Project Name	2 × 235 MW ATTARAT OIL SHALE POWER PLANT - JORDAN
Project Owner APCO ATTARAT POWER COMPANY	EPC Contractor CEEC CHINA ENERGY ENGINEERING GROUP GUANGDONG POWER ENGINEERING CO.,LTD
Owner Engineer MOTT MACDONALD	EPC Contractor Technical Adviser WorleyParsons resources & energy

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Electrical Design Criteria

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SYNOPSIS

This document presents the Electrical Design Criteria for 2 × 235MW ATTARAT OIL SHALE POWER PLANT-JORDAN project.

Disclaimer

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1. INTRODUCTION

1.1 General

The purpose of this Electrical Design Criteria is to define the standards and procedures to be used for the engineering design of the electrical installation for the 2X235 MW Attarat Oil Shale Power Plant - Jordan.

This Design Criteria describes the power plant electrical equipment and systems, their functions, and the general criteria upon which their design will be based. An overview is also shown on the main single line diagram.

This Electrical Design Criteria ensures uniformity and consistency of the design by describing:

- Technical documentation used to control the Electrical Design
- Electrical tools, software and procedures used in preparing the design
- Specific requirements for system design
- Requirements for protection and control systems
- Equipment sizing and selection methods
- Equipment specifications

Electrical equipment and devices shall be provided by the equipment supplier as required to make all system equipment operational.

Most electrical equipment shall be in accordance with IEC Standards and shall meet or exceed the requirements of appropriate ANSI, NEMA, NEC, IEEE, and NFPA codes when plausible. Generator circuit breaker and metal enclosed phase bus duct shall be in accordance with ANSI/IEEE standards. The system descriptions and equipment specified in this document represents the minimum electrical requirements for all electrical equipment to be used in the Power Plant.

The plant shall be designed to the above indicated standards for the power plant industry with an expected life of 40 years subject to operation and maintenance in accordance with manufacturers' instructions.

The key electrical software that may be used in the design shall include ETAP and CDEGS.

1.2 Terminology

Owner: Attarat Power Company (APCO)

Contractor: Guangdong Power Engineering Cooperation (GPEC)

NEPCO: National Electric Power Company (of Jordan)

1.3 Definitions and Abbreviations

Table 1. Key Definitions Applied For the Project

Abbreviation	Definition
ac	alternating current
ACC	Air Cooled Condenser
AF	Air Forced
AN	Air Natural
ANSI	American National Standards Institute
AVR	Automatic Voltage Regulation
BOP	Balance of Plant
dc	direct current
DCS	Distributed Control System
ESD	Emergency Shut Down
ETAP	Electrical Transient Analysis Program
Exn, Exd, Exe	Degrees of explosion protection
GCB	Generator Circuit Breaker
GSUT	Generator Step-Up Transformer
HMI	Human Machine Interface
HSBT	High Speed Bus Transfer
HVAC	Heating, Ventilating and Air-Conditioning
Hz	Hertz
IEC	International Electrotechnical Commission
IP	(degree of) Ingress Protection

IPB	Isolated Phase Busduct
kVA	Kilo-Volt Amps
kVAr	Kilo-Volt Amps reactive
kW	Kilo-Watts
LA	Lightning Arrester
LCP	Local Control Panel
LED	Light Emitting Diode
MAT	Mine Auxiliary Transformer
MCB	Miniature Circuit Breaker
MCC	Motor Control Centre
MW	Mega-Watts
MWHr	Mega-Watt hours
NEC	National Electric Code (NFPA 70)
NEMA	National Electrical Manufacturers Association
NETC	Non-Excitation Tap Changer
NSPB	Non-Segregated Phase Bus
OHL	Overhead Line
OLTC	On Load Tap Changer
ON	Oil Natural
ONAF	Oil natural, Air Forced
ONAN	Oil Natural, Air Natural
SWGR	Switchgear
PF	Power Factor
PVC	Polyvinyl Chloride
rms	root mean square

RTD	Resistance Temperature Detector
s	seconds
SAT	Station Auxiliary Transformer
SEE	Static Excitation Equipment
SF6	Sulphur Hexafluoride
SOE	Sequence of Events
STG	Steam turbine generator
SWGR	Switchgear
TEFC	Totally Enclosed Fan Cooled
TP	Terminal Point
UAT	Unit Auxiliary Transformer
UPS	Uninterruptable power Supply
VAr	Volt Amps reactive
VFD	Variable Speed Drive
VT or PT	Voltage Transformer or Potential Transformer
WP	Weather Proof
XLPE	Cross-Linked Polyethylene

1.4 Ambient Conditions

Table 2. Ambient Conditions

Average temperature	18 °C
Maximum temperature	45 °C
Minimum temperature	-10 °C
Average humidity	49 %
Maximum humidity	98 %

Minimum humidity	4 %
Normal ambient air pressure	932mbar
Ground average elevation above sea level (for process design not civil works)	800 m
Well water temperature Maximum	59 °C
Seismic zone	2B
Seismic zone factor (Z)	0.20
Type of soil profile	SC - SB
Seismic index related	
To acceleration (Ca)	0.20 – 0.24
To velocity (Cv)	0.20 – 0.32
Air pollution level	Level IV
Creep ratio	31mm/kV (maximum voltage)
400 kV Basic Insulation Level (BIL)	1425kV

1.5 Electrical Terminal Points

A total number of six terminal points are defined for Electrical:

TP 5.1 - NEPCO overhead transmission line is

at the EHV bushing of the generator step-up transformers (GSUT) in the Plant

at the EHV bushings of the station auxiliary transformer (SAT) in the Plant

at the EHV bushings of the mine auxiliary transformer (MAT) in the Plant

GPEC will supply the Transformers HV bushings clamps, Surge Arresters clamps, T-clamps and down-leads to connect the NEPCO's conductors with the surge arresters.

NEPCO is responsible to design, procure and erect the gantries inside the power plant supporting the OHL conductor interconnecting the transformers and NEPCO's 400kV switchgear. Construction schedule of the gantries inside the power plant will be coordinated between NEPCO and GPEC.

TP 5.2 - Contractor's protection, control and monitoring signal cabling from the Plant at the interface panel which is supplied and installed by NEPCO in the substation building.

Power tariff metering is In Contractor's scope including all tariff metering devices, signal, cabling & installation.

All necessary interfacing work to the RTU.

Interface panels are provided in the substation by NEPCO and at the power plant end by the Contractor. Contractor is responsible for the control cabling between these panels. Contractor is responsible for civil works associated with the cable route (in a cable trench) to the NEPCO substation boundary only. Contractor's works are inside the power plant area. Civil works within the substation are the responsibility of NEPCO.

NEPCO's interface panel inside NEPCO's control building is supplied by NEPCO

All signal cabling and termination from the power plant to the interface panel is GPEC's responsibility.

Civil works for control cables up to the inner fence of NEPCO's switchyard is GPEC's responsibility

TP 5.3 – Electrical connection to the well pumping stations

The well pumping stations shall be fed via 11kV feeds from the 11kV station switchgear via step-down transformers located at each well pumping station. The Contractor's scope includes design, supply, and installation of the electrification system for the well pumping stations, including supply of any necessary transformers and switchgears in the nine pumphouses, and commissioning of the entire electrification system including the well pumps. A ring network scheme shall be adopted with a total number of three rings provided. Terminal Point 5.3 shall be at the electrical loads of the Raw Water Supply Facility. (Note: According to the latest scope, the electrical loads shall be the contractor's responsibility).

TP 5.4 – Power connection to mine yard and housing

Contractor's scope includes the supply of 11 kV switchgears for mine yard and housing; the 11 kV power connection between the station 11 kV power and the 11 kV switchgear; and 11 kV power connection between the mine transformer (including mine transformer) and the 11 kV switchgear. The Contractor shall deliver these connections with bi-directional metering according to NEPCO's requirements in the System Grid Code. Except for the in-pit crusher and conveyor package feeders (see TP 5.4a), the terminal point TP 5.4 shall be at the outgoing feeders at the 11 kV switchgear for mine yard and housing. The details of the outgoing feeders will be provided later by the Owner.

TP 5.4a – Power connection to in-pit crushers and conveyors

Contractor's scope includes the electrical supplies to the mine in-pit crushers, overland conveyor and associated equipment. Contractor's scope includes cabling from the Mine and Housing switchgear, and the necessary in pit transformers and switchgear, both included in Contractor's scope. Terminal Point 5.4a shall be at the electrical loads of the crusher and conveying system equipment.

TP 5.5 – Electrical connection to the Ash Disposal package

The Contractor shall provide all power supplies to the ash disposal package equipment including cabling from the Power Plant 11kV station switchgears, transformers and LV switchgear in the ash dump area. The terminal point shall be at the electrical loads of the ash disposal package equipment. For the sizing of the station auxiliary transformer, the Contractor has to consider that the ash handling equipment will be extended at later stage to start mine backfilling in accordance with the load schedule. The Owner estimates that crusher and conveying package equipment maximum power requirement will be 3.2 MVA and ash disposal package equipment will be 3 MVA.

TP 5.6 – Low voltage power supply to NEPCO

The Contractor shall provide two, 400Vac circuit feeders from two separate designated low voltage switchgears in the Power Plant with the following features:

- Rating of each circuit: 400kVA
- Total power from both circuits: 315kW
- Metering facilities: Each circuit shall be complete with VT, CT and Tariff Meter in accordance with the Schedule 2, Section 9.
- Civil works for LV cables up to the inner fence of NEPCO's switchyard is GPEC's responsibility.

The terminal point shall be at the outgoing terminals in the 400Vac circuit feeder panels.

2. CODES, STANDARDS AND REFERENCES

It is preferred that equipment be designed in accordance with equivalent IEC Standards that will take precedence over reference ANSI Standards unless otherwise noted. The key codes and standards are listed below.

IEEE 80, "Guide for Safety in AC Substation Grounding"

IEEE C37.23, "Metal Enclosed Bus"

IEEE C37.013, "IEEE Standard for AC High-Voltage Generator Circuit Breakers Rated on a Symmetrical Current Basis"

IEEE 485, “IEEE Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications”

NFPA 780, "Standard for the Installation of Lightning Protection Systems"

IEC 60034, "Rotating Electrical Machine"

IEC 60071, "Insulation Co-ordination - Definitions, Principles and Rules"

IEC 60076, "Power Transformer"

IEC 60726, "Dry Type Power Transformers"

IEC 62271-200, "High-voltage switchgear and controlgear - Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV"

IEC 61869, "Instrument Transformers"

IEC 62271, "High-voltage Switchgear and Controlgear”

IEC60439, “Low-voltage Switchgear and Controlgear Assemblies”

IEC 60947, "Low-voltage Switchgear and Controlgear"

IEC 60694, "Common Specifications for High Voltage Switchgear and Controlgear Standards"

IEC 60265, "High-voltage Switches"

IEC 60470, "High-voltage Alternating Current Contactors and Contactor-Based Motor-Starters"

IEC 60502-1, "Power Cables With Extruded Insulation and Their Accessories for Rated Voltages from 1kV to 30kV"

IEC 60502-2, "Power Cables With Extruded Insulation and Their Accessories for Rated Voltages up to 1kV"

IEC 60079, “Explosive Atmospheres”

IEC 60529, “Degrees of Protection Provided by Enclosures (IP Code)”

IEC 60071-1, “Insulation Co-ordination – Part 1: Definitions, Principles and Rules”

IEC 60071-2, “Insulation Co-ordination - Part 2: Application Guide”

EN12464, "Light and Lighting"

EN1838, "Lighting Applications - Emergency Lighting"

EN50172, "Emergency Escape Lighting Systems"

Where the above referenced codes and standards contain recommendations in addition to requirements, the recommendations shall be considered requirements and shall be followed unless stated otherwise by other technical specification.

In the event of any conflict between codes, or this Design Criteria and codes, the more stringent applies.

3. ELECTRICAL SYSTEMS AND EQUIPMENTS

3.1 Connection to National Network (NEPCO)

The Plant will be connected to the national network via a 400 kV switchyard located adjacent to the Plant. The generator step-up transformer (GSUT) shall be provided with oil filled, open air bushings suitably designed to receive the 400 kV overhead lines provided by NEPCO. The surge arresters on the HV side of the GSUT shall be provided by the Contractor. The connected overhead line will be provided by NEPCO. A similar arrangement will be used for the station auxiliary transformer (SAT) and mine auxiliary transformer (MAT).

According to the NEPCO Transmission Grid Code dated February 2010, the planned maximum short circuit fault current levels will not be greater than 95% of 40 kA (38kA) for one second at the 400 kV level. Therefore, the short circuit capability of the 400kV electrical equipment of the Power Plant shall be no less than 40kA for 1 second.

According to APCO-TQ-WPC-GPEC-0004, the expected short circuit values at the 400 kV switchyard at the time of connection of the Power Plant in 2019 is indicated in the following table. While the values indicated in the bracket shall be actually used as the input of short circuit calculation as well as any other relevant calculations.

Table 3. Short Circuit values at switchyard

	3ph	1ph
Short Circuit Capacity [MVA]	2262 (24297)	845 (24297)
X/R	11.34 (40)	
Ikss[kA]	3.26 (38)	3.66 (38)

The 400 kV Transmission Network is solidly earthed.

For the 400 kV systems, the Basic Insulation Level (BIL) shall be 1,425 kV or higher.

High accuracy CTs required for the tariff metering system shall be provided by the Contractor as part of the 400 kV line bushings of the GSUTs, SAT and MAT. The required high accuracy PTs and its ancillary steel structure and anchor bolts, as per NEPCO's specifications and approval, shall be provided by the Contractor, and NEPCO shall take responsibility for the installation in the 400 kV substation; the 400kV PTs will be installed, tested, commissioned, operated and maintained by NEPCO.

3.2 Utility System Frequency and Voltages

The nominal AC-system frequency 50Hz±2.5%

EHV-connection to the grid	400 kV ±10 %
Generator voltage	20kV ± 5%
Medium voltage system	11kV±5%, 3-phase, unearthed
Normal low voltage system	400/230V±5%, 3-phase 4-wire, solidly earthed
Emergency low voltage system	400/230V±5%, 3-phase 4-wire, solidly earthed
AC control voltage	230Vac, 1 phase
DC power voltages	220Vdc, ± 10%
DC control voltages	110Vdc, ±10%
UPS voltages	230Vac, 1 phase

Other voltage differs from above may be proposed by equipment Supplier. And the Supplier shall provide transformer itself to gain the special voltage.

3.3 General Requirement

The units of measurement and dimension adopted for the execution of the project shall be the metric system in accordance with ISO 80000-1:2009.

Particular attention shall be given to the weatherproofing and corrosion protection of all electrical equipment. The level of equipment IP protection shall be according to IEC 60529 or NEMA equivalent shall be as follows:

- 11kV switchgear: IP30
- 11kV/0.42kV dry type transformer: IP20
- SWGR and MCC switchgear in electrical rooms: IP22
- Indoor MCC switchgear in process areas: IP34
- Indoor MCC switchgear in dusty areas (oil shale and ash areas): IP54
- Indoor motors: IP54
- Outdoor motors: IP55
- Motor terminal boxes: IP55

- Indoor protection relay and control panel: IP4X

When sizing the equipment and conductors outdoor or in process area, the maximum and minimum temperatures to be considered is provided in Section 1.4 above. The effect of solar radiation shall be considered by the equipment supplier. Equipment of tropical and/or humidity type could be offered as an option by the equipment supplier if necessary.

When sizing the equipment and conductors in electrical rooms and control rooms, the highest temperature to be considered is 40 degrees C, and the lowest temperature to be considered is 0 degrees C.

The electrical equipment shall meet the following noise level requirement:

Table 4. Indoor Noise Limit

At 1.0 m from an individual apparatus	85 dB(A)
In the Control Room	55 dB(A)

Table 5. Outdoor Noise Limit

	Daytime	Night Time
Level caused by the Plant measured at the site boundary shall not exceed	70 dB(A)	65 dB(A)
During Start-up and shutdown exceeding the limit by up to 5dB(A) is allowed, and during emergency operation for period of short duration		

3.4 System Description

Power will be generated by two (2) Steam Turbine Generators (STG) and stepped up through Generator Step-Up Transformers (GSUT) connected to the utility high voltage system. Each STG will be connected to their associated GSUT via Isolated Phase Bus (IPB) and low side Generator Circuit Breakers (GCB).

The facility will not be “Black Start” capable initially. During Plant Start-up when the generator is isolated from the network, the GSUT shall provide power to the plant via the generator connections to the UAT, which in turn shall provide power to the MV system for the unit auxiliaries. The plant's common service will be fed from the SAT via the station MV switchgear for start-up. If it is not feasible to feed the unit auxiliaries via the UAT, the unit auxiliaries may be fed from the MV station switchgear. If it is not feasible to feed the station auxiliaries via the SAT, the station auxiliaries may be fed from the MV unit switchgear. A high speed transfer device will be provided. The transfer between MV unit supply and MV station supply will be automatic following a fast bus transfer scheme (about 100ms). To startup the generator, a startup power source will be fed from the 400V turbine SWGR to the excitation system to provide the initiate excitation power for the generator. When the generator voltage is established, excitation power shall be switched back to the generator itself.

To take the Unit off the system, the generator shall be gradually unloaded to the lowest allowable level, and then the GCB shall be tripped manually, leaving the necessary Unit auxiliary loads operating from the UAT now fed from the 400 kV Grid via the GSUT.

Following start-up and synchronization to the Grid, auxiliary loads of each Unit shall be met by its own generator. Each Unit's auxiliary load shall be supplied by its own UAT connected to the generator via the 11kV Unit Switchgear. During normal operating conditions the SAT shall provide the Plant's common service loads via the 11kV Station Switchgear. If there is any problem with the UAT the MV incomer to the unit switchgear shall trip and the backup supply for the unit auxiliaries will be extended from the 11kV Station Switchgear. This transfer from unit supply to the station supply will be automatic following a fast bus transfer scheme. High speed transfer devices will be provided. There is synchronism check function in the high speed transfer device. Also DCS can send out transfer command to this device, and then it will do the transfer. Following the return of normal operating conditions, the Unit auxiliaries will be returned to the UAT manually by a momentary parallel operation of the Unit supply and the Station supply after checking for synchronism between the supplies. This operation is possible only when the generators are synchronized and connected to the 400 kV Grid.

The 11kV Station Switchgear and the 11kV Unit Switchgear shall provide backup supply to each other. In addition the 11kV station switchgear shall be the backup power for 11kV Mine Yard and Housing Switchgear, when the MAT power is not available.

Hazardous area shall be classified according to applicable IEC or NFPA standards. In hazardous (classified) areas, IECEx Certified Equipment shall be properly used and labelled.

3.5 Steam Turbine Generator

The steam turbine generators are located in the turbine generator building. The key parameters of the Steam Turbine Generator are as follows:

Manufacturer	Siemens AG
Type	SGen5-1200A
Cooling mode	Closed Air-cooled
Rated frequency	50Hz
Rated output	326MVA
Rated power factor	0.85 lag/0.9 lead
Rated terminal voltage	20kV

Excitation	Static
Neutral grounding	Transformer-resistor

The neutral connection and grounding shall be in SIEMENS's scope. The generator line leads and neutral leads shall be at the bottom side of the generator. The generator shall be on the pedestals on the 12.6m elevation inside the STG building.

The excitation system will be high response; static type utilizing a dry insulated excitation transformer supplied from the generator bus with redundant thyristor converters (2x100%) and shall incorporate an automatic voltage regulator. Excitation system will be supplied with integrated Power system stabilizer (PSS).

Each generator will be equipped with on line partial discharge and magnetic flux monitoring.

Each of the generators will be synchronized to the utility's transmission system using their associated low side Generator Circuit Breaker (GCB) and the generator synchronization system. If the power plant shall be required to operate isolated from the national grid, the 400kV circuit breaker(s) will be used as the synchronizing breaker. And the generators will be synchronized to national grid through 400kV circuit breaker.

3.6 Generator Step-Up Transformers (GSUT)

The generator step-up transformers shall not impose any restrictions on the associated generator as in exporting the full output of the generator under all site ambient and operating conditions. Generator Step-Up Transformers shall be a three-phase, two-winding, wye-delta, oil immersed transformer, following IEC standards. The ONAN rating shall be no less than 60% of the total rating. The key parameters of each of the GSUTs are as follows:

Rated capacity	210MVA/340MVA (45°C hottest spot temp)
Ratio	420±8x1.25%/20kV (OLTC)
Cooling method	ONAN/ONAF
Rated frequency	50Hz
Vector group	YNd11
HV neutral grounding	Solid
Impedance	14% (@ 340 MVA)

The high voltage bushings shall be 550kV class due to the dusty atmosphere at site. The minimum creepage distance shall be 17050mm. The GSUT shall be located to the west side of the ACC platform. Properly sized surge arresters shall be provided on the transformer HV side. The low voltage bushings shall be 24kV class.

On line analyzer for dissolved gas & moisture in oil shall be provided. Other accessories shall include oil level indicator(alarm), pressure-relief device(tripping), silica gel breather, Buchholz relay(with alarm and trip contacts), oil / winding thermometer (with alarm and trip contacts), cooling fans and radiators as required, fully wired marshalling cubicle with power, control and wiring to all transformer mounted devices, current transformers (CT) on line bushings and neutral bushing, isolation/filling/sampling/draining valves, rating plate and diagram plate, and earthing terminals. All bushing CT windings shall be wired out to terminal blocks located in an easily accessible metal box, rated IP55. The box shall have a bolted and gasketed cover. A remote OLTC control cubicle with visible tap changer position indication shall be provided for each GSUT. Two sets of step-up transformer remote OLTC device shall be installed in one panel located in the central control room.

3.7 Unit Auxiliary Transformer (UAT)

The unit auxiliary power system shall be supplied by two (2), three winding, Unit Auxiliary Transformers (UAT), one for each generating unit. Each UAT shall be connected via a tap in the main IPB between the GCB and the GSUT. The LV side connection of each UAT shall connect to the MV switchgear via Non-Segregated Phase Bus (NSPB). Each UAT will be capable of providing the total unit auxiliary power system demand of its own generating unit, the common auxiliary load of the plant. The ONAN rating shall be no less than 60% of the total rating.

The key parameters of the UAT are as follows:

Rated capacity	70/40-40MVA (45°C hottest spot temp)
Ratio	20±2x2.5%/11.5-11.5kV (NETC)
Cooling method	ONAN/ONAF
Rated frequency	50Hz
Vector group	D,d0-d0
LV neutral grounding	Ungrounded
Impedance	16% (@ 65 MVA)

The UAT shall be located between the STG building and the ACC platform.

Accessories shall include oil level indicator (alarm), pressure-relief device (tripping), silica gel breather, Buchholz relay (with alarm and trip contacts), oil / winding thermometer (with alarm and trip contacts), cooling fans and radiators, fully wired marshalling cubicle with power, control and wiring to all transformer mounted devices, current transformers (CT) on line bushings, isolation/filling/sampling/draining valves, rating plate and diagram plate, earthing terminals. All bushing CT windings shall be wired out to terminal blocks located in an easily accessible metal box, rated IP55. The box shall have a bolted and gasketed cover.

3.8 Station Auxiliary Transformer (SAT)

The common auxiliary power shall be supplied by one (1) Station Auxiliary Transformer (SAT). The SAT is connected to the 400kV Switchyard directly. The HV side connection of the SAT shall implement 400kV overhead line, while the LV side shall be connected to the MV switchgear located in the plant via Non-Segregated Phase Bus (NSPB). The SAT shall be sized to supply the load of one unit, the common loads, the mine and housing loads, and the water wells. The ONAN rating shall be no less than 60% of the total rating.

The key parameters of the SAT are as follows:

Rated capacity:	78/42-42MVA (45°C hottest spot temp)
Ratio:	400±8x1.25%/11.5-11.5kV (OLTC)
Cooling method:	ONAN/ONAF
Rated frequency	50Hz
Vector group	YN,d11-d11
LV neutral grounding	Ungrounded
Impedance	18% (@ 80 MVA)

The high voltage open air bushing shall be 550kV class due to the dusty atmosphere at site. The minimum creepage distance shall be 17050mm. The SAT shall be located to the west side of the ACC platform. Properly sized surge arresters shall be provided on the transformer HV side.

Accessories shall include oil level indicator (alarm), pressure-relief device (tripping), silica gel breather, Buchholz relay (with alarm and trip contacts), oil / winding thermometer (with alarm and trip contacts), cooling fans and radiators as required, fully wired marshalling cubicle with power, control and wiring to all transformer mounted devices, current transformers (CT) on 400kV line bushings and neutral bushing, isolation/filling/sampling/draining valves, rating plate and diagram plate, earthing terminals. All bushing CT windings shall be wired out to terminal blocks located in an easily accessible metal box, rated IP55. The box shall have a bolted and gasketed cover.

3.9 Mine Auxiliary Transformer (MAT)

Mine Auxiliary Transformer (MAT) shall be 20MVA according to the Contract, and shall be connected to the 400kV Switchyard directly via overhead transmission line. The HV side connection of Mine Auxiliary Transformer will implement 400kV overhead line. The LV side of the MAT shall be connected by cables to the 11kV mine yard and housing Switchgear located in the mine yard and housing area. The ONAN rating shall be no less than 60% of the total rating.

The key parameters of the MAT are as follows:

Rated capacity:	20MVA (45°C hottest spot temp)
Ratio:	400±8x1.25%/11.5kV (OLTC)
Cooling method:	ONAN/ONAF
Rated frequency	50Hz
Vector group	YN,d11
LV neutral grounding	Ungrounded
Impedance	8%

The high voltage bushings shall be 550kV class due to the dusty atmosphere at site. The minimum creepage distance shall be 17050mm. The MAT shall be located to the west side of the ACC platform. Properly sized surge arresters shall be provided on the transformer HV side.

The calculated load on the MAT for design shall follow the latest available load consumer list.

Accessories shall include oil level indicator(alarm), pressure-relief device(tripping), silica gel breather, Buchholz relay(with alarm and trip contacts), oil / winding thermometer(with alarm and trip contacts), cooling fans and radiators as required, fully wired marshalling cubicle with power, control and wiring to all transformer mounted devices, current transformers on 400kV line bushings and neutral bushing, isolation/filling/sampling/draining valves, rating plate and diagram plate, earthing terminals.

3.10 Generator Circuit Breaker (GCB)

The Generator Circuit Breaker (GCB) shall be an SF6 type and suitable for outdoor installation, designed in accordance with ANSI Standard C37.013. Natural air cooling method is preferred. The GCB shall be located on an outdoor platform as near to the outgoing terminals of the ST generator as possible. The GCB shall be packaged equipment equipped with the following devices:

- Surge arresters
- Grading capacitors
- Earthing switches on both transformer side and generator side
- Line isolator

- SF6 circuit breaker
- Voltage transformer
- Current transformers

The minimum technical requirements for the GCB assembly shall be:

• Nominal voltage:	20kV
• Nominal current:	12000A
• System-Source Interrupting Capability:	100kA
• Generator-Source Interrupting Capability:	80kA
• Close, Latch Capability:	300kA
• Enclosure:	IP65

3.11 Isolated Phase Bus

The isolated phase bus shall be of natural air cooled, air pressurized type. The IPB shall be designed, manufactured and tested in accordance with ANSI 37 series of standards. The isolated phase bus (IPB) system shall be completed with aluminum conductor, cast resin insulators, and aluminum enclosure. The IPB shall connect the generator terminal box, GCB, GSUT, UAT, Excitation transformer and PT/LA cubicle. Instrument air shall be used for pressurization. A hot air system shall be provided to eliminate moisture when the IPB is not charged.

The main IPB connecting the generator and GCB shall be installed at 6.3m floor of the STG building.

The main IPB connecting the GCB and the GSUT shall be overhead arranged on the steel structure, below the ACC platform.

The branch IPB connecting the main IPB and UAT shall be overhead arranged on the steel structure.

The branch IPB connecting the main IPB and the excitation transformer shall be vertically arranged since the excitation transformer is located at the 0.00m floor of the STG building.

The branch IPB connecting the main IPB and PT/LA cubicle shall be vertically arranged since the PT/LA cubicle is located at the 0.00m floor of the STG building.

3.12 Non Segregated Phase Bus

Non Segregated Phase Bus (NSPB) shall be designed, manufactured and tested in accordance with ANSI 37 series of standards. Bus conductor material shall be high conductivity copper. The three-phase conductors shall be totally enclosed in a common enclosure. The enclosure shall be made of aluminum alloy and provided with removable bolted covers. The minimum protection degree of the NSPB shall be IP55.

The bus duct shall be the self-cooled type and shall be furnished with all necessary connectors and material for field assembly. Thermostatically controlled space heaters shall be provided along the busduct.

NSPB shall be used to connect from the SAT to the 11kV station switchgear, and from the UATs to the 11kV unit switchgears. The interconnection between the 11kV station switchgear and the 11kV unit switchgears shall also by NSPB.

All NSPB shall be overhead arranged. Generally, the NSPB under the ACC platform shall be hung from the steel structure; NSPB going along the STG building shall be fixed on the brackets on the facade along STG building column A.

3.13 11kV Power Distribution

The 11kV power distribution system shall be an ungrounded system. It is able to run for a few more hours (normally 2~3 hours) when fault happens, thus to maintain an uninterrupted power supply for the consumers. This grounding method is usually advised for power systems that are not robust enough.

When fault happens, the 'alarm' signal shall be sent to the operator to indicate a fault happens, but the circuit breaker shall not trip immediately.

Comparing with resistance grounding, this grounding method would cause higher overvoltage in normal phases when a phase to ground fault happens. Consequently, the equipment including cables will be specified with the appropriate insulation level to withstand this overvoltage'

Medium Voltage Switchgear shall comply with IEC standards, and be metal-clad, free standing type, having a short-circuit interrupting rating of no less than 40 kAIC. The MV switchgear shall have a thermal withstand time of 3 seconds for through faults and shall be designed to withstand internal faults for 1 second. Vacuum circuit breakers shall be used in each MV feeder. Automatic temperature and moisture regulation device shall be provided for all 11kV switchgears. The general single line diagram shall be as indicated in the APCO-1-DW-EL-GEN-206-002. Each section shall have two equipped spares and two spaces at the rear side of the section.

The 11kV Unit Switchgear 1 shall have two sections, i.e. section A and section B. Each section shall have two power sources feeding from UAT 1 and 11kV Station Switchgear respectively. The switchgears shall be located in the 11kV unit switchgear room 1 on the 6.3m floor of the STG Building.

The 11kV Unit Switchgear 2 shall have two sections, i.e. section A and section B. Each section shall have two power sources feeding from UAT 2 and 11kV Station Switchgear respectively. The switchgears shall be located in the 11kV unit switchgear room 2 on the 6.3m floor of the STG Building.

The 11kV Station Switchgear shall have two sections, i.e. section A and section B. Each section shall have three power sources. Besides feeding from SAT LV winds, a second incomer could gain power from either 11kV Unit Switchgear 1 or 11kV Unit Switchgear 2, as indicated by APCO-1-DW-EL-GEN-206-002. The switchgears shall be located in the 11kV station switchgear room adjacent to the STG Building.

The 11kV Mine Yard and Housing Switchgear shall be split double-ended design, i.e. section A and section B connected by a bus tie circuit breaker. Section A shall be connected to the 11kV Station Switchgear B via cables, Section B, fed from the MAT, shall be connected to the MAT also via cables. The switchgears shall be located in the mine yard and housing area. Further coordination with the mine contractor will be required.

The 11kV Oil Shale Handing Switchgear shall be split double-ended design, i.e. section A and section B connected by a bus tie circuit breaker. Both sections shall be connected to the 11kV Station Switchgear by cables. The switchgears shall be located in the oil shale handling control building. Generally, this switchgear shall serve power for the loads in the oil shale yard, both mine operating area and plant operating area.

The 11kV Ash Dumping Switchgear shall be split double-ended design, i.e. section A and section B connected by a bus tie circuit breaker. Both sections shall be connected to the 11kV Station Switchgear by cables. The switchgears shall be located in ash transfer station 4. Generally, this switchgear shall serve power for the loads in ash dumping area.

The power supply to the nine water well stations shall be transferred through three rings formed by ring main units. Each water well station shall be provided with one (1) Modular Electrical building. The Modular Electrical building shall include all main electrical equipment including the ring main unit, the LV transformer, the LV switchgear, and remote I/O station etc.

3.14 400V Power Distribution

The low voltage distribution system shall be rated 400/230 VAC, 3-phase, 4-wire, with the neutral solidly grounded at the LV side of each of the 11kV/0.42kV distribution transformers.

The low voltage distribution transformers shall transform 11kV medium voltage suitable for 400/230V distributions. These transformers shall be cast-coil, AN cooled, dry type transformers built according to applicable IEC standards. The insulation shall be minimum Class F; 130 degrees C rated for a 80K average temperature rise over the indoor ambient temperature of 40 degrees C maximum. The transformers shall be sized to the maximum possible loading plus 10% spare capacity for future load growth. The maximum allowable rating of the transformer shall be 2500 kVA for this project.

Generally, the transformers shall be housed and close-coupled to the low voltage switchgear lineup. The secondary shall connect to the LV switchgear via bus conductors. Except for the transformers of the Modular Electrical building, which shall be arranged according to the overall layout without fitted enclosure.

Each LV distribution transformer shall include a manual adjusted Non-Excitation Tap Changer (NETC) on the primary side with taps ranging from 5 percent above nominal voltage to 5 percent below nominal voltage in 2.5 percent increments.

The low voltage AC distribution system shall use a "SWGR-MCC" (Switchgear-Motor Control Centre) scheme. Both the SWGR and MCC shall use switchboards of the same grade built in accordance with IEC 61439 and IEC 60947 standards. The switchgear assemblies shall be metal-clad, free standing type, having a short-circuit interrupting rating of 50 kAIC according to the short circuit level. The LV switchgear shall have a thermal withstand time of 1 second. Space heaters are not required for the low voltage switchboards.

All SWGR shall be located in dedicated electrical switchgear rooms. MCC could be located in electrical rooms or in process areas close to the load. Generally, important loads and motors above 90kW shall be fed from SWGR directly. However, the concept is not stringent and the load allocation to SWGR and MCC could be flexible.

Air circuit breakers shall only be applied in SWGR and unit MCC incomer, SWGR and unit MCC tie, and SWGR to MCC feeder circuits. All other feeders shall be implemented with Molded Case Circuit Breakers. The control and protection of process related LV motors shall be realized by intelligent motor controller.

All 400/230V SWGR shall be double-ended connected, three-phase, four-wire with continuous ratings not to exceed 4000 amps. A PE conductor shall be provided in the switchboard and be connected to the ground grid nearby at two separated points. All 400/230V SWGR shall include an auto main-tie-main transfer scheme. Except for the raw water well SWGRs, which shall be fed from the RMU.

The proposed low voltage SWGR sections shall be as following:

- One Turbine SWGR (two sections) for each unit.
- One Boiler SWGR (two sections) for each unit.
- One ACC SWGR (four sections) for each unit
- One Closed Cooling Water SWGR (two sections) for each unit
- One ESP SWGR (two sections) for each unit
- One Lighting & HVAC SWGR (two sections) for two units in the STG building
- One Water Treatment SWGR (two sections) for the plant
- One Ash Handing SWGR (two sections) for the plant

- Two Oil Shale Handing SWGRs (two sections each) for the plant
- One Admin Area SWGR (two sections) for the plant

The low voltage power distribution scheme for the ash dumping yard has not been determined yet.

The 400/230V MCC shall be three-phase, four-wire, double-ended or single section with two power sources. A PE conductor shall be provided in the switchboard and be connected to the ground grid nearby at two separated points. MCC for the unit shall use an auto main-tie-main transfer scheme to switch the power. MCC for the BOP shall have two power sources that could switch manually.

3.15 AC Emergency Power System

A dedicated self-contained 420V Emergency Diesel Generator (EDG) set shall be provided for each Unit. Each generator set shall be sized to supply all essential loads including any others required for a safe and orderly plant shutdown in the event of loss of normal power supply.

The generator fuel system shall include a local day tank having capacity for a minimum of 8 hours operation. This tank shall be connected and supplied from the main plant fuel tank by use of a separate fuel transfer pump suitable for the day tank. The day tank shall include level controls and high level alarm to the central control room.

The generators shall connect with Emergency Power SWGR. Emergency Power MCC 1, Emergency Power MCC 2 and Station Emergency Power MCC shall be fed from the Emergency Power SWGR as their alternate power source. The primary power source for these three (3) MCC sections shall be from the normal power SWGR.

Each EDG is sized to feed the essential load of unit 1, unit 2, and common plant. In the event of normal power failure, both diesel generators shall start automatically; the one first reaches rated voltage and frequency shall be connected to the Emergency Power SWGR by closing the connecting circuit breaker, and the other one shall be in hot standby mode. The emergency/essential loads shall be switched to the emergency power source automatically. Local and remote manual and automatic synchronizing facilities to allow short time parallel operation with the mains supply shall be provided for testing and maintenance purposes.

When normal power is restored, the load shall transfer back to the normal power supply manually, and diesel generators shall be shutdown manually.

Essential equipment is defined as that equipment of which the lack of operability could lead to damage or hazard to the key equipment or personnel and which is required to be operable for the safe shutdown of the unit during a loss of normal power supplies. The loads in the following list shall be considered essential and shall be provided with facilities for automatic transfer to a standby supply in event of loss of normal voltage.

- DC Battery Chargers in STG building

- Vital AC power load
- Control system power-DCS, DEH, TSI, etc.
- Uninterruptible power supplies
- Motor operated valves if necessary
- Lubricating oil if necessary
- Heaters for lubricating oil if necessary
- Surface heating equipment as necessary
- Central control room lighting
- Elevators
- Aviation Warning Lighting

3.16 DC Power System

220Vdc and 110Vdc battery systems shall be provided in the power plant. The 220Vdc system shall provide power to the emergency power consumers such as dc motors, UPS etc. Control system power supplies for the plant shall be supplied from the 110Vdc system.

Each battery system shall be comprised of 2x100% rated batteries and 2x100% chargers and dc switchboards, two main distribution switchboards connected by a tie breaker, and two or more 220 Vdc load switchboards. The batteries shall be valve regulated, sealed lead-acid maintenance free battery. The 220Vdc battery system shall also supply dc power requirements for the 220Vac Uninterruptible Power Supply (UPS) system.

The 220Vdc and 110Vdc battery systems shall be sized to supply the plant emergency loads for a maximum of one (1) hour.

Unit 1/2 battery shall be located in the steam turbine building battery room located on the 0.0m level.

An additional individual 110Vdc system shall be provided for the auxiliary workshop/building. This building is located far away from the steam turbine building, and therefore, it is difficult to supply power from the unit dc system in the steam turbine building due to the large voltage drop. These individual dc systems shall be comprised of 2x100% rated batteries and 2x100% chargers and some necessary dc switchboards. The battery shall be installed in panels, no battery room required. The following workshop/building will be equipped the individual 110VDC system.

- Oil shale handling control building

- Fire brigade building
- Ash transfer station 4

The preliminary battery size shall be as indicated below. It will be updated according to the final calculation.

- Unit 1 220Vdc system: 1600Ah
- Unit 2 220Vdc system: 1600Ah
- Unit 1 110Vdc system: 800Ah
- Unit 2 110Vdc system: 800Ah
- 110Vdc system in oil shale handling control building: 200Ah
- 110Vdc system in fire brigade building: 100Ah
- 110Vdc system in ash transfer station 4: 100Ah

The following typical loads shall be fed from the dc battery systems:

- MV Switchgear relay and control power (110Vdc)
- Protection relay & control power (110Vdc)
- Relay and control power for major 400/230V SWGR/MCC air circuit breaker except SWGR/MCC located is far away from ST building such as water well station, admin building (110Vdc)
- Indication and alarm systems (110Vdc)
- RTU Communication device (110Vdc)
- Fault Record system (110Vdc)
- STG Emergency Lube Oil Pump (220Vdc)
- Instrument emergency systems (220Vdc)
- Plant ac UPS Power System (220Vdc)

Regarding operation/interlocking of the main DC circuit breakers, shall be described as below and please also reference to the 220V/110V DC System Single Line Diagrams.

Circuit breaker CB3 and CB4 are mechanical interlocked by each other.

1. During normal operation, CB3 connects with 220V DC Bus, and CB4 is open by the interlock; battery will receive power (floating charge) from 220V DC Bus.

2. When the batteries request to discharge test, open CB5 and close CB6, batteries will discharge to the pre-set voltage step by step.

3. When the batteries finished discharge and request recharge, close CB10, open CB3 (i.e. close CB4), the loads on DC bus 1A will be supplied by bus 1B and meanwhile the batteries will be recharged from rectifier through CB4.

4. When the batteries finished charging, close CB3 (i.e. open CB4), open CB10 and close CB5 to finish the battery discharge-recharge cycle. The DC system back to normal.

3.17 Uninterruptible Power System (UPS)

Uninterruptible Power Supply (UPS) shall be provided for each unit to provide continuous, regulated ac power to essential loads that require 230 Vac power to operate under normal and abnormal conditions. The UPS of each unit shall include two (2) identical, 100-percent redundant UPS systems each including one inverter, one static by-pass switch, one by-pass power transformer, and any required power distribution panels. Each of the two (2) ac UPS inverters shall be powered from the plant's 220Vdc battery systems.

Under normal conditions, the UPS inverter should receive a supply from the battery. In the event of inverter failure, the load shall be automatically connected to the by-pass transformer. Facilities to manually initiate changeover from inverter supply to by-pass transformer supply without break should also be provided.

In the event of loss of voltage to a switchboard the alternate switchboard shall be manually connected to the other switchboard via an automatic transfer switch.

The following loads shall be supplied from the UPS:

- DCS Cabinet
- DEH Cabinet
- ETS Cabinet
- TSI Cabinet
- Boiler I&C Power Cabinet
- Turbine I&C Power Cabinet

- Common DCS Power Cabinet
- I&C Network Cabinet
- Metering and Measuring Panel
- Fire alarm control panel

Each unit UPS system capacity shall be 100kVA.

3.18 Electrical Controls

Electrical systems (generators and auxiliary power system) shall be controlled and monitored via the main plant DCS. Control and monitoring of motor starters shall be done in the DCS. In addition, local emergency stop push buttons are provided for special drives (e.g. conveyor). Motors not process related such as building exhaust fans, air conditioners etc. shall have local controls only and shall not be controlled through the DCS.

Interlocking between circuit breakers, trucks and earthing switches are either mechanical (inside one cubicle) or electrical (wired between cubicles). High speed transfer device for 11kV switchgear and automatic changeover device for 400V SWGR and unit MCC (MCC serving the unit) incomer/tie breakers shall be provided for stand-by power supplies transfer. The electromagnetic interlocking between these related breakers shall be provided by transfer device, not made in the DCS.

Indication and alarm of electrical equipment (generator circuit breaker, MV switchgear, LV SWGR and MCC, DC battery system, UPS) faults shall be provided local to the equipment. Indication and alarm of generators and transformers fault shall be provided on their related protection relay panel. In addition, the alarms and indications for the above electrical equipment shall be monitored in the plant DCS if the equipment is controlled by the DCS. For some MCC breakers/contactors which shall not be control from the DCS, e.g. some non-process related equipment, only local indication and alarm shall be provided.

All protective relays need to be monitored in the DCS.

Generator Synchronizing

- Power plant synchronizing is at the generator circuit breaker when islanding operation mode is not required. Each STG shall be synchronized automatically from the DCS through their respective synchronizing systems, which are included as part of each generator package. The synchronizing system shall control turbine speed/generator frequency, generator voltage, and breaker closure. Manual synchronization of the units shall be provided in the central control room from a manual synchronization panel for each unit. The manual synchronization associated equipment (double voltmeter, double frequency meter, synchronoscope, raise/lower voltage/speed control switch or push button) shall be provided in this panel.

- If the power plant shall be required to operate isolated from the national grid, the 400kV circuit breaker(s) shall be used as the synchronizing breaker. The synchronization controls and equipment shall be further clarified with NEPCO.

- Manual and automatic synchronization shall be provided for the emergency diesel generators. The synchronizing shall be performed at the diesel generator circuit breaker, and the synchronizing device and control shall be provided by the diesel generator vendor.

- Synchronism check relays (ANSI device 25) shall be provided for all MV switchgears for checking the synchronism between redundant incoming supplies. For all LV switchgears synchronism check relays are not required but the redundant incoming power supplies shall be connected in parallel only when the relevant upstream MV supplies are in synchronism.

- Automatic Generation Control (AGC) shall be provided for each main generator. The control and monitoring shall be achieved by the DCS system via the power plant Remote Terminal Unit (RTU) connected with the national grid control center.

11kV Switchgear Control

- All 11kV switchgear shall be controlled and monitored by the DCS. Each circuit breaker cubicle front panel shall be provided with a Local/Remote selector switch to select test operation from local and remote operation from the DCS. Switchgear close/open command will be came from DCS by hardwire. Important signals such as switchgear CLOSED status, OPEN status, in REMOTE/LOCAL, protection trip, etc. shall be sent to the DCS by hardwire. Signals shall also be sent to the DCS by communication protocol RS485 (Modbus).

- Each Unit’s 11kV load shall be supplied by its own 11kV Unit switchgear. During normal operating conditions, the SAT shall provide the plant’s common service loads via the 11kV Station Switchgear. If the UAT becomes incapable of providing power to the load, the 11kV unit switchgear incomer shall trip and the backup supply for the unit auxiliaries shall be extended from the 11kV station switchgear. Conversely, if the SAT becomes incapable of providing power to the load, the 11kV station switchgear incomer shall trip and the backup supply shall be extended from the 11kV unit switchgear. This transfer between unit supply and the station supply shall be an automatic fast bus transfer scheme. An automatic changeover facility (High Speed Transfer devices) shall be provided. The required logic, signals, synchronism check relay etc. shall be provided to ensure that the scheme operates reliably. Normally, the DCS can send out a transfer command to this device, and then it will do the transfer. Momentary parallel operation of the redundant supplies shall be possible using the synchronism check relay under manual mode of operation from the plant DCS. However, in the case that both the incomer and tie breakers are all closed simultaneously, an alarm shall be initiated in the DCS and locally. The high speed transfer device shall be equipped a free standing panel and located in the Steam Turbine Building in the 11kV switchgear room.

- The 11kV Oil Shale Handing Switchgear and 11kV Ash Dumping Switchgear shall also be performed with fast bus transfer scheme. An automatic changeover facility (High Speed Transfer devices) shall be provided.

- Control power for the 11kV switchgear shall be supplied from the 110VDC load switchboard for the circuit breaker trip, charge, close circuits and protection relay. Each line-up of switchgear shall be provided with two dc supplies with an automatic supply changeover facility.

400V SWGR/MCC Control

- All 400V SWGR and MCC incomer/tie electrically operated circuit breakers (except Oil Shale Handling System) shall be controlled from the plant DCS. Signals for measuring and control shall be hardwired to the DCS I/O modules, except for non- process related feeders e.g. lighting, HVAC loads, etc..

- 400V electrically operated circuit breakers for Oil Shale Handling System SWGR and MCC incomer/tie circuit breakers shall be controlled from the Oil Shale Handling System DCS. Signals for measuring and control shall be hardwired to the Oil Shale Handling System DCS. This DCS system shall connect with the main plant DCS by an RS485 communication data link.

- The control and monitoring of loads powered from MCC (except Oil Shale Handling System) shall be from the plant DCS. Oil Shale Handling System MCC shall be monitored and controlled from the Oil Shale Handling System DCS.

- Intelligent motor controllers shall be used for all motor starters. The internal Profibus-DP net shall be completely supplied and connected to each motor controller. MCC starter close/open command shall be initiated from the DCS and circuit breakers status shall feedback to DCS through the internal Profibus – DP net, not hardwire.

- 400V SWGR and unit MCC's incomer/tie circuit breakers shall be provided with local control facility. Local operation of the circuit breakers shall be possible in test position and service position operation shall only be possible from remote.

- All 400V SWGR and unit MCC synchronism check relays are not required but the redundant incoming power supplies shall be connected in parallel only when the relevant upstream MV supplies are in synchronism.

- One alternate power automatic changeover device shall be provided for each 400V SWGR and unit MCC redundant supplies. Momentary parallel operation between redundant supplies shall be possible if the upstream MV supplies are already in parallel operation. Normally, the DCS can send a transfer command to this alternate power automatic transfer device, and then this device will do the transfer automatically.

- Control power for the major 400V SWGR and unit MCC incomer/tie circuit breakers shall be supplied from the 110Vdc load switchboard for the circuit breaker trip, charge, and close circuits. Duplicated dc supplies with automatic changeover facility shall be provided. For SWGR and MCC located is far away from ST building such as water well station, admin building, the control power shall be derived from dedicated control transformer or from a centrally installed control transformer within the MCC. For MCC motor feeder, the control power shall be derived from dedicated control transformer or from a centrally installed control transformer within the MCC.

3.19 Electrical Protection

Protective relay devices shall be coordinated to the extent feasible to interrupt electric disturbances (fault, overload, abnormal operating condition, etc.) at the point nearest the fault, with the next upstream protective device providing back-up protection. Protective devices shall be operated through a lockout relay (ANSI device 86) or equivalent latching device or circuit to prevent automatic restart/reclose of the equipment.

Protective relays shall be electronic, multi-function type. Draw-out protective relays will have provisions for their removal without tripping their associated circuit breakers.

All protection relay and control panels for each unit generator, GSUT, UAT, SAT and MAT shall be located in the Steam Turbine Building protection relay room.

As a minimum, the following protective relays shall be provided:

- Steam turbine generator (STG) (redundant protection relay)
    - Generator differential
    - Generator Overvoltage
    - Generator Under/over–frequency
    - Generator Thermal overload protection
    - Under impedance
    - Generator under-excitation
    - SEE (excitation) Transformer overfluxing
    - Negative phase sequence
    - Overcurrent
    - Reverse power

- Stator earth fault (100%)
- Stator earth fault (90%)
- Rotor earth fault
- Fuse failure
- Inadvertent energization
- Over-excitation

- Generator Step-up Transformer (GSUT) (redundant protection relay)
  - Generator/Transformer overall differential
  - Transformer differential
  - Overcurrent
  - Ground fault over-voltage (neutral displacement protection when generator output isolated phase bus has a ground fault.)
  - Transformer neutral over-current
  - Transformer overfluxing
  - Winding and oil temperatures
  - Buchholz surge and oil level
  - Conservator oil level
- Unit Auxiliary Transformer (UAT) (redundant protection relay)
  - Transformer differential
  - Overcurrent
  - Earth fault at HV-side
  - Winding and oil temperatures
  - Buchholz surge and oil level
  - Conservator oil level

- Station Auxiliary Transformer (SAT) (redundant protection relay)
  - Transformer differential
  - Overcurrent
  - Transformer neutral over-current
  - Winding and oil temperatures
  - Buchholz surge and oil level
  - Conservator oil level
- Mine Auxiliary Transformer (MAT) (redundant protection relay)
  - Fiber optical transformer differential
  - Overcurrent
  - Transformer neutral over-current
  - Winding and oil temperatures
  - Buchholz surge and oil level
  - Conservator oil level
- 11kV incomer (protection located on 11kV switchgear)
  - Three phase over / under voltage
  - Phase time over-current
  - Earth-fault detection
- 11kV – 400 Volt Transformers feeder (protection located on 11kV switchgear)
  - Phase time over-current
  - Phase instantaneous over-current
  - Ground over-current
  - Transformer over temperature

- 11kV motors feeder (protection located on 11kV switchgear)
  - Phase instantaneous over-current
  - Non-directional earth-fault protection
  - Thermal overload
  - Phase unbalance
  - Over temperature (done by DCS)
- 400V SWGR and MCC incomer & tie breakers
  - Overcurrent
  - Earth fault
- 400V Motors feeder
  - Thermal overload protection, motor shaft lock protection, phase balance protection, all these protections should be incorporated in the intelligent motor controller.

3.20 Fault Record (Monitoring) System

There is a Fault Monitoring System that will monitor the equipment, provide sequence of events recording and disturbance recording of the electrical system.

Current, voltage, generator circuit breaker closed/open status and protection trip signals etc. for generators, GSUT, UAT, SAT and MAT shall be sent to individual unit fault record panels.

Current, voltage, circuit breaker closed/open status and protection trip signals etc. for 11kV switchgear shall be recorded via each compartment protection relay built-in fault record function. The circuit breaker trip signal also shall be sent to the DCS as sequence of events (SOE) recording.

400V bus voltage, incomer current and 400V SWGR & MCC incomer/tie circuit breaker trip signals shall also be sent to the DCS as disturbance recording and sequence of events recording.

3.21 Measurement and Metering System

The following measurements shall be transferred as a minimum to the DCS:

- Generator: Voltage, Current, Frequency, Active Power, Reactive Power, kWh, kVARh
- 11 kV Supply Feeder: Voltage, Current, kWh, kVARh

- 11kV Transformer Feeder: Current
- 11 kV Motor Feeders: Current
- 11 kV Busbars: Voltage
- 400V Supply Feeders: Voltage, current
- 400V Motor Feeders (≥75 kW): Current

Main and check tariff metering equipment per unit, SAT HV side and MAT HV side must be provided, including for connection from Station Switchgear to Mine Transformer and for low voltage power supply connection to NEPCO.

Tariff meter ION 8800 is preferred to be used.

All tariff meters shall be installed in a panel and located in the Steam Turbine Building protection relay room.

Measurement of tariff meters shall be sent to NEPCO metering system via fiber optical switch over OPGW cable. The OPGW cable shall be furnished and installed by NEPCO.

3.22 Local Billing System

A local billing system shall be provided in the power plant. The billing system shall be connected to the NEPCO remote billing system. Authorized users will have access to the server using web browser via VPN connection.

The main purpose of the Billing System is to replicate calculations contained in the Power Purchase Agreement (PPA) to produce capacity, energy and supplemental invoices on a monthly basis using half-hourly resolution.

The local billing system shall include a Communication module (Enterprise Data Server) server, Billing Engine Server, Ethernet connector and one operator station. Enterprise Data Server and Billing Engine Server shall be installed in free standing panel located in the Steam Turbine Building protection relay room, and the billing system operator station shall be located in the central control room.

3.23 Remote Terminal Unit (RTU)

A Remote Terminal Unit (RTU) shall be provided in the power plant for data collection and for secure communications between the plant and the NEPCO dispatch center. The RTU shall be configured to acquire and transmit power plant data to NEPCO national control center (NCC) and execute commands received from NCC and regulate the units under the AGC function built-in DCS. All power plant data to RTU shall be transferred from the main plant DCS via IEC 61850 protocol.

Two redundant RTUs with individual gateways shall be provided in the power plant. The two gateways shall be connected to NEPCO NCC via two fiber optical switch over OPGW cable. The communication protocol is IEC 104. NEPCO will furnish and install the OPGW cable.

3.24 Motors

The motors shall be IEC standard with minimum IE2 efficiency. Only direct-on-line squirrel cage induction type shall be used. If two-speed motors are supplied, they must have separate windings.

Medium Voltage (11kV) nominal voltages shall be used for motors rated above 200kW. Motors rated below 200kW shall be rated for 400V. Only exception shall be the raw water well pump motors of the K wells, which are 1000V.

LV motors 90 kW and larger and all frequency converter driven motors shall be equipped with stator winding thermistors. In frequency converter drives, the motor shall be specially designed, sufficient motor cooling shall be ensured.

MV motors shall be equipped with six Pt100 temperature sensors, two sensors in each phase. The first sensor shall be used and the other shall be spare. All sensors are to be wired to an easily accessible terminal box. Pt-100 sensors shall also be included if the winding temperature shall be monitored in the plant DCS.

Motors with frame size 160 and larger shall be able to equip SPM-nipples for vibration measurement at both ends of the motor. The measurement shall be possible to carry out without removal of any parts.

All MV motors and LV motors rated above a 50kW shall be equipped with anti-condensation heaters.

Standard totally enclosed cast iron type electric motors fitted with a shaft mounted cooling fan (TEFC) shall be preferred. The terminal box shall be made of steel, with a diagonally split gasketed, screw on cover. The terminal box shall be at an appropriate position of the motor, rotatable in 90 degree increments to allow for easy cable entrance.

The degree of protection shall be IP54 as a minimum, IP55 for terminal box and motors installed outdoors. Motors shall be suitable for heavy environments and operation conditions.

Sufficient reserve power (about 15 %), exceptional use (long starting time, frequent starts, jogging) and ambient temperature at the motor location (over +35 °C) shall be taken into account in motor selection.

The motors shall be of insulation Class F with Class B (+80 °C) temperature rise.

Motor rating shall comply with the duty type S1 (continuous duty) in line with required output and torque.

Motor operated valves, boiler soot blower motors and equal drives shall comply with the duty type S4 or S5.

Motors shall be capable at least for consecutive starts as follows:

- three (3) starts for cold motor (motor at ambient temperature)
- two (2) starts for warm motor (motor at normal operating temperature)

The motors shall be capable to start and accelerate the driven equipment with 85% of rated voltage applied at the motor terminals.

3.25 Cable and Cable Routing

Rating and sizing of cables shall be according to applicable IEC codes. Power and control cables may have XLPE insulation and PVC insulation respectively with PVC or PE sheath without armouring, except that any directly buried cables shall be steel wire armoured beneath the outer sheath. The insulation level of MV power cables shall be 8.7/15kV (Ph-Gnd/Ph-Ph). The insulation level of LV cables shall be 0.6/1kV (Ph-Gnd/Ph-Ph). The insulation level of control cables shall be 0.45/0.75 kV (Ph-Gnd/Ph-Ph).

The material of the core conductor of power and control cables shall be copper.

Multi-core power cable is preferred for both MV and LV feeders. For the convenience of cable routing, the maximum cross-section of the cable is limited. The maximum cross-section of three core MV power cable shall be 3X185 sq. mm. The maximum cross-section of one core MV power cable shall be 1X400 sq. mm. The maximum cross-section shall be 185 sq. mm for multicore LV cables, e.g. 3, 4, or 5 conductors. The maximum cross-section of one core LV power cable shall be 400 sq. mm.

The minimum conductor size for motors shall be 4 sq. mm copper conductors with XLPE insulation and 2.5 sq. mm for small power and lighting circuits subject to voltage drops. For control circuits and VTs 2.5 sq. mm copper with PVC insulation and for CTs 4 sq. mm. Similar sizes shall be used in the wiring of switchgear equipment, control panels, etc.

Cables outside of buildings may be installed underground in trenches, on cable ladders or above ground in overhead raceway on cable ladders or trays. Cables inside buildings shall be installed in cable ladders or trays either hanging from the ceiling where feasible or installed in trenches underneath switchgear equipment and panels. Hot dip galvanized steel type cable ladder and tray shall be used in most part of the plant. In areas of high risk of corrosion such as water treatment building, aluminum alloy type cable tray shall be used, galvanized type is prohibited.

Cable road crossings shall be in trenches surrounded by at least 150mm cover of reinforced concrete, or protected by steel conduit.

Tray cable runs shall be segregated by voltage and duty into groups. Adjacent groups shall have a minimum spacing of 200 mm. Separate ladders or trays or ducts shall be used for MV power cables, LV power cables, control cables, instrumentation cables and communication cables. It will be ensured that power cables do not cause any interference to signals carried by instrumentation and communication cables. Each cable tray shall include at least 10% spare capacity.

Duplicated circuits, cables for service to main distribution systems and emergency distribution systems shall either follow different routes or be separated from each other as far as practicable.

Fire resistant (FR) cables shall be used for emergency system, DC system, UPS, fire pumps, fire protection and alarm systems, subject to compliance with Applicable Requirements. Fire block measures shall be adopted along the raceway.

Galvanized conduits shall be used as the protection when cables are off the trays towards the consumer. The steel conduit shall terminate as close to the consumer as possible. All cables shall be terminated using appropriate cable glands and termination kits. Termination kits used for terminating MV cables shall be provided with stress relief devices. The cable between the conduit end and the gland/termination kits shall be left unprotected. This length shall be less than 50 cm. The conduit edge shall be well polished and the conduit opening shall be well sealed.

Cables shall be either solidly bonded or single point bonded as long as the sheath voltage is not an issue.

3.26 Grounding

The grounding system of the power plant shall consist of an outdoor, in ground, main plant grounding grid and several indoor facility grounding grids.

The outdoor ground grid shall consist of horizontal conductors, vertical ground rods, and ground wells as required. The design of the grid shall be in accordance with IEEE 80 and IEEE 665 standards. The plant grounding calculation shall be done using ETAP or CDEGS software. The main ground grid shall cover most area of the power plant and thus will be able to provide convenient grounding for the equipment and structures as required. Ground wells shall be provided as necessary for interconnection and inspection purpose. Specifically, there shall be two ground wells on the grid edge of the 400kV switchyard side for the interconnection of the switchyard grid and the plant grid if necessary.

The horizontal ground conductors shall be bare, soft-drawn, copper cable installed at an average depth of 0.7 meter below final grade. The conductor shall be sized based on actual maximum grid current of the plant. The short circuit duration until the fault is cleared is conservatively assumed to be 0.25 seconds. The vertical ground rods shall be copper-clad steel.

Generally, exothermal weld shall be used for the interconnection of both underground and above ground conductors. Exothermal weld shall be used for the connection of the ground grid and steel structures. Grounding risers shall be provided close to the equipment grounding terminal. Appropriate grounding crimps or lug shall be used for the grounding of the equipment.

An indoor ground grid shall be developed in each building for the easy grounding connection of the electrical equipment inside the building. The indoor ground grid shall be connected with the main outdoor ground grid via at least four (4) separated conductors. Equipment and electrical systems in the plant power block area will be grounded in accordance with the National Electrical Code (NEC), IEEE 142 or IEC equivalent.

The ground method type of the LV system shall be TN as defined in IEC 60364-1. The star neutral of the LV distribution transformer shall be connected to the ground grid. Protective (PE) wire shall be provided.

The ground method type of the lighting system shall be TN-C-S as defined in IEC 60364-1. Separate PE wire shall be provided for each feeder from the lighting distribution panels to the fixtures.

A dedicated instrumentation ground system shall be provided for the sensitive control and instrumentation equipment. This small ground system shall be isolated from the main grid or other possible electrical disturbance.

Special consideration shall be applied where necessary, e.g. water well area.

3.27 Lightning Protection

Lightning protection for buildings and structures shall be in accordance with NFPA 780 or IEC equivalent. All buildings and other equipment installed outdoors shall be provided with lightning protection. The lightning protection system shall consist of suitably arranged roof mounted air terminals network, consisting of copper or aluminum spikes, copper conductor grids etc. and down conductors and earth rods to safely discharge the currents associated with a lightning strike to ground. The lightning protection system ground rods shall be bonded to the plant ground grid.

The lightning protection system must have a maximum zone of protection to limit destruction, fire, damage, death, or personal injury from lightning. The zone of protection is determined from the "Rolling Sphere Concept," in NFPA 780. The lightning protection must provide a direct and easy low-resistance metallic path for lighting current to follow the ground. Open steel structures, e.g. boiler, do not require lightning protection. However, every other steel column in such structures shall be connected directly to the plant grounding grid/system at the base of the column.

Where determined by the lightning calculation, air terminals and down conductors shall be installed. Air terminals are located around the top of structures and the down conductors are then connected to the plant ground grid by exothermic welds with dedicated ground rod nearby. A minimum of four (4) down conductors is required at each structure. Each air terminal must have at least two (2) separate paths to ground.

3.28 Lighting System

Lighting systems shall be in accordance with EN12464 or IEC equivalent. Emergency lighting shall fulfil requirements mentioned in emergency lighting standards EN1838, EN50171 and EN50172.

Aircraft warning lights on stack and boiler shall be provided in accordance with the statutory requirements.

Sufficient lighting shall be provided to enable operators to circulate freely and safely within the accessible areas. The lighting provisions will be generally as below and when measured 1 meter from the floor or on the floor as appropriate, the average illumination will not vary by more than minus 25% or plus 60%.

The illuminance values of the common areas over the lamp life are required by the following table.

Table 6. Typical Illuminance Requirement

Place	Illumination Level (Lux)
Control rooms, offices	400
Toilets and locker rooms	100
Interior store rooms	100
Switchgear Rooms	500
Workshops	400
Steam Turbine hall	300
Boiler areas	200
Water treatment areas	150
General access and stairs	150
Tank farm and storage areas	25
Roadways	5
Outdoor operational areas	150

More detailed minimum illumination levels shall be in accordance with standards EN12464 or IEC equivalent.

Lighting shall generally be by means of fluorescent light fixtures, supplemented in open and high bay areas by high pressure sodium (HPS) discharge flood light projectors type fixtures. Outdoor roadway and area lighting may be mercury vapor or HPS. LED energy saving lighting shall be used as much as practical.

In addition to the general area lighting for normal operation, permanently energized emergency lighting, powered from the emergency power system shall be provided for access and escape routes and for all operating areas. Emergency lighting shall be provided by integral battery packs that will last for at least one hour, and will not be connected to emergency power. The emergency lighting shall function the same as the normal lighting when normal ac power is available. And they would be switched to battery power automatically when normal ac power is lost. Generally, the ratio of emergency lighting to overall lighting is 20% for operating areas. Emergency and maintained light fittings shall be labeled to identify their function.

For most areas of the power plant, the lighting power shall be fed from normal 400Vac power source. Except for the center control room, where the lighting power will be powered from the emergency power switchgear.

Generator area, boiler and high vessel lighting shall, as much as possible, be split across lighting boards, such that the loss of one board shall not darken an area completely. Fixtures around rotating plant equipment shall be supplied from different phases to minimize the "stroboscopic effect."

Luminaries installed in the central control room shall be fitted with low glare louvers, specially designed for use in VDU screen environments. The luminaries shall be dimmable to allow the VDU operators to set a comfortable illumination level.

Aircraft warning lights shall be provided for the stack or any other structures that are higher than150 meters. From the stack top to the 150m elevation, a group of warning lights shall be installed every 50 meters. In each group, there shall be six lights installed around the stack facade with equal Intervals. The aircraft warning lights shall be fed from the emergency power switchgear.

Permanent security lighting shall be provided for all plant gates.

Outdoor lighting shall be fully weatherproof and controlled by photo cell/time switch. Explosion proof lighting shall be adopted according to the result of hazardous area classification.

3.29 Socket outlets

General purpose socket outlets of the two poles and earth type to Jordanian standards shall be provided as follows:

- Within rooms of buildings where required for supplies to portable office equipment or cleaning equipment.
- In rooms and other areas of the Plant and associated facilities where their use may facilitate inspection or repair of equipment, located so that the necessary coverage of the room or area may be achieved with flexible cables not exceeding 30 meters in length.

Socket outlets of the three pole and earth type generally rated for 63 A to Jordanian standards shall be provided as follows:

- In rooms or other areas of the Plant where supplies to portable welding sets and similar equipment may be required, located so that the necessary coverage of the room or area may be achieved with flexible cables not exceeding 50 meters in length.

In transformer compounds for supplies to oil filtration equipment, the socket outlet shall be 400V, 250 A.

The general two pole socket outlets shall be fed from lighting distribution panels; whilst the three pole socket outlets shall be fed from maintenance panels. All socket circuits will be provided with overload and short circuit protection in accordance with applicable IEC standards.

3.30 Cathodic Protection

The geotechnical test results indicate that most of the tested materials are located within the "Moderately and Highly Aggressive" Zones. Accordingly, it is advisable to protect most of the underground steel elements, e.g. piping, by cold asphalt paint.

Cathodic protection will be considered for field-erected storage tanks. The tank bottoms shall be set on a concrete ring-wall or slab foundation. Cathodic protection shall be provided if required.

The cathodic protection shall be designed according to standards as EN 12068, EN12499, EN 12954, EN 13173 and EN 14505.

Since only a small number of tanks require protection, sacrificial anode method shall be considered prior to the impressed current method.

END