MV switchgear for mining power system applications- IEC vs ANSI

Mining Power Systems Competency Centre White Paper No 03

Revision 00

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Executive summary

MV switchgear is a key component of mining power systems as any failure results in loss of production. This paper describes the IEC and ANSI/NEMA standards, MV switchgear types and technologies used in typical designs for each of the standards. It analyses advantages and disadvantages of each MV switchgear type for the main applications found in mining power systems. It provides practical advice and recommendations to EPCs and mining end users involved in power system design

Introduction

Mining sites have installed power ranging from 20 MVA to 150 MVA used to feed MV and LV electric motors that drive the machines required for the process. The main power source is the utility High Voltage (HV) transmission network. Power transformers are used to stepped down to Medium Voltage (MV) levels ranging from 11 KV to 38 KV. The optimal choice of MV voltage level depends on the installed power and distances to load centers. WP 02 shows how to optimize HV/MV transformer specification and MV network voltage.

Mining power systems are very demanding installations for electrical equipment due to the environmental constraints (dust, pollution) and their locations (high altitude mountains and underground pits). There are also electrical and mechanical constraints (large number of operations, high harmonic currents, high motor staring currents, etc.). WP 01 illustrates the types of MV network architectures that can be used in mining power systems according to the power requirements and physical location of motor loads. Figure 1 illustrates a typical mining power system MV network with three main MV switchgear applications:

1. MV main switchboard (also known as "primary switchboard") that uses circuit breakers to connect the utility HV/MV transformers and local MV generators to the cable feeders. MV motors > 5 MW for grinding mills are also connected to the MV main switchboard using circuit breakers. Smaller motors are often connected using MV fused contactors.
2. MV secondary switchboards that use switches and circuit breakers to control and protect MV/MV and MV/LV transformers that feed Motor Control Centers.
3. MV motor control centers (MCC) provide connection to the MV/MV transformers via circuit breