Electrical Philosophy

CO_2 Capture – BOD & Tender Specifications

AEB Amsterdam

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Abbreviations

Abbreviation	Definition
CB	Circuit Breaker
DSO	Distribution System Operator
ECS	Electrical Control System
EDGS	Emergency Diesel Generator Set
HMI	Human-Machine Interface
HV	High Voltage
ISBL	Inside Battery Limits
kV	Kilo Volts
LAN	Local Area Network
LV	Low Voltage
MCC	Motor Control Centre
MV	Medium Voltage
MVA	Mega Voltage Ampere
MW	Mega Watts
MVAr	Mega Voltage Ampere reactive
OSBL	Outside Battery Limits
PCC	Plant
PPA	Power Purchase Agreement
TSO	Transmission System Operator
UPS	Uninterruptible Power Supply

1 Scope

This document covers the electrical philosophy of the power supply and distribution to various work packages of the CO_2 capture plant as a whole system. For simplification and better understanding, this report is to be read in conjunction with the following document:

- 416041-47990-E.01-001 - Key One Line Diagram

2 Power Supply Conditions at Site

AEB is looking into various possibilities to bring in the power required to run the CO_2 Capture Plant. One option is connecting to a 10 kV grid connection. Another option that AEB is building a 50 kV station to serve its future developments and supply power to the CO_2 Capture Plant. From this station, 100% of the power will be supplied using two feeders at 10 kV.

As agreed with AEB, it is hence assumed that for the design of the electrical system, the power will be available at a voltage level of 10 kV at the battery limit of the plant.

3 System Design Philosophy

3.1 General

The proposed electrical system is designed to ensure the following:

- Technically and economically efficient
- Sustainable
- Safety to personal and equipment during operation and shutdown
- High reliability with minimal risk
- Easy maintenance
- Automatic protection of all electrical equipment
- Adequate provision for future extensions and modifications
- Electrical supply to equipment within the design and operating limits

The Power Distribution System consists of but shall not be limited to the following Main Equipment:

- Two redundant 10 kV power feeders (OSBL)
- 10 kV MV switchgear (double bus bar configuration with bus coupler and synchronisation system, as needed)
- 10 kV MV circuit breakers
- 10/0.69/0.4 kV step down transformers for LV levels (three winding)
- Variable Frequency Drive (VFD) system for CO_2 Compressor
- VFD systems for other big pumps/compressors (to be confirmed in next project phase)
- 690V Switchgears and motor control centres (MCCs)
- 400V Switchgears and motor control centres (MCCs)
- 400V/230V Uninterruptible Power Supply System (UPS), incl. Rectifier/Charger, Inverter, Static Switch and Backup Battery
- Automatic Power Factor Improvement Equipment at 10kV level.
  - A complete study is necessary to determine the exact need for power factor compensation
- Emergency Power Supply (to be confirmed in the next phase)

The ratings and characteristics of the main equipment are shown in the KOL diagram. A detailed study shall be performed in the next phase and when more vendor data is known.

4 Equipment Design Philosophy

The electrical distribution system was designed in accordance with good engineering practice and project specifications. AEB Technical Standards are applicable and leading.

The adopted design is based on the continuity of supply to the plant, flexibility of operation with the Grid supplier, the operational costs, and the required reliability of supply from all the power sources available to the plant and the individual loads.

All the main equipment such as transformers, switchgears, variable speed drivers were sized to satisfy the maximum load requirements under the most severe scenarios. This approach will cover all the assumptions and contingencies made at this stage of the project.

4.1 System Voltages

The voltage levels are chosen as follows:

- 10 kV incoming supply voltage available
- 10 kV main voltage level for power supply to MV pumps/compressors
- 690 V for power supply to main LV motors
- 400 V for power supply to utilities and other LV motors

Supporting calculations shall be included in study to validate chosen design parameters and ratings of installation and equipment.

4.2 Voltage Drops

The system was designed in such a way that the voltage drops at motor starting is not foreseen to exceed the minimum allowable values for correct functioning of the plant. However, a complete motor starting, and reacceleration study shall be performed in future stages of the project to ensure this principle. Special attention must be given to the 10 kV busbars during start-up of the large motors and/or motor reacceleration conditions, where the maximum permissible voltage drop shall not go above 15%, which means the available voltage at the busbars should not drop below 0.85 per unit of nominal voltage.

Experience suggests that potential 50/10 kV transformers that are outside battery limits, may consist of larger impedance Z (%) or larger tap changers to overcome voltage drop issues. Further dedicated VFD systems used as main drivers to the large consumers can help dampen voltage drops. Detailed study to advise/determine impedance a tap changer requirement on supply side. If connected directly to the grid the supplying power company's requirements shall be met.

For the 10 kV motors the voltage available at the terminals shall not be less than 75% of the rated value during start up or reacceleration.

4.3 Short Circuit Capacities

The proposed design considers (for the various distribution and voltage levels) the short circuit capacities of the available switchgears and main equipment on the market. Calculations were done on a very high level to have rated short circuit breaking capacity and making it equal or higher than the maximum value of short circuit current (rms).

The related values, shown in the representative key one lines, are based on a minimum period of one second (1s) for MV and LV levels.

A full and detailed analysis shall be done in later stages of the project.

4.4 DC Power Supply

An independent DC power supply is foreseen in the design to provide a complete plant shutdown system:

- Including DC instrumentation
- All the electrical switchgear controls including critical lighting
- Battery backup

4.5 Emergency Power Supply [HOLD]

The source of emergency power supply for the new capture plant is to be decided along with AEB. For now, emergency power supply is not included in the design.

Due to double busbar configuration and further redundancy to the LV levels, the overall reliability of the plant is high. An emergency power supply might not be necessary but would ultimately depend on the plant availability requirements by AEB and any contractual requirements by the off taker. Safe shutdown of the plant should be foreseen in all possible conditions, including total black-out. This needs to be investigated in the next phase.

4.6 Uninterrupted Power Supply (UPS)

Uninterrupted power supply system is required for meeting critical loads that cannot withstand a momentary interruption in voltage like:

- Critical instrumentation, control, HMI for substation automation system, electrical control system, communication system and LAN system.

The batteries shall have the adequate capacity to meet the back-up time dictated by the process conditions. While sizing the battery system, an aging and temperature safety factor shall be applied.

The UPS shall help in safe shutdown of the plant in case of a major loss of power.

In next project phase, it shall be assessed whether the existing UPS' capacity will be sufficient to support the new PCC Plant. If needed, additional UPS capacity shall be installed.

4.7 Power Factor Improvement

A power factor improvement calculation shall be performed to assure that no re-active power (MVAr) needs to be generated to compensate the power factor of the system.

If required, it is proposed that automatic power factor correction equipment shall be provided on the main 10 kV switchgear. However, the need for power factor correction shall be dependent on the results of detailed power system studies.

When Power Factor Compensation Systems are needed, these shall be provided to achieve a minimum Power Factor of 0.92 lagging at all the buses, under Full Load Conditions as a minimum and shall be further agreed together TSO/DSO.

These shall be regulated automatically with microprocessor based, multi-step controllers and contactors. Filters shall be considered as required to prevent overheating due to higher harmonic currents.

4.8 Electrical Control System (ECS)

Electrical control system shall be provided to monitor and control electric power distribution of electricity to the complete capture plant. The ECS shall include, as minimum; distributed RTUs & I/O panels, HMI, servers, fibre optic, data highways, etc.

Base and advanced functionalities as specified in project design shall be assessed in later stages of the project.

5 Operating Design Philosophy

The proposed philosophy provides a reliable high redundant system for both normal and critical loads to prevent a whole plant Shutdown in case of Momentary Power Outage or Excessive Voltage Dips. This is achieved by means of:

- Two independent main incoming 10 kV Feeders for power supply and plant load.
- A double busbar 10 kV switchgear with bus coupler and synchronisation system (if needed).
- Double in-feeds for 690V and 400V switchgears and motor control centres.
- Emergency power supply [HOLD].
- 400V/230V UPS system with full capacity for critical loads.

5.1 Normal Power Supply System

The 10 kV feeders are designed to provide 100% of power required by the plant. Both feeders are part of a redundant system (2 x 100%) where each feeder can provide the total power required by the plant.

During normal operation the power supply is split between the two main incoming feeders, in total supplying to all the necessities of the plant. Facilities for synchronisation and balancing of power shall be supplied, as necessary. During normal operation each 10 kV busbar is foreseen to provide 50% of the power. All 10 kV loads shall be connected to the busbars via circuit breakers. In case of fault at one feeder or overloading, this configuration can ensure shifting the load from one busbar to another, ensuring 100% supply to all the loads.

A high-level load assessment was performed to determine the location (voltage levels) of the loads. If closing times of circuit breakers are not fast enough to provide a smooth online switching, then automatic restarting of critical users in the plant shall become necessary. Restarting groups shall be determined in accordance with the process requirements, with re-starting intervals of 3 to 5 seconds (to be confirmed during detail engineering) and grouped in such a way that the voltage drop will not exceed the allowable limits.

Restarting shall be via the DCS System. Also, to achieve abovementioned performance, the Tie-Breaker Cubicle shall be complete with a two-position switch enabling the “Auto” or “Manual” mode.

Under normal plant operating conditions, all the critical loads are supplied from either one of the Normal Supply busses. The same operating philosophy applies to the 400V systems.

5.2 Emergency Power Supply System [HOLD]

To be assessed in next project phase.

5.3 Power and Quality Measurement

The system shall ensure to have certified power quality characteristics at the 10 kV terminals, that demonstrate full compliance with all applicable power quality standards including those set forth in IEC Standards and the Grid Connection Agreement. In the next phase of the project, it would be important to assess the need for reactive power and power quality correction devices as a part of the electrical system.

The amount of normal and peak power expected to be imported from the grid during the plant operation shall be monitored and must be clearly defined and set forth in the Power Purchase Agreement (PPA) with the grid authorities.

5.4 Electricity Capacity Reservation

When connecting to the Grid further operating requirements are to be adhered to. One of the most important, that affects the operation of the electrical system, is the capacity reservation. The capacity reservation is used to stabilize the grid frequency and power balance during imbalances and frequency deviations.

The above shall be addressed and discussed with all stakeholders in later phases of the project.

5.5 Island Operation

The proposed system does not foresee island operation, neither heavy load shedding, thus power import from the substation shall be always required.

5.6 Black Start

Facilities to make the black start possible without the connection to the Grid are not provided since no island operation is required, and due to the availability of two main redundant 10 kV feeders from the Grid.