

# MINING POWER SYSTEM

Recommended power generation and electrical distribution for high altitude lithium mine

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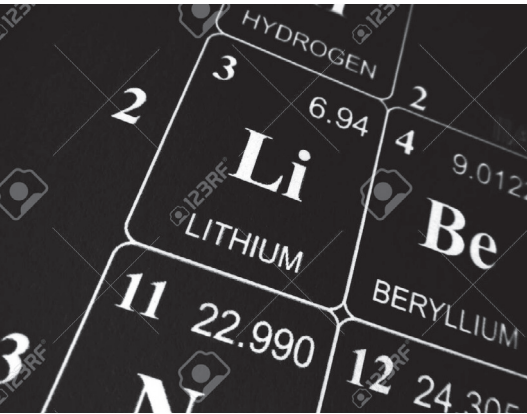
The choice of the power generation and electrical network architecture have a major impact on the total cost of mining power systems and the availability of an electrical power supply. To optimise the power system's total cost and its impact on availability, different options taking into consideration the effect of altitude, need to be evaluated.

This paper outlines recommendations for establishing an optimised flexible power generation and electrical network architecture, illustrated by a case study of a lithium mine located at high altitude.

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# PURPOSE OF THIS PAPER



The power system equipment represents less than 5% of a mining project's CAPEX but is, nevertheless, essential for the safety and availability of the entire operation.

Traditionally, mining power systems have been designed by engineering companies (EPCs) and/or mining sector end-users using their knowledge of the industrial process and their experience from previous projects. This results in robust installations that are often not optimized for cost and footprint, since the electrical design approach focuses on individual packages, rather than considering the entire system.

Electrical equipment manufacturers are not usually involved in the design phase. They are consulted only later, during the request for quotation process once the design is completed. However, manufacturers have a deep understanding of factors such as product cost and technology limitations, which could be used to create optimized cost and reliability for the complete mining power system.

This design recommendation guide will provide a concrete example of optimization that could be achieved when the end-user, EPC, and manufacturer work together at an early stage in the project.

## RECOMMENDED DESIGN FEATURES THAT RESPOND TO KEY END-USER NEEDS

Key end-user needs	Features of recommended design
Safety: Low risk of operator arc flash and electrocution accidents	<ul style="list-style-type: none"><li>• Limited fault currents by having the correct electrical network architecture and component characteristics</li><li>• Internal arc tested MV &amp; LV switchgear with intuitive operation, earthed metal barriers and comprehensive interlocks</li></ul>
Low total cost of ownership	<ul style="list-style-type: none"><li>• Choice of network voltages and equipment to minimise capital investment and reduce operating costs related to system losses</li><li>• High power quality to reduce energy losses and prevent equipment failure</li><li>• On-line asset management system to reduce maintenance costs</li></ul>
Power availability adapted to the process	<ul style="list-style-type: none"><li>• High availability power supply for critical loads of the process plant and site facilities</li><li>• Proper protection system coordination to avoid unnecessary outages</li><li>• Scalable power generation with modular power plant</li><li>• Flexible and expandable power system with open ring network architecture</li></ul>

**Table 1. End-user needs and recommended design features**



# INTRODUCTION

This power system design is recommended for a lithium extraction site using brine pumped from salt lakes (also called salars), located at high altitude, delivering 20 kTons/year Lithium Carbonate Equivalent (LCE). It is designed for reduced CAPEX and low total cost of ownership (TCO) while providing a high level of operator safety. Cost optimisation is achieved using a simple electrical distribution architecture with suitable MV and LV connected equipment installed in E-Houses. An Ethernet based system integrates the electrical network management, energy consumption, and asset condition with the industrial process control.

## LITHIUM DIRECT EXTRACTION PROCESS

The direct extraction process is favoured because it is less expensive and more environmentally friendly than the conventional evaporation process.

- The upstream begins with the pumping of the natural brine and continues with the production of purified lithium rich brine. The brine then goes through the extraction material, which selectively captures lithium from the brine. The lithium-depleted brine is sent back to the salar.
- The brine is finally treated with a reagent, such as sodium carbonate, to form battery grade lithium carbonate by precipitation. The product is then filtered, dried and packaged before shipping.

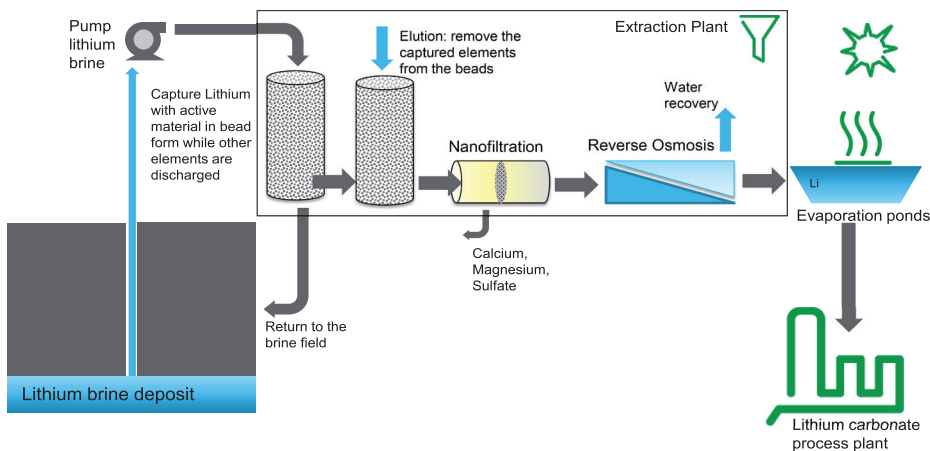


Figure 1: Lithium direct extraction process

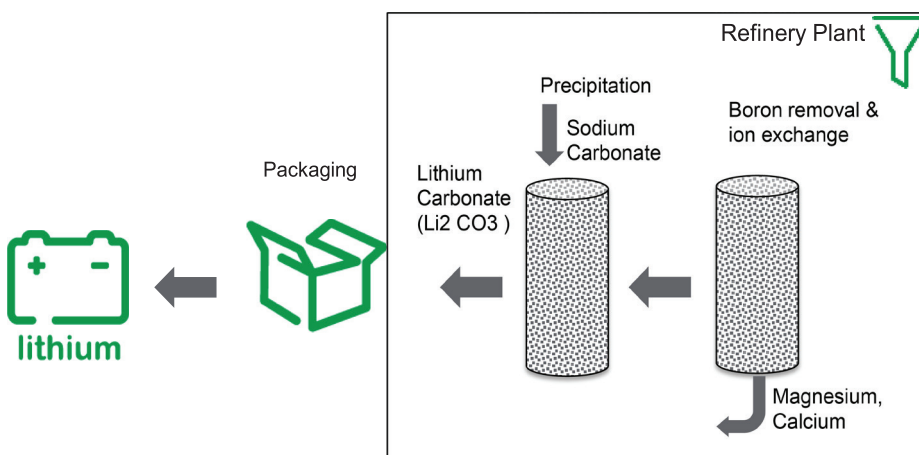


Figure 2: Lithium purification process

## Mining site characteristics

- Mineral: Lithium
- Mine type: Brine deposit
- Production: 20 kT LCE
- Altitude: 4,000 m
- Temperature: -10°C to 20°C
- Relative humidity: 70%
- Dust pollution: high
- Site surface: 20 km<sup>2</sup>



# ELECTRICAL DESIGN REQUIREMENTS

## Availability

An overall power supply availability of greater than 99.5 % is required for the electrical distribution. The site will be equipped with standby generators and UPS to supply non-process facilities (base camp, offices, water treatment, fire control system, etc.) and some critical loads in the concentration process, since these loads require a higher level of availability

## Altitude

The design of the electrical power system in very high altitudes poses many constraints to electrical equipment and machines due to their reduced air dielectric withstanding and cooling properties. A poor choice of network voltages, load currents, and equipment technology can result in a significantly higher capital investment requirement than a similar plant built at sea level.

To optimise the total cost of the installation, the impact of high altitude on the MV switchgear, MV/LV transformers, LV switchgear, motors, generators and variable speed drives needs to be considered. The Footprint and weight are particularly important as they determine the size and cost of the pre-fabricated buildings housing the electrical equipment (E-Houses).

## SITE ELECTRICAL LOADS

The lithium process plant's electrical loads involve small and medium size LV motors (less than 500 kW) driving the pumps and blowers, as well as large MV motors (1.5 MW) that drive the compressors needed for the forced evaporation process.

The main electrical loads of the production process and the utilities are listed below.

Process type	Load type	Motor power	Total installed power
Brine extraction	Pumps	55-75 kW	2 MVA
Water pumping	Pumps	110-160 kW	1 MVA
Brine preparation	Compressors, pumps	1 to 315 kW	2 MVA
Solvent extraction	Pumps, agitators	1 to 110 kW	2 MVA
Lithium extraction	Pumps	3 to 400 kW	2 MVA
Evaporation	Blowers	1500 kW	3 MVA
Water treatment	Pumps, agitators	6 to 160 kW	2 MVA
Purification	Pumps, blowers	1 to 400 kW	2 MVA
Downstream process	Pumps, blowers, conveyors	1 to 250 kW	2 MVA
Power plant	Pumps, fans	1 to 75 kW	2 MVA
Ancillaries	Lighting, offices, canteen	1 to 30 kW	2 MVA

**Table 2. Main electrical loads**



# ELECTRICAL NETWORK ARCHITECTURE

## FLEXIBLE POWER GENERATION

The site requires a flexible power supply with a capacity of 20 MW. It will be supplied by generators driven by natural gas engines since there is no electrical utility supply near the site.

## MV DISTRIBUTION NETWORK CHARACTERISTICS

### Voltage level

The MV network voltage has a direct impact on TCO. The common practice is to use the same voltage as the local utility, but often this does not provide a cost optimised installation. Cost comparisons using 6.6 kV, 11 kV and 22 kV MV network voltages showed that the lowest TCO is achieved using 11 kV. This choice does not need additional MV/MV transformers to supply overhead lines for the brine wells, and enables the use of cost-effective MV switchgear and cables.

### Architecture

The MV/LV electrical network architecture adopted is shown in Figure 3.

The gas engine generating sets are connected to the main switchboard, and power is distributed from the main switchboard to the different substations of the processing plant. The main switchboard is split in two busbars connected by a bus coupler.

For the process plant, an open ring architecture is selected to supply the MV/LV transformers. This architecture minimises the MV cable length while providing better availability than radial distribution. The connection of the MV cables and protection of the MV/LV transformers distributing power in the concentration plant, is carried out using Ring Main Units (RMU). This MV switchgear configuration has 2 switches connected to the MV cables and a tee-off circuit breaker inside a metallic tank filled with SF6 gas.

Good availability is also ensured without complete redundancy of the transformers by having a supply of spare parts on-site. To minimise, the quantity of spare parts, a standardized transformer power rating has been applied.

Considering the short cable distances (< 50 m), the high-altitude insulation and cooling constraints, the optimal choice for motor loads < 500 kW, is to use 400 V. This allows the use of cost-effective, low footprint MCCs and VSDs that minimize the total cost of the E-house, including its transport to the site. The 1.5 MW MV motors for vapor blowers are fed via VSDs directly from the MV busbar to avoid the use of additional transformers.

The pumping stations for brine and clear water require small loads < 200 kVA. They are located remotely and are supplied by overhead lines. Each MV line feeds several pumping stations with a maximum load of 2 MVA per line. The connection to the MV lines and the protection of MV/LV transformers is made using Ring Main Units (RMU) with 2 switches and a tee-off circuit breaker.

### Power system parameters

- Installed power: 25 MVA
- Frequency: 50 Hz
- MV level: 11 kV
- MV neutral: resistor earthed
- 11 kV network Isc < 25 kA
- LV level: 400 V
- LV neutral: TN-S
- Installation standard: IEC
- Motor load > 90 %
- Total length of MV cables: 10 km
- Total length of MV overhead lines: 25 km
- Total length of LV cables: 30 km

The MV network neutral earthing method determines the earth fault current magnitude and overvoltage level. The design uses high impedance grounding through zig-zag transformers to limit the earth fault current to below 30 A. This choice provides low TCO and high operator safety by limiting arc flash incident energy.





# ENGINE TECHNOLOGY

The engines discussed in this paper are based on medium-speed gas engine technology. In comparison to more commonly known high-speed diesel engines, the benefits of this technology are a higher efficiency and substantially lower emission levels. As a matter of fact, reciprocating engines represent the most efficient simple cycle (combustion) power generation technology available today. At the same time, natural gas is inherently the cleanest of all fossil fuels, in terms of both local (NO<sub>x</sub>, SO<sub>x</sub> and particulate matter) and global (CO<sub>2</sub>) emissions. The emissions from gas engine power plants are often lower than the average emissions from a regional power generation mix, e.g. in the EU.

Medium-speed engines are heavier and bulkier than containerized diesel engines. However, they are designed for heavy-duty applications making them very durable for extended continuous and cyclic operation. Furthermore, they typically have longer maintenance intervals and by design can be maintained on site.



## SELECTING PLANT AND ENGINE CONFIGURATION

The appropriate plant and engine configurations are determined based on several factors starting from the customer's power demand and power availability requirements. Other factors to be considered are:

- Plant duty type
- Site load profile
- Fuel quality and availability
- Plant architecture and redundancy
- Maintenance policy

These factors will be further discussed below. However, once all the requirements are set and the above design factors known, a solid basis for the plant configuration can be ascertained with the help of a so-called Reliability, Availability and Maintainability (RAM) study.

## Plant duty type

The duty types of power plants supplying lithium mines in remote locations can be essentially divided into two categories: standby and base load operation.

The standby (a.k.a. back-up) operation is a predominant duty type when a grid connection is available, albeit with uncertain or unsatisfactory reliability. In such a case an on-site gas engine power plant can be utilized to resume the mine's full-scale operations in the event of a planned or unplanned grid outage. Typically, the running hours for this duty type remain well below 500 hours per annum.

A base load plant naturally acts as the primary or only power supply to a mine. In base load operation, the number of operating hours typically exceeds 4000, while the number of start-ups remains below 50 per each generating set. Characteristically, base load units have a high utilization rate and load factor, because of which the units are subject to increased planned maintenance, and hence lower availability, compared to the standby units. Due to the typical locations of lithium mines, grid connections are rare and thus the base load duty type is more prevalent.

## Site load profile

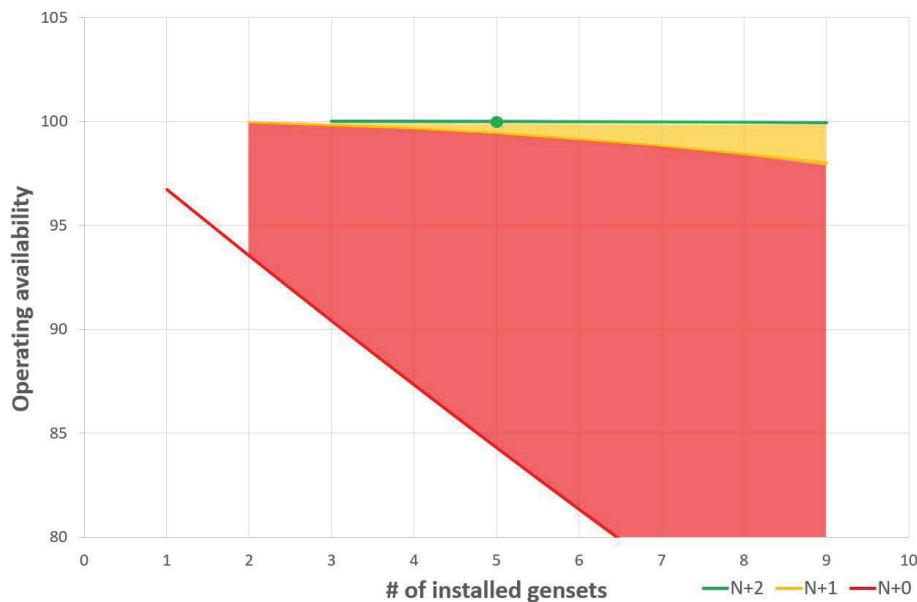
Engine power plants practically always consist of multiple parallel-connected generating sets. These plants can typically operate in all generating set configurations, from complete standby to full output. In addition, each generating set can operate, at least temporarily, at partial output between 10 and 100 % depending on the engine brand and type. The highest efficiency is attained at 100 % output. This operational flexibility can be utilized to operate the plant at all times with the optimal amount of capacity, while the reserve units can remain on standby or undergoing maintenance.

The term "site load profile" refers to the variation in the mine's power consumption. The variation can be of a temporary nature or related to long-term changes, such as a ramp-up (or ramp-down) of production. Temporary load fluctuation can be met by adjusting the number of operating gensets or the output of the gensets. In the latter case, if the load profile is known the size, and hence the output, of the generating sets can be optimized for best efficiency while securing maximum site output with the redundant units.

## Plant architecture and redundancy

The impact of generating set redundancy on operating availability can be observed by studying Figure 4. Here, the operating availability is represented as a function of the number of installed units for three different redundancy configurations N+0, N+1 and N+2. N refers to the number of generating sets operating to serve the load, while the number indicates the number of redundant units. For off-grid sites an N+1 configuration is required as a minimum to enable planned maintenance without disruption to the overall operations.





