 - a. Present total power
 - b. Total generating capacity of the day
 - c. Cumulative total generating capacity
 - d. Total cumulative CO₂ reductions
 - e. Daily power generation graph etc.
- 2) Each inverter operating parameters, operating state of all inverters, including the use of sound-light alarm to warn of faulty devices. Fault reason and time can be viewed as well.
- 3) Operating state of all PV strings of the combiner boxes,

including the use of sound-light alarm to warn of faulty devices. Fault reason and fault time can be viewed as well. The following electrical data will be monitored:

- A. DC voltage of PV strings
- B. DC current of PV strings
- C. Fault alarm of PV array.

4) Environmental monitoring function should also be incorporated into the monitoring & control software. This includes the monitoring of irradiance, wind speed, wind direction, outdoor temperature, the solar panel temperature, etc.

5) All operational data and fault data should be stored for at least 20 years.

6) Honeywell hall elements and high reliability DSP processor will adopt in the combiner box for monitoring the PV strings, including the current, alarm, and local fault location. The combiner box communicates with the local monitoring & control device via RS485.

7) A highly reliable industrial PC should be utilized for the monitoring & control host computer. It is required that the monitoring continuous 24 hours a day.

3.2.6 Relay Protection and Automatic Safety Devices

3.2.6.1 Generation Part

The protection will be provided for 33kV collection lines, inverters, 33kV switchgear, LV switchgears and combiner boxes, 132kV step-up transformers and 132kV switchgear, The protection function is described as follows:

- 1) High temperature alarm, over temperature trip protection, differential protection, over current protection and line protection interlock tripping will be provided for the 132kV step-up transformer. Some important signals uploaded to the electrical monitoring & control system by hardwire, such as 132kV circuit breaker, isolator switch position of HV/LV side, protection trip signal, non-electrical signals of 132kV step-up transformer.
- 2) The measurement & protection device for the 33kV collection lines will be installed in the switchgear. Over current protection and zero-sequence over current protection will also be included.
- 3) High temperature alarm, over temperature trip protection, over current protection and LV switch interlock tripping will be provided for the 132kV step-up transformer. Some important signals uploaded to the electrical monitoring & control system by hardwire, such as isolator switch position of MV/LV switchgear, protection trip signal, non-electrical signals of 132kV step-up transformer.
- 4) The protection function of inverter will be supported by inverter itself. Instantaneous short current protection (phase), single-phase earthing fault protection, reverse power protection, overload protection, under voltage protection, anti-islanding protection and temperature protection are all included. All signals are uploaded to the PV monitoring & control system.
- 5) The DC circuits in combiner box are protected by the over

current module of MCCB. The signals are uploaded to the PV monitoring & control system via the monitoring & control units of combiner box.

- 6) An intelligent trip is installed in the 380V ACB and is protected by an instantaneous trip and overload protection provided by the breaker itself. The 380V MCCB is protected by the over current protection which is included in its own breaker.

3.2.6.2 33kV Distribution Part

A 33kV bus differential protection device will be installed in the one of the switchgears, which connect with the 33kV bus. The protection signals will be uploaded to the electrical monitoring & control system. Protection trip signal will act on each branch breaker of the 33kV bus.

3.2.6.3 132kV System Protection

The PV plant will be connected to the national network via two 132 kV lines. Two 132kV line protection devices for every line will be installed in relay room. The detailed protection functions will be provided according to local Grid requirement. The protection device will act tripping on the circuit breaker of 132kV transmission line, and the protection signals will be uploaded to the electrical monitoring & control system.

3.2.7 Tariff Meter

Tariff point will be at every 132kV transmission line circuit in PV plant.

The main and backup tariff meter shall be in compliance with grid specifications. The accuracy class will be active power 0.2s

and reactive power 2.0.

The tariff meter will be able to measure positive active power, reverse active power, lagging reactive power and leading reactive power. The tariff meter will have a serial communication interface and load control interface that can be remotely transmitted.

3.2.8 Control Power Supply

3.2.8.1 DC Power System

One set of 110V DC system will be provided in the PV plant. The batteries will be valve regulated lead-acid type, and the charger will be high frequency switch type. DC system should be capable of supplying power to the DC load for 1 hour after loss of AC power.

Sectionalized single-bus configuration will be adopted in the 110V DC system, while a radial power supply will be adopted in the DC system. The DC panel is equipped with DC insulation monitor which can monitor the running of the DC system insulation in real time.

3.2.8.2 Uninterrupted Power System

One set of UPS will be provided to supply power for some important devices such as electrical monitoring & control system, fire alarm monitor and communication devices. The batteries of the UPS units shall be rated to supply the total load for a period of 30 minutes in the event of a loss of normal power supply.

3.2.9 Fire Alarm

One set of fire alarm system is provided for the solar PV plant,

and the fire alarm monitor will be located in the control room. Heat detectors and smoke detectors will be installed in the relay room, 33kV distribution room, and DC and UPS distribution room. In the event of a fire, these detectors will send signals to the control room.

3.2.10 CCTV and Security Protection System

A CCTV and security protection system will be setup at the PV station covering the most important facilities including the PV array, the main entrance of PV station and the entrance of electrical control building. A single digital video recorder will be setup to receive all video signals, with one monitoring host computer installed in the console, and reserved signal interface, the video signal could be transmitted to the remote control central.

The proposed CCTV and security protection system, which will be equipped with access system, will be able to display in real time video, control access, manage records, store and search the video and access data, process images, control and switch images, and more. It also can give an alarm if there is abnormal condition.

3.3 Communication

3.3.1 Internal Communication

A set of digital PABX (Private Automatic Branch Exchange) shall be supplied for internal telephone system. This system consists of PABX center control cabinet and the auxiliary equipment, MDF (main distribution frame), distribution terminal

equipment, cable network, etc. It will not only provide the communication among designated locations in the substation, but also realize the external communication with the dispatching center, the local public telephone network and power system communication network.

Furthermore, video surveillance, alarm and control signals will be monitored in control room of PV power station.

3.3.2 System Communication

System communication device will consist of SDH optical transmission equipment, MDF (main distribution frame), distribution terminal equipment, etc. The type and specification of equipment will be decided according to the requirements of system reports.

The communication equipment will be supplied by communication power supply system. The 48V DC communication power supply system for PV station will consist of one set of high frequency switch power equipment and two banks of maintenance-free batteries.

3.4 Civil Work

3.4.1 General Layout

3.4.1.1 Overall Plan

The 600MW PV Power Project will be located south-west of the town of Bethulie, Xhariep, Free State Province, South Africa. It will be split into 3 development phases of 200 MW each.

The assessment area is approximately 1400 ha. The project will be in the suitable development areas which avoid all the site

sensitivity. The site is flat. It is situated at an altitude of approximately 1275~1325 m above mean sea level.

The site is well accessible from the north existing public road, which passes through the site.

The 132kV output will be connected to the existing Eskom substation which located at north of the Project site.

3.4.1.2 Layout

The 600MW PV Power Project is split into three phases. There will be 32 PV arrays in each phase, and the capacity of each PV array will be 6867kWp. Each one PV array will contain one 0.8/33kV MV box step-up station.

There will be one 132/33kV Step-up Substation in each phase, which contains monitoring & control container, 33kV MV switchgear container, 132/33kV HV step-up transformer and 132kV HV GIS container. In addition, Phase 1 132/33kV Step-up Substation also includes complex water pump house, complex building, warehouse, education/training centre.

New roads will be built on the site in order to meet the transport, maintenance and fire-fighting requirements. The new road will be 6.0 and 4.0m wide, and the turn radius is 6~9m.

The cable will be buried directly, and will be 0.85 m deep. The route of the cables will be normally parallel to the solar plant roads.

The site will be enclosed by 2.0m steel fence and the area within the boundary fence is 740 ha.

3.4.1.3 Vertical Layout

The project site is flat. The smooth slope style of vertical layout will be adopted.

The cable trench will be buried directly on site. The rainwater will flow together by utilization of the appropriate ground slope and discharge it out of the site by open trench.

3.4.2 Architecture Design

Four electrical prefabrication containers will be constructed in each 132/33kV Step-up substation:

- 1) 132KV HV GIS container: It will be a one-storey container, with dimension of 6mx5m, and will be supplied by the manufacture.
- 2) 33KV MV switchgear container: It will be a one-storey container, with dimension of 10mx10m, and will be supplied by the manufacture.
- 3) Monitoring & relay container: It will be a one-storey container, with dimension of 8mx3.4m, and will be supplied by the manufacture.
- 4) Control container: It will be a one-storey container, with dimension of 8mx3.4m, and will be supplied by the manufacture.

Five buildings will be constructed in the Phase1 132/33kV Step-up Substation.

- 1) Education/Training centre: It will be a one-storey building, with dimension of 100mx50m, and it will be steel structure.
- 2) Complex building: It will include office, meeting room, dormitory, kitchen and washroom. It will be a two-storey

building, with dimension of 25mx10m, and it will be reinforced concrete structure.

- 3) Warehouse: It will be a one-storey building, with dimension of 25mx8m, and it will be steel structure.
- 4) Complex water pump house: It will be a one-storey building, with dimension of 18mx8m, and it will be steel structure.
- 5) Guard room: It will include reception room and washroom. It will be a one-storey building, with dimension of 7mx5m, and it will be reinforced concrete structure.

3.4.3 Foundation Proposal

As there is no geologic conditions data, the foundations for PV array, buildings, prefabrication containers and equipments are considered as natural shallow foundation in this stage and will be revised according to the soil investigation report in the next stage

3.5 Water Supply and Drainage System

The project will be completed in three phases with 200MWp for each phase, and for each phase, the water supply and drainage system will be the same, so only one of the systems will be described here:

3.5.1 Raw Water System

Raw water will be provided by deep well water.

The raw water system for the PV station is assumed as follows:

The water yield of single well is about 5m³/h.

The flow diagram of deep well water system: One (1) deep well

pump→Pressured pipe → potable water supply system.

There are 1×100% deep well pump and one deep well in the booster station of the PV plant. The parameters of the deep well pump are as follows:

Quality:	5m ³ /h;
Head:	approx. 100m;
Number:	1 set .

3.5.2 Potable Water Supply System

One set of integrated water supply equipment will be supplied to purify the raw water and meet the drinking water standards. It Includes two frequency conversion pumps, one stainless steel potable water tank, pump parameters: Q=0~5m³/h, H=50m, N=5kW, potable water tank capacity: 8m³. Drinking water will be stored in tanks, and the water will be pumped to washbasins, toilets, etc. Activated carbon filter and ultraviolet sterilizer will be used to clean the raw water.

The flow diagram of potable water system: Raw water →
Activated carbon filter → Potable water storage tank →
Ultraviolet sterilizer → Potable water point.

3.5.3 Service Water Supply System

To maintain maximum efficiency, the PV panels should be cleaned periodically (generally every one month). Two water trucks will be provided to supply the cleaning water.

When rainfall is heavy, the frequency of cleaning can be

reduced.

In order not to affect power generation efficiency, cleaning work of PV panels should better be done after sunset.

3.5.4 Sanitary Wastewater Drainage System

Sanitary wastewater drainage system includes: regulating pond, sanitary wastewater collection pipe network, and sanitary wastewater treatment facility. The sanitary wastewater from every water point will be collected by the collection pipe network, later it flows into regulating pond, and then discharges to sanitary wastewater treatment facility. After treated, it can be used for the plant greening, and no water flow out of the booster station. The sanitary wastewater facility is under the ground with a capacity of 1 m³/h.

3.5.5 Rainwater Drainage System

Most of the rainwater will flow together by utilization of the appropriate ground slope and the terrain, and in an organized way, rainwater will discharge outside of the booster station by the rainwater structures such as the open trench and ditch.

3.6 Fire Fighting

The project will be completed in three phases with 200MWp for each phase, and for each phase, the fire fighting system will be the same, so only one of the systems will be described here:

3.6.1 General

For different constructions and facilities, a variety of fire fighting measures will be taken. The design of the process, equipment,

material selection, layout and fire passage will be carried out in accordance with NFPA and local regulations.

3.6.2 Fire Fighting system

Indoor and outdoor hydrant system will be equipped in the booster station to protect important buildings and structures. Water spray system will be used to protect the main transformers, the total flow is about 90L/s, and the total water demand during firefighting time is about 650m³. Two water basins with the volume of 350m³ for each will be constructed with the resource coming from wells which also supply potable water, two firefighting pumps and one set of stabilized pressure pump group including two stabilized pressure pumps and one pressure tank will be installed. Parameter of the firefighting pump will be: Q=90L/s, H=90m, and for the stabilized pressure pump: Q=5L/s, H=95m, volume of the pressure tank will be 1m³.

3.6.3 Portable and Movable Fire Extinguishers

The portable & movable fire extinguishers will be designed to extinguish the initial fire at the hazardous areas. Portable & movable fire extinguishers are provided with larger capacity units at major risk areas throughout the plant.

3.6.4 Fire Fighting Measures for Cable and Transformer Area

Grouped electrical cables will be routed away from exposure hazards or protected as required by the fire risk evaluation. In particular, care will be taken to void routing cable trays near sources of ignition or flammable and combustible liquids. Where such routing is unavoidable, cable trays will be designed and

arranged to prevent the spread of fire.

The portable fire extinguishers will be set at transformer area to extinguish electric fire and emergency oil pond will be constructed to prevent transformer fire spreading, when the transformer catches fire, oil in the transformer will flow into the pond to avoid greater losses.

3.7 VAC system

3.7.1 General

The content of VAC systems will include ventilation and air conditioning systems for containers and buildings in this project.

3.7.2 VAC system for the container

The VAC system will be provided for the containers, and will be supplied by the manufacture.

3.7.3 VAC system for the buildings

Five buildings will be constructed in the Phase1 132/33kV Step-up Substation. The VAC system will be provided for these buildings.

The air-cooled split air conditioners will be provided for the education/training centre, and the room temperature will be at 24~26°C.

The air-cooled split air conditioners will be used for the office, meeting room and dormitory in the complex building in the summer, and the room temperature will be at 24~26°C.

The ventilation system will be provided for the kitchen and washroom. The axial fans or ventilators will be used in the

system.

The ventilation system will be provided for complex water pump house. The axial fans will be used in the system.

The air-cooled split air conditioners will be used for guard room.

4 **Appendix: Drawing List**

NO.	LIST OF DRAWING	NAME OF DRAWING	REV
1	AF2019044-D01	A PV ARRAY UNIT ELECTRICAL CONNECTION DIAGRAM	REV 0
2	AF2019044-D02	A PV ARRAY UNIT LAYOUT	REV 0
3	AF2019044-D03	TYPICAL PV ARRAY & TRACKER LAYOUT	REV 0
4	AF2019044-Z01	GENERAL LAYOUT	REV 0