**Figure 4. Operating availability for different redundancy configurations**

Considering only the plant output demand and reliability requirements, the cost-optimised plant arrangement for this case study is with 5x20V engines in N+2 configuration. Taking the prevailing ambient conditions and altitude derating (@ 4000 m.a.s.l.) into account, each generating set can provide approximately 7 MWe. Thus, 3 generating sets can satisfy the 20 MW load demand.

### Fuel quality and availability

Fuel selection plays an important role in the economic and environmental feasibility of an on-site power generation investment. The selected fuel has also an impact on the plant's reliability and availability. The key criteria affecting the fuel selection are:

- Environmental impact and local regulations
- Cost and quality of the fuel
- Availability and reliability of the fuel supply
- Need of on-site fuel storage based on fuel availability

As discussed above, natural gas is the cleanest fossil fuel available. However, natural gas can also be the most accessible type of fuel for lithium mines located in remote places and at high altitudes. The mines are often located in the vicinity of natural gas deposits, as opposed to continuously transporting large quantities of diesel fuel, which is cumbersome and risky at best.

The use of dual-fuel (DF) engines can be well-justified if on-site fuel storage is needed as a provision against abrupt disruptions to the gas supply. The DF engines use natural gas as the primary fuel and liquid fuel (diesel) for ignition and back-up purposes. In gas mode, the DF engines operate almost completely on gas but require a small and continuous dose of liquid fuel for ignition purposes. In liquid mode, the engine can operate fully on diesel alone. With modern DF engines the transition from one fuel to another is seamless.

## **Maintenance policy**

Reliability is strongly linked to the prevailing operation and maintenance (O&M) practices. Critical power plants, like on-site generation plants for mines, should be under comprehensive O&M supervision requiring elements of preventive and predictive maintenance, which are often also stipulated in the O&M agreements. Such plants typically have dedicated on-site O&M personnel, as well as an on-site supply of consumable, wear parts and critical spare parts. Immediate access to other spares may be secured with a spare parts agreement. This is an important factor for lithium mines in remote locations with limited logistics access to the site.

A distinctive difference in maintenance scheduling between grid connected and off-grid power plants should also be noted. In grid connected plants a total plant outage is generally acceptable, allowing all units to be effectively serviced at the same time, thereby minimizing the overhaul time. In off-grid mines – and other off-grid facilities as well – the overhaul of various units must be staggered (= phased) to maximize the uptime of the site at the expense of prolonging the maintenance work.

## **ENGINE PERFORMANCE AT HIGH ALTITUDES**

Engine performance setups (hardware matching and software settings) are typically arranged to reach optimal performance within given boundary conditions. Performance setup optimisation can be made for different fuel qualities, NO<sub>x</sub> emission requirements, and ambient conditions. High altitudes introduce specific limitations that must be considered in the engine configuration. The most critical parameters affecting engine performance at high altitudes are:

- Ambient air pressure (altitude)
- Engine suction air temperature and associated coolant temperatures

Additionally, engine performance is dependent on the fuel properties, lower heating value, feed pressure, and the gas fuel methane number.

### **Derating**

Specific high-altitude conditions lead to engine derating. In derating, the engine's power output is reduced from its nominal values to ensure optimal performance under given site conditions. It also protects the engine from exceeding its nominal design parameters with regards to temperature, pressure, and knocking limits to avoid any associated damage. Derating is carried out within boundaries set by emission levels at the site location.

### **Altitude derating**

The lower air pressure at high altitudes results in a lower lambda factor (air-fuel ratio), which affects engine performance if not addressed. Turbochargers are the key engine components that affect the charge (combustion) air flow, and hence also the lambda factor. To ensure the best performance at high altitudes, the turbochargers must be matched to operate within an optimum range for the site conditions.



## Ambient derating

Typically, a high-altitude site location experiences a wide operating temperature range, and the engines must be configured to operate in this foreseen temperature range.

The graph below shows a typical example of derating factors for a certain engine configuration, considering both high altitude and high temperature conditions. Colored lines indicate the derating factors in relation to different suction air temperatures and pressures (= altitude). The derating tables are individual for each engine type and configuration. Generally the ambient temperatures at high altitudes are relatively low, thus derating remains moderate.

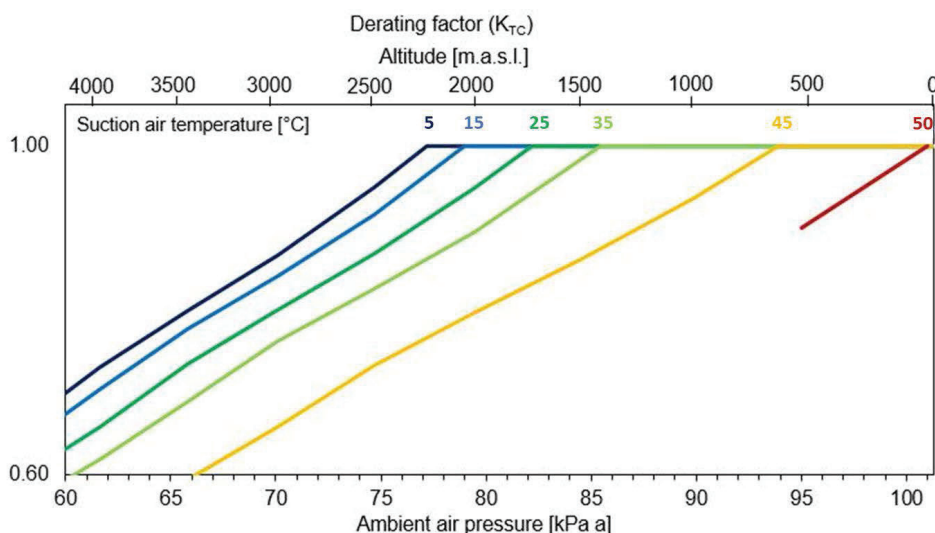


Figure 5. Example of an engine altitude derating

## Fuel characteristics

The methane number (MN) of the gas fuel also affects engine performance. An MN variation of between 70 and 80 may alter the engine's loading performance characteristics, nevertheless the output remains unaffected. Derating of the engine typically starts when the MN falls below 70. It is also important that the gas feed pressure is maintained at a recommended level in order to avoid additional derating due to low gas feed pressure.

## GENERATOR

Generators have the following main features:

- Design bases: IEC 60034, ISO8528 and ISO R773-775
- Duty type: S1, Continuous
- Bearings: Self-lubricated sleeve bearings
- Ingress protection: IP23
- Cooling: IC0A1 (air cooled)

The generators used for generating sets of this capacity are always medium-voltage, thereby allowing them to supply the local distribution grid without additional step-up transformers. The number of paralleled generators and their

## Wärtsilä Generator

- Type: Salient pole
- Rated voltage: 11 kV
- Rated frequency: 50 Hz
- Rated power: 8.8 MVA at 4000 m, Max Amb +30 °C
- Output Cosφ: 0.95 leading, 0.8 lagging @ full engine output
- X"d: 15%
- Excitation: Brushless, AVR power supply VT/Boost CT or integrated coil
- Neutral earthing: Resistive
- Instrumentation: 3+3 Pt-100 in stator, 1+1 Pt-100 in bearings, anticondensation heater, 1+1 Pt100 for cooling air (in /out), AVR
- VT for exc. power & actual value measurement.
- CT's for short circuit exc. power, actual value measurement and differential protection

characteristics play a decisive role in the design and dimensioning of the local distribution system. In particular, the generator's sub-transient reactance ( $X''_d$ ) is an important parameter impacting the MV network fault current and the choice of MV equipment (switchgear, cables). Analyses have shown that a value  $X''_d = 15\%$  gives an optimum cost/performance ratio as it allows the use of 11 kV equipment with a rated fault current of  $< 25$  kA.

## **GENERATOR ALTITUDE DERATING**

According to IEC 60034, standard air-cooled generators are designed for a maximum altitude of 1000 m.a.s.l., an ambient temperature of  $+40\text{ }^{\circ}\text{C}$ , and a relative humidity of 90%. Higher elevations have a negative impact on both the insulation and cooling capabilities of air.

The reduced dielectric properties of air must be accounted for in the design of the generator winding insulation. This is achieved by increasing the insulation air gaps and altering the corona protection of the end windings.

The generator cooling air is usually taken from the engine hall to ascertain an acceptable humidity level and minimum temperature. In an operating plant, however, the engine hall temperature is generally  $10\text{ }^{\circ}\text{C}$  higher than that of the ambient air. The reduced cooling effect of the air may thus have to be considered, either by improving the generator's cooling arrangement or by derating. The derating factors are based on international standards, as well as on the manufacturers' experience.

## **MV SWITCHBOARD ALTITUDE DERATING**

The IEC and ANSI standards for MV Air Insulated Switchgear (AIS) apply altitude derating factors for the rated voltage and normal current when installed at an altitude above 1,000 m to account for the reduced dielectric and cooling properties of air. An MV AIS used at high altitude requires a higher rated voltage and normal current than a comparable installation at sea level. This results in the switchgear cost being greater, the footprint being larger, and the weight being heavier.

MV switchgear, where live parts are screened (gas or solid insulation), does not require derating at altitude because the insulation is independent of the atmospheric air pressure.

### **Screened Solid Insulation technology**

For screened solid insulated switchgear (SSIS), the dielectric performance is independent of the ambient air condition as all live conductors are encapsulated in epoxy resin coated with a conductive paint. No voltage derating is necessary at 4000 m but care must be taken with the internal arc membrane in the air disconnector enclosure. Busbars, voltage transformers, and cable terminations have earthed screens, hence they are not affected by the ambient air. In some designs, the current rating has to be reduced to account for less efficient heat convection.

## Gas Insulation technology

For gas insulated switchgear (GIS), the dielectric performance is not affected by altitude as all live conductors are placed in sealed metallic enclosure filled with high dielectric gas. No voltage derating is necessary at 4000 m, however, some GIS' need to operate with reduced SF6 gas pressure and/or a lower current rating above certain altitudes to avoid unintended operation of the over-pressure protection. This reduced gas pressure can result in a lower dielectric withstand (BIL) and reduced short-circuit current interruption capability of the switch and circuit breaker

## MAIN MV SWITCHBOARD

The MV main switchboard uses SSIS technology with fixed vacuum circuit-breakers (VCB) rated at 12 kV, 1250 A and 25 kA. The switchboards have LSC2B-PM and A-FLR Internal Arc Classification (IAC) to ensure maximum operator protection.

Each panel includes an Intelligent Electronic Device (IED) that provides protection, monitoring, and control functions. The generator incomer protection includes overcurrent (50/51), earth fault (50G/51G) and differential (87G). The cable and transformer feeders are protected by overcurrent protection (50/51) and (50G/51G). All IEDs have power metering and communicate via a Modbus TCP/IP protocol.

The recommended Schneider Electric equipment is Premset fitted with Easergy P3 protection and control IED.

## SECONDARY SUBSTATIONS

The electrical power supply to the remote areas of the process plant is comprised of 11 kV cables and ground mounted 11 kV/0.4 kV substations with embedded remote monitoring, metering and control.

The MV/LV substation includes 11 kV ring main units with transformer protection relay, and remote terminal units (RTU).

The Schneider Electric recommended products are RM6 (IBI ring main units with 2 network switches and one circuit breaker) fitted with a VIP40 relay.

## PUMPING STATIONS

The electrical power supply to the brine and water wells is comprised of 11 kV overhead lines and ground mounted 11 kV/0.4 kV substations with embedded remote monitoring, metering and control.

The outdoor package MV/LV substation has 4 main components:

- 11 kV ring main unit with a transformer protection relay
- 11 kV/0.4 kV oil insulated transformer
- 400 V panel with MCCB feeders and an energy meter
- Remote terminal unit (RTU)

### Main MV switchboard

- Rated voltage: 12 kV
- Busbar/Incomer CB: 1250 A
- Feeder CB In: 630 A
- Rated Isc: 25 kA
- Cubicle type: SSIS LSC2B-PM
- CB type: fixed VCB
- IAC: 25 kA (1 s) A-FLR
- Cabling: front
- Standard: IEC 62271
- IED Metering: U, I, kW, kVA
- Modbus TCP/IP

### Incomer protection

- 50/51, 50G/51G,
- Arc flash optical detection

### Cable & transformer feeders

- 50/51, 50N/51N
- MV Motor feeders: IMPR

### Secondary MV switchboard

- Rated voltage: 12 kV
- Ring switches In: 400 A
- Circuit-breaker In: 200 A
- Rated Isc: 25 kA
- Cubicle type: GIS
- CB type: fixed SF6 - 3 position
- IAC: 25 kA (1 s) A-FLR
- Cabling: bottom
- Standard: IEC 62271

### Protection & Metering IED

- Relay 50/51 50G/51G
- Metering: U, I, kW, kVA
- Modbus TCP/IP

### Package substation MV switchboard

- Rated voltage: 12 kV
- Ring switches In: 400 A
- Circuit-breaker In: 200 A
- Rated Isc: 25 kA
- Cubicle type: GIS
- CB type: fixed SF6 - 3 position
- Cable earthing: integral
- IAC: 25 kA (1 s) A-FLR
- Cabling: bottom
- Standard: IEC 62271

### Protection & Metering IED

- Relay 50/51 50G/51G
- Metering: U, I, kW, kVA
- Modbus TCP/IP

### MV/LV transformer

- Primary voltage: 11 kV
- Secondary voltage: 0.4 kV
- Rated power: 1.6 MVA
- Zsc: 6 %
- Winding connection: Dyn 11
- Insulation: mineral oil
- Bushing: Plug-in
- Cooling: ONAN
- Installation: outdoor
- Earthing: TN-S
- Standard: IEC 60076

This factory-built package provides the lowest cost as it can be installed outdoors without the need of a building or site work. The RTU has an integral fault passage indicator (FPI) and allows remote operation of the circuit-breaker from the electrical network control system. The Schneider Electric recommended products are RM6 (IBI ring main units with 2 network switches and one circuit breaker), VIP40 relay, Minera transformer, and Flite 210 fault passage indicators. The RM6 ring main units are installed in an additional enclosure to allow installation outdoors. The 11 kV overhead lines require 24 kV rated insulators to achieve the 75 kV BIL at 4000 m needed for insulation coordination.

## MV/LV TRANSFORMER

The MV/LV transformers feed the 400 V switchboards and VSDs. Oil insulated transformers with natural cooling (ONAN) are used as they are more robust and better adapted to harsh mine environments. Outdoor installation enables a smaller footprint and a reduced HVAC requirement for the E-houses.

- Transformer power is standardised to minimize the cost of spare units.
- The 11 kV/ 400 V transformers have a rated power of 1.6 MVA and Zsc 6% to keep In < 2500 A and Isc < 40 kA (including 400 V DOL motor contribution). This choice allows the use of cost-effective 400 V switchboards.
- Aluminium winding is preferred to copper because it implies a lower cost, even if the dimensions are larger.
- High efficiency transformers are the best choice from a TCO standpoint. OPEX savings resulting from reduced losses during the transformer life cycle can represent several times the initial CAPEX.

### Altitude derating

For liquid filled transformers, the windings are submerged in oil, while the internal insulation is not affected by ambient air conditions. Only the bushings and external clearances require a greater level of insulation to meet the system BIL.

The IEC 60076-3 standard states that external clearances must be increased by 1% every 100 m. To avoid this impact, plug-in bushings can be used instead of porcelain insulators.

A thermal derating is required as the natural cooling of the transformer will be less efficient. According to IEC 60076-2, the winding temperature rise for oil transformers has to be reduced by 1°K / 400 m. This can be compensated for by a lower ambient temperature at high altitude.

The Schneider Electric products used are Minera oil immersed transformers with plug-in bushings



## MOTORS CONNECTION & CONTROL MODE

The main motor loads of the production process are listed below.

Motor power	Voltage	Process function	Motor control	Qty
1500 kW	MV	Blower	VSD	2
$100 < P < 500$ kW	LV	Pumps, filters, blowers, compressors	DOL, Soft starter, VSD	50
$1 < P < 100$ kW		Pumps	DOL, VSD	150

**Table 3. Main motors**

The optimal choice of voltage and control mode for a given motor depends on the motor's rated power, its function in the process, the available voltage level, and the cable lengths. The choices described below are based on TCO calculations that include the equipment's CAPEX and the energy savings (OPEX).

### Vapor blowers

The vapor blowers used in the forced evaporation process are driven by 1500 kW motors controlled by VSDs. To optimise the total cost of the motor feeder, the VSDs are connected to the 11 kV main switchboard, but with a motor output of 6.6 kV.

The benefits of using VSDs for these MV motors are:

- Low motor starting transient current, which avoids any voltage dips and transient stability risks for the generators
- Energy savings resulting from the variable load

### Pumps

Pumps are used during all stages of the process. They are driven by motors with various power of up to 400 kW. As the load is variable, most of them are controlled by VSD to save energy. They are connected to 400 V Motor Control Centers (MCC).

### Blowers and compressors

Blowers and compressors are used in the concentration process. They are driven by motors with various power of up to 400 kW. As the load is variable, most of them are controlled by VSD to save energy. They are connected to 400 V MCC.

## MV VSD FOR VAPOR BLOWERS

The VSD for the vapor blowers uses a multi-winding phase shift transformer and series connected single phase LV IGBT inverters. This multi-level architecture provides a smooth output voltage and a low current distortion on the grid side. This drive topology avoids the need for harmonic mitigation equipment, reduces motor losses, and avoids harmful vibration and torque pulses. It also allows a connection to the 11 kV main switchboard with a different motor voltage of 6.6 kV. The VSD is equipped with sensors to continuously monitor the condition of the input transformer, the power electronic modules, and the MV motor. As it is connected with the asset management system, it provides preventive and predictive maintenance.

### MV VSD

- Rated input voltage: 11 kV
- Rated motor power: 1.5 MW
- Rated output voltage: 6.6 kV
- Overload: 150% -1 min/10
- Output frequency: 0.1-120 Hz
- Efficiency: > 96 %
- Power factor:  $\geq 0.96$
- Input TDHI < 1.5%
- Output THDU < 2%
- Control mode: torque, speed
- No of quadrants: 2
- Degree of protection: IP31
- Cooling: forced air ventilation
- Communication: Modbus TCP/IP
- Standard: IEC 61800

## Altitude derating

The lower air density at high altitudes requires increased creepage and clearances, and it greatly affects the nominal current rating because of the loss of convection cooling. A typical current derating factor is 1% for every 100 m above 1,000 m.

The Schneider Electric products used in this design are an Altivar Process ATV 1200H (11 kV/ 6.6kV, 1.5 MW) with Modbus TCP/IP. The ATV1200H is optimized and exclusively designed for high-altitude and seismic applications. The design includes adapted cooling with top fans, and reinforced insulation for both the LV and MV sections.

## LV POWER AND MOTOR CONTROL CENTER SWITCHBOARD

### LV switchboard

- Rated voltage: 400 V
- Busbar/ Incomer ACB: 2500 A
- Rated I<sub>cw</sub>: 40 kA – 1s
- Internal arc: 40 kA (0.3 s)
- Form of separation: 3b
- Degree of protection: IP31
- Power & control cables: front
- Auxiliary voltage: 24 V DC
- Standard: IEC 61439

### Incomer ACB functions

- 50/51, 50N/51 N
- Metering: U, I, kW, kVA
- Communication: Ethernet

### Power feeder MCCB functions

- 50/51, 50N/51N
- Metering: U, I, kW, kVA
- Communication: Modbus TCP/IP

The power control center (PCC) and motor control center (MCC) panels are LV switchboards that group all the motor feeders for a given part of the process, as well as the power feeders for loads such as lighting and HVAC. The PCC and MCC use an IED (intelligent Electronic Device) that can provide information over an internal network, which can further support the communication network to higher level systems. This configuration, known as an Intelligent Power Motor Control Center (iPMCC), is adopted in this design to reduce TCO and increase system availability.

The LV switchboards use a cable compartment accessible from the front to minimise the footprint in the E-Houses and to simplify maintenance.

Each feeder is accommodated within a functional unit (FU). These FUs can be withdrawable, disconnectable, or fixed according to the load criticality. The MCC switchboards have Form 3b segregation between the compartments as this allows operation and maintenance to be carried out without complete stoppage of the switchboard. The degree of protection is IP31 degree, which is suitable for installation in E-Houses.

The “power” side of the switchboard includes two types of FUs:

- **Incomer:** Withdrawable air circuit breakers (ACB) equipped with a control unit with energy metering, circuit protection, and control with Ethernet protocol. The protection functions include overcurrent (50/51) and earth fault (50N/51N).
- **Power distribution feeders:** Fixed Molded Case Circuit Breakers (MCCBs) equipped with a control unit for protection and measurement, and Modbus RTU communication.

The recommended Schneider Electric LV iPMCC switchboard is Okken or Blokset. The components used in the switchboard FUs are:

- **Incomer:** MasterPact MTZ ACB - Micrologic 6.0 X with Ethernet interface
- **Power load feeder:** Compact NSX MCCB with Micrologic 5/6E and IFE Ethernet communication interface.

The LV motor feeders are arranged in columns that include three types of FUs.

- **DOL feeders:** For motors operating at fixed speed, a combination of MCCB for protection and disconnection, a contactor, and an Intelligent Motor Protection Relay (IMPR) with energy measurement, motor protection, control functions and system connectivity, are used. DOL feeders use a single integral unit for motors < 15 kW or three discrete components for motors > 15 kW, up to a maximum of 250 kW. Motor feeders use withdrawable FUs to allow fast replacement in case of maintenance and/or component failure. They are installed in the cubicle in half-width drawers for power up to 30 kW to increase the feeder density and to reduce the footprint.

The components used in the switchboard FUs are:

- DOL feeders - Three components: TeSys GV or Compact NSX MCCB, TeSys D or TeSys F contactor and IMPR TeSys T with Ethernet/IP.
  - All-in-one starter: TeSys U with Modbus RTU
- **Soft starter feeders:** these are used to control 400 V fixed speed motors that drive the pumps and blowers during the concentration process. They reduce the starting current and mechanical coupling stress during motor starts. Soft starter feeders are placed in fixed FUs that are fitted with an MCCB for protection and disconnection, the power thyristor module, and a contactor used to by-pass the power electronics module once the motor reaches nominal speed.
- The components used in the switchboard FUs are NSX MCCB, TeSys D contactor for by-pass and ATS48 Soft Starter with Modbus RTU.
- **VSD feeders:** these are used to control the 400 V motors driving pumps and compressors with variable loads with the aim of reducing energy consumption. VSD feeders include an MCCB for protection and disconnection, and a power electronics VSD module. Units with a rated power of up to 75 kW are integrated within the LV switchboard, while VSDs with a higher rated power are installed in separate IP21 wall-mounted or floor-standing enclosures.
- The components used for VSD feeders are Compact NSX MCCB, ATV 600 VSD for pumps and blowers and ATV 900 VSD for conveyors.

## Altitude derating

### Switchboard

Due to the lower air dielectric strength, the rated impulse voltage  $U_{imp}$  is reduced for altitudes exceeding 2,000 m with a factor of  $K_a = \exp(h - 2000 / 8150)$

As LV switchboard ranges are designed with a rated operational voltage of 1000 V and category IV overvoltage, they can operate with a rated voltage of 400 V at 4000 m without limitation.

Due to the lower air density and heat transfer capacity, the thermal current should

## DOL feeders

### Single integral component

- Motor: < 15 kW
- Coordination: Total
- Measurement: I, V, kW, kVA
- Communication: Modbus TCP/IP

### Three discrete components

- Motor: 15 kW < P < 250 kW
- Protection: IMPR
- Coordination: Type 2
- Measurement: I, V, kW, kVA
- Communication: Modbus TCP/IP

## Soft starter feeders

- Motor power: up to 400 kW
- Start current:  $3 I_n < 25 \text{ sec}$
- Feeder protection: MCCB
- Bypass contactor
- Measurement: I, U, kW, kVA
- Motor protection: integral
- Communication: Modbus TCP/IP
- Standard: IEC 60947-4-2

## VSD feeders

- Motor power: up to 400 kW
- Efficiency > 98 % -
- THDI < 48 %
- Control mode: torque, speed
- Measurement: I, V, kW, kVA
- VSD feeder protection: MCCB
- Motor protection: integral
- Communication: Ethernet/IP
- Standard: IEC 61800

also be reduced. However, as the ambient temperature in electrical rooms does not exceed 25°C, it is not necessary to decrease the nominal current.

### ACB, MCCB and contactors

According to the IEC 60947-1 standard, the rated characteristics are valid up to 2000 m. At 4000 m, the circuit breaker must be derated by applying an 0.78 coefficient on the voltage. Current derating is also applied to reflect the reduced cooling efficiency. The breaking capacities remain unchanged.

### LV variable speed drives and soft-starters

The reduction of cooling at high altitude affects the current rating. A typical current derating factor is 1% for every 100 m above 1,000 m. As the maximum ambient temperature in the E-Houses does not exceed 25°C, the altitude derating factor can be reduced to 0.9. There is no need to apply voltage derating for 400 V VSD as these devices have been designed with an insulation voltage of 690 V.

The following table gives the values to be applied at an altitude of 4000 m.

### LV main components altitude deratings

Altitude derating	Range	Max voltage	Uimp at 4000vm	Current derating at Tmax 25°C
Switchboard	Okken / Blokset	780 V	9.3 kV	1
ACB	Masterpact	630 V	9.3 kV	1
MCCB	Compact NSX	520 V	6.2 kV	1
Contactor	Tesys D	550 V	6.2 kV	1
Motor starter	Tesys T	550 V	4.6 kV	1
VSD	ATV 600/900	480 V	4.6 kV	0.9

**Table 4. LV main components altitude deratings**

### Safety features

The LV switchboards include the following safety features to provide a high level of operator protection against electrocution and arc flash:

- IP2X protection (finger safe) against accidental contact with live parts
- Drawout FU with 3 positions (Connected, Test, Disconnected)
- Safety padlocks and a clear indication in each of the three positions
- Internal arc withstand in compliance with IEC TR 61641
- A local HMI control panel to minimize operators' need to open drawers.



# POWER QUALITY OPTIMISATION

The Power Quality includes transient voltage variations, harmonic distortion, and power factor correction (PFC). A high PQ level is necessary for the site's energy efficiency.

## Power factor correction

For installations not connected to the grid, the benefits of power factor correction are reduced because there is no charge for reactive energy.

For a mix of loads including mainly DOL motors and VFDs, the power factor is higher than 0.85. As the generators are designed to deliver their rated active power with a PF of 0.8., the power factor correction does not allow more power to be available from the generators.

However, capacitor banks installed next to the MCCs supplying more than 70% of DOL motors provide the following benefits:

- Reduction of losses in the MV/LV transformers and MV cables
- Reduction of voltage drop
- More active power available.

The Schneider Electric product used in this design is a Varset capacitor bank.

## Altitude derating

For Varset capacitor banks, a heavy-duty range with overrated voltage is selected taking into consideration a maximum ambient temperature in the E-houses of 25°C.

## Harmonic mitigation

Harmonic mitigation is required to avoid disturbances from sensitive loads. The objective is to keep the voltage distortion THDU lower than 5% in the installation at the MV and LV level.

Harmonic pollution is mainly caused by VSDs with diode rectifiers. These standard VSDs are lower cost than low harmonic models with Active Front End (AFE), but the installation requires additional active harmonic filters (AHF). AHFs use power electronics technology and advanced controllers to generate harmonic currents that cancel the ones created by the loads. In this design, the lowest TCO solution to reach the harmonic distortion objectives uses the following arrangement:

- Low Harmonic VSDs (THDI < 5 %) for MV motors
- LV VSD without AFE (THDI < 48 %) for LV motors with an AHF connected to the LV switchboards to compensate for the harmonic pollution.

The Schneider Electric product used to meet the site PQ target is an AccuSine PCS+ active harmonic filter.

## Altitude derating

For Accusine active filters, a current derating factor of 80% is applied, taking into consideration a maximum ambient temperature in the E-houses of 25°C.

## Capacitor bank

### Rated voltage: 400 V

- Rated power: 300 kvar
- Detuned reactor: required with polluted network
- Degree of protection: IP31
- Standard: IEC 61921 & 61439

### PF Controller functions

- High temperature alarm
- High harmonic alarm
- Automatic PFC sequence
- Modbus RTU

## Active Harmonic Filter

- Rated Voltage: 400 V
- Rated current: 300 A
- Rated frequency: 50/60 Hz
- Power module: 3 level IGBT
- Harmonic range: up to 51st
- Correction time: < 2 cycles
- Control system: closed loop
- Degree of protection: IP31
- Modbus TCP/IP

## Power Quality Monitoring

To monitor power quality disturbances, and to understand issues affecting the process, equipment and power meters are connected to the EcoStruxure Power Monitoring Expert, which can provide detailed PQ dashboards and reports.

## EMERGENCY POWER SUPPLY FOR CRITICAL LOADS

In case of emergencies, the power plant will be equipped with 2 standby diesel generators to supply all non-process facilities (base camp, offices, potable water treatment, waste water treatment, fire control system, etc.), as well as some critical loads in the concentration and downstream processes, to avoid any disruption to the concentrate delivery.

The power plant services needed for a black start of the main generators are fed from one of the standby diesel generators.

### ATS for motor loads

In case of loss of the main supply, the Automatic Transfer Switch (ATS) controller sends a signal to the Generator Control Unit (GCU) to start the diesel engine and opens the transformer incomer ACB. When the generator reaches nominal voltage and frequency, the ATS controller closes the generator incomer ACB to energize the 400 V switchboard, and the control system will then automatically re-start all motors. Once the main power supply is restored, the ATS controller will transfer back the supply and the control system will sequentially re-start all motors.

Mechanical interlocks prevent both ACBs being closed at the same time, which could put both sources in parallel. This open transition method is the most cost-effective solution when the critical loads can accept a supply interruption time of < 1 min.

The Schneider Electric products used in this design are Transferpack ATS equipment, including a UA controller and Masterpack MTZ with rod mechanical interlocks, integrated within a single switchboard column.

### ATS Controller 400 V

- Transfer type: Open transition
- Transfer time: < 1 min

#### Protection

- Undervoltage
- Phase failure

#### Monitoring and control

- ACB status
- Voltage presence
- AUTO mode ON
- Genset start/stop
- ACB trip/close
- Load shedding
- Communication: Modbus TCP/IP
- Standard: IEC 60947-6-1

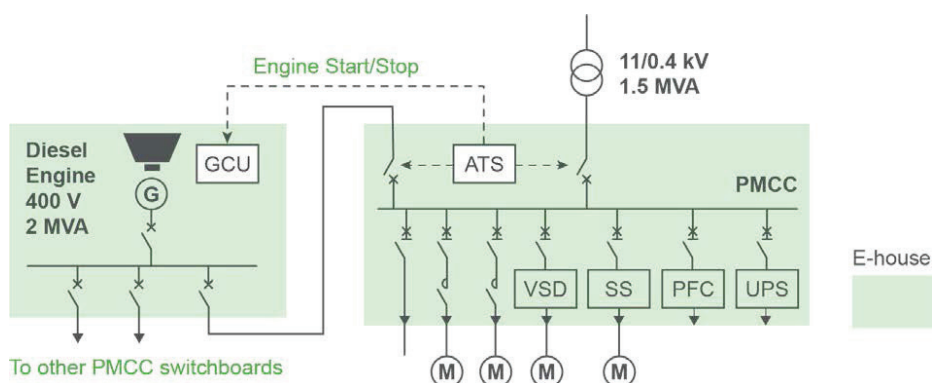


Figure 6. Recommended emergency power supply for critical loads



### UPS for sensitive loads

UPS systems will be installed in the electrical rooms to provide power for the control system and other critical loads for a minimum of 30 minutes after a power failure.

Non-motor critical loads, such as the site data center, control room, process automation, fire protection, and security systems are assured by a 15 kVA Uninterruptible Power Supply (UPS) located in the main substation.

### Altitude derating

At an altitude of 4000 m, a power derating factor of 0.85 is applied according to the IEC 62040-3 standard. The UPS installed in e-Houses will be running with an operating temperature ranging from 15 to 25°C and in a controlled atmosphere.

The recommended neutral grounding is solidly grounded (TNS).

The UPS selected is a Gutor PXC, industrial UPS designed for harsh environmental conditions and a 20-year life expectancy.

### UPS

- Rated voltage: 400 V
- Rated power: 10 kVA at 4000 m
- Efficiency: up to 94%
- PFC Rectifier
- Seismic design 1g
- Battery: Lead acid
- By-pass: integral
- Local HMI: LCD screen
- Degree of protection: IP42
- Cooling: forced air
- Communication: Modbus TCP/IP
- Standard: IEC 62040-3 Class1

# INTEGRATION IN E-HOUSE

## Characteristics

- Number of E-Houses: 10
- E-House surface: 800 m<sup>2</sup>
- Main E-House: Interlock technology
- Secondary E-Houses: ISO container

## E-HOUSE DESIGN

The Electrical House (E-House) is a factory integrated, tested, validated, compact power distribution solution. The E-House contains Medium Voltage switchgear, LV switchboards, VSD, UPS, HVAC and control systems. It helps to increase safety, reduce construction lead times, optimise the cost of transportation, installation and commissioning, and enhance uptime thanks to its qualified and reliable design.

The E-House design process takes several iterations to optimise its cost. The MV/LV network architecture design and equipment selection are made with the aim to minimize the equipment's footprint, height and weight, which are the parameters that determine the E-House's cost of manufacturing and transport to site.

Three levers are applied to optimise the E-Houses:

- Layout optimisation:
  - Footprint: overall dimensions of the E-house
  - Clearances: reduction in clearances between equipment to the minimum codes and standards requirement.
- Technology optimisation:
  - fully welded, skeletal frame, interlock technology, sandwich panel
- Component optimisation:
  - HVAC type, HVAC duct type, fire suppression systems, gas selection, equipment doors, lighting systems, cable routing, cable tray, flooring material, internal and external linings.

The design optimisation of the E-House is performed using expert engineering capabilities to address the following items:

- Steel structure calculation
- Thermal exchange calculation
- Internal arc behavior
- Seismic behavior
- Blast, cyclone, and wind response

**HVAC Design at high altitude:** The HVAC system's efficiency is reduced with altitude. Optimal sizing requires consideration of the equipment's heat load, the lower ambient air temperature, and the solar radiation.

Considering the site conditions, cooling can be ensured by forced ventilation. The air exchange rate is designed to maintain the indoor electrical room temperature within a maximum of 25 degrees Celsius and a minimum of 15 degrees Celsius.

In this recommended design, the main E-House uses interlock technology, whereas the E-Houses for secondary switchboards are made of a pre-engineered modular solution using ISO containers. These have the advantages of low cost, fast construction, and easy transportation.

The cooling system is designed with a N+1 redundancy. A pressurization system is provided to avoid the entry of dust.

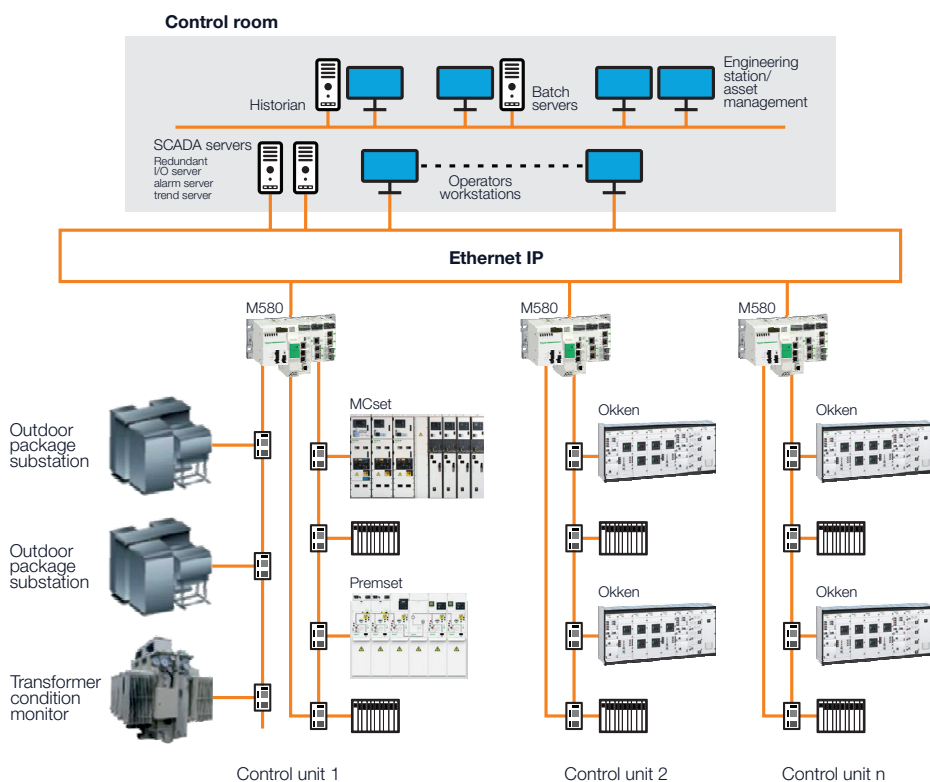


# DIGITAL APPLICATIONS

The lithium mine installation is equipped with a comprehensive digital monitoring and control system. Although this represents a higher CAPEX, it enables significant OPEX benefits by enabling lower maintenance costs, reduced energy consumption, and higher plant availability by minimising unplanned power supply interruptions.

The control system architecture, illustrated in Figure 7, was selected to minimise CAPEX while providing a good level of system availability. It is based on open communication standards, such as an Ethernet and Modbus TCP/IP, which reduces the engineering cost, allows easy integration, and ensures future evolution. The architecture allows information to be shared between the mining process and the electrical network control, as well as with the asset management systems. The integrated system provides process control engineers with real time information on the MV and LV motor feeder status, energy cost, the electric motor condition, and the START-STOP control. This allows informed decisions to be made for optimizing the cost per ton of lithium produced while minimising the risk of unplanned outages.

The architecture is based on PLCs connected to an Ethernet ring network that uses a Rapid Spanning Tree Protocol (RSTP) to manage the Ethernet loop and provide good availability. Each PLC acts as a “Control Unit” integrating data from the process controllers, field instruments, and electrical equipment. All electrical network IEDs have Ethernet communication with a native Ethernet/IP or Modbus TCP/IP, as well as embedded Web servers. This choice minimises the use of gateways and reduces the system engineering workload and integration cost.

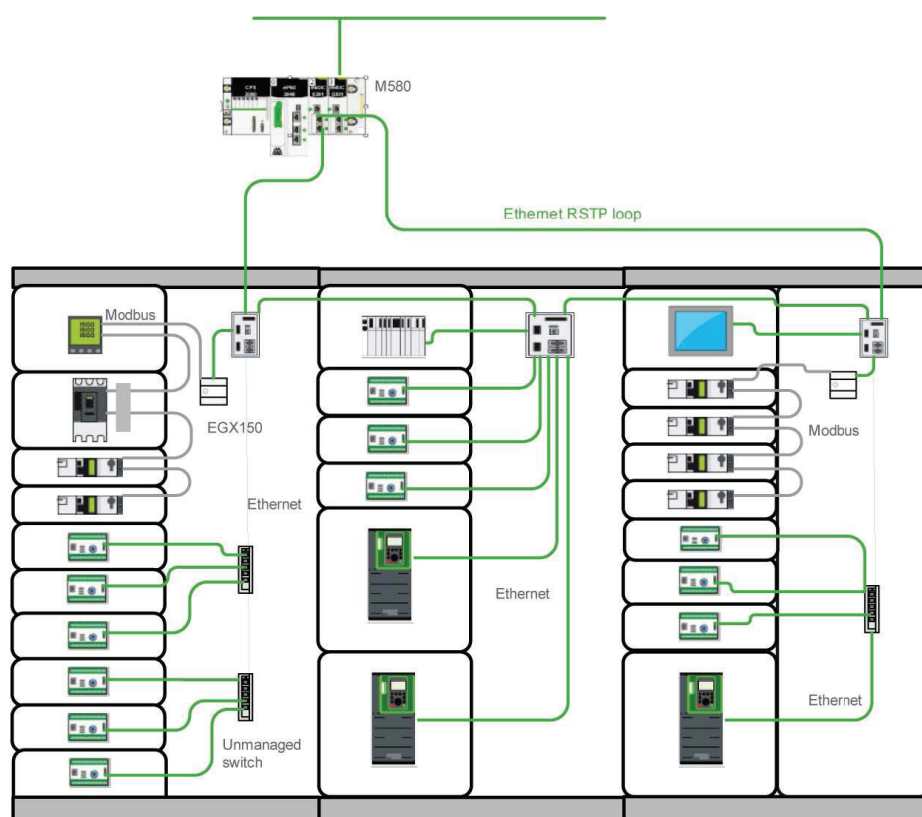


**Figure 7. Electrical network monitoring and control system architecture integrated within the Process Control System**

The PLC has an Ethernet communication module that provides access to both the Ethernet/IP and Modbus TCP/IP networks with a data rate of < 100 Mbps. The MV switchboard's internal communication network Modbus TCP/IP is integrated into the Ethernet network. The MV/LV substation RTUs and the condition monitoring devices for the HV/MV and MV/MV power transformers are connected to a Modbus TCP/IP network, which is also controlled by the PLC.

The Schneider Electric Modicon M580 ePAC has a library of pre-configured screens and objects that include all the IEDs mentioned in this recommended design. This minimises the system design and integration cost, while also providing high-level system reliability.

The iPMCC internal communication illustrated in Figure 8 uses a hybrid architecture. The switchboard is connected to the PLC Ethernet network by a cost-effective Ethernet unmanaged switch (e.g. ConneXium TCSESU05). Devices with Modbus RTU communication (MCCB, Soft Starter feeders) are connected via a Link 150 gateway to the Ethernet switch. Devices such as VSD, DOL feeders with IMPR and local LCD control panel have native Ethernet communication links, and are connected to the Ethernet switch.



**Figure 8. Hybrid communication network using Modbus TCP/IP and Ethernet/IP in iPMCC**



### EcoStruxure™ solution

The recommended architecture for the process automation of the mine is based on EcoStruxure™ Hybrid DCS. **This system** combines the management of fieldbuses, instrumentation, intelligent connected devices, operator stations, engineering stations, and alarm management in a scalable, powerful automation platform.

The recommended architecture for the energy management and control system of the mine is based on EcoStruxure™ Power. On the Edge control layer, the solution will use Power SCADA Operation (PSO) for power management and control, with advanced Power Monitoring Expert (PME) reporting and dashboards embedded within the PSO.

### Cybersecurity

The products, solutions, and secure software development lifecycle conforms to cybersecurity standards, such as IEC 62443 and the ISO2700x suite.



# APPENDIX A: PRODUCTS USED IN THIS DESIGN

Network function	Product name	Main technical characteristics		Link to offer
<b>MV Main switchboard</b>	Premset	SSIS 15 kV, 630 A, 25 kA, LSC2B-PM, fixed VCB, full earth screen		<a href="#">PremSet</a>
<b>MV Protection and control unit</b>	Easergy P3	Protection relay with optical arc flash detection and Modbus TCP/IP used in MV switchgear		<a href="#">Easergy</a>
<b>MV/LV Transformer</b>	Minera	Oil filled 11 kV/0.4 kV, 2 MVA, ONAN		<a href="#">Minera</a>
<b>MV Variable Speed Drive</b>	Altivar Process ATV 1200 H	11 kV/6.6 kV - 1.5 MW VSD with low TDH output and Ethernet/IP		<a href="#">Altivar Process ATV6000</a>
<b>LV iPMCC switchboard</b>	Okken or Blokset	LV switchboard with a high level of operator safety integrating LV incomers, power feeders, ATS, motor feeders (DOL, Soft Starter and VSD)		<a href="#">Intelligent Power and Motor Control Systems</a>
<b>LV transformer incomer</b>	Masterpact MTZ	ACB with integral metering, protection and control IED with Ethernet/IP		<a href="#">Masterpact MTZ</a>
<b>LV Automatic Transfer Source</b>	Transferpact	UA controller with pre-defined ATS logic sequences Masterpact MTZ with rod mechanical interlock mounted in an LV switchboard		<a href="#">Transferpact</a>
<b>LV power feeder</b>	Compact NSX	LV MCCB with current rating 100 A < In < 630 A used in power and motor feeders		<a href="#">Compact NSX</a>
	PM5000	Energy and PQ meter with Modbus TCP/IP		<a href="#">PM5000</a>
<b>LV DOL starter</b>	TeSys U	Integral DOL motor feeder < 15 kW with Modbus TCP/IP		<a href="#">TeSys U</a>
	TeSys GV, TeSys D, TeSys T, Compact NSX	3 component DOL feeder with MCCB, contactor, motor IED with Ethernet		<a href="#">TeSys</a>
<b>LV Soft Starter</b>	Altistart 48	400 V Soft Starter motor feeder integrated in Okken fixed FU with Modbus TCP/IP		<a href="#">Altistart 48</a>
<b>LV Variable Speed Drive</b>	Altivar Process ATV 600	400 V, VSD for pump, fan and compressor applications with Ethernet/IP		<a href="#">Altivar Process ATV 600</a>
	Altivar Process ATV 900	400 V, VSD for conveyors and hoisting applications with Ethernet/IP		<a href="#">Altivar Process ATV 900</a>



Network function	Product name	Main technical characteristics		Link to offer
<b>MV/LV outdoor package substation</b>	RM6	Ring main unit GIS 12 kV, 400 A, 25 kA,		<a href="#">RM6</a>
	Easergy T300	RTU with Modbus TCP/IP		<a href="#">Easergy T300</a>
<b>Power factor correction</b>	VarSet LV	Automatic PFC equipment in floor standing cabinet with Modbus RTU		<a href="#">VarSet LV</a>
<b>Active Harmonic Filter</b>	AccuSine PCS+	Active filter for harmonic cancellation in a floor standing cabinet with Modbus TCP/IP		<a href="#">AccuSine PCS+</a>
<b>Uninterruptible Power Supply</b>	Gutor PXC	400 V, 10 kVA 3 Phase UPS for industrial site applications with lead acid battery and Ethernet		<a href="#">Gutor PXC</a>
<b>E-House</b>		Pre-fabricated modular building accommodating MV and LV switchgear, VSD, AHF, UPS, PLC, HVAC, F&S equipped with Ethernet connectivity		<a href="#">Schneider-Electric E-House</a>
<b>Controller</b>	Modicon M580	Ethernet Programmable Automation Controller		<a href="#">Modicon M580</a>
<b>Ethernet connectivity devices</b>	Link 150	Modbus RTU to Ethernet gateway		<a href="#">Link 150</a>
	ConneXium TCSESU 05	Ethernet unmanaged switch with 5 ports		<a href="#">Modicon Switch</a>
<b>Edge Control Software</b>	EcoStruxure™ Plant Hybrid DCS	Integrated control system with specific mining library		<a href="#">schneider.electric.com</a>
	EcoStruxure™ Power SCADA Operation	SCADA software system for electrical distribution monitoring and control		<a href="#">schneider.electric.com</a>
	EcoStruxure™ Power Monitoring Expert	Power Management software		<a href="#">schneider.electric.com</a>
<b>Advisor Services</b>	EcoStruxure™ Asset Advisor	Cloud-based asset monitoring service for predictive and preventive maintenance		<a href="#">schneider.electric.com</a>



## APPENDIX B: LIST OF ACRONYMS

<b>AHF</b>	Active Harmonic Filter	<b>MCCB</b>	Molded Case Circuit Breaker
<b>AFE</b>	Active Front End	<b>MN</b>	Methane Number
<b>ACB</b>	Air Circuit Breaker	<b>MV</b>	Medium Voltage (1 kV < MV < 52 kV)
<b>A-FLR</b>	Authorized- Front Lateral Rear	<b>NO<sub>x</sub></b>	Nitrogen Oxide
<b>AIS</b>	Air Insulated Switchgear	<b>OEM</b>	Original Equipment Manufacturer
<b>ATS</b>	Automatic Transfer Source	<b>OLTC</b>	On Load Tap Changer
<b>CAPEX</b>	Capital Expenditure	<b>O&amp;M</b>	Operations & Maintenance
<b>CT</b>	Current Transformer	<b>ONAN</b>	Oil Natural Air Natural
<b>DCS</b>	Distributed Control System	<b>OPEX</b>	Operating Expenditure
<b>DF</b>	Dual-Fuel	<b>PAC</b>	Programmable Automation Controller
<b>DOL</b>	Direct On Line	<b>PCC</b>	Power Control Center
<b>F&amp;S</b>	Fire & Security	<b>PFC</b>	Power Factor Correction
<b>FPI</b>	Fault Passage Indicator	<b>PLC</b>	Programmable Logic Controller
<b>FU</b>	Functional Unit	<b>PQ</b>	Power quality
<b>GCU</b>	Generator Control Unit	<b>PWM</b>	Pulse Width Modulation
<b>HMI</b>	Human Machine Interface	<b>RAM</b>	Reliability, Availability and Maintainability analysis
<b>HVAC</b>	Heating Ventilation and Air Conditioning	<b>RMU</b>	Ring Main Unit
<b>IAC</b>	Internal Arc Containment	<b>SO<sub>x</sub></b>	Sulphur Oxide
<b>IEC</b>	International Electrotechnical Commission	<b>SS</b>	Soft Starter
<b>IED</b>	Intelligent Electronic Device	<b>SSIS</b>	Screened Solid Insulated Switchgear
<b>IEEE</b>	Institute of Electrical and Electronic Engineers	<b>TCO</b>	Total Cost of Ownership
<b>IGBT</b>	Insulated Gate Bipolar Transistor	<b>THD</b>	Total Harmonic Distortion
<b>IMPR</b>	Intelligent Motor Protection Relay	<b>UPS</b>	Interruptible Power Supply
<b>iPMCC</b>	Intelligent Power Motor Control Center	<b>VCB</b>	Vacuum Circuit Breaker
<b>LCD</b>	Liquid Crystal Display	<b>VSD</b>	Variable Speed Drive
<b>LV</b>	Low Voltage (< 1 kV)	<b>VT</b>	Voltage Transformer
<b>LSC</b>	Loss of Service continuity		



## RESOURCES

Wärtsilä Energy

<https://www.wartsila.com/energy>

Wärtsilä Energy Mining & Cement

<https://www.wartsila.com/energy/solutions-by-industry/mining-and-cement>

Schneider Electric Solutions for Mining

<https://www.se.com/ww/en/work/solutions/for-business/mining/>

Schneider Electric Medium Voltage Technical Guide-2018

[www.schneider-electric.com/en/download/document/AMTED300014EN](http://www.schneider-electric.com/en/download/document/AMTED300014EN)

Mining Power Systems Competency Center - Recommended Design for Mid-size Iron Ore Mines- IEC Standard

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Mining Power Systems Competency Center - White Paper 01- Network architectures for optimized mining power system

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Mining Power Systems Competency Centre – White Paper 03 – MV Switchgear for mining power system applications ANSI vs IEC

<https://www.se.com/ww/en/download/document/MVswitchgearMiningPowerWP03/>

Schneider Electric Mining Solutions

[www.se.com/mining](http://www.se.com/mining)



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If you are a customer and have specific questions to your mining project contact your Wärtsilä or Schneider Electric sales representative in your country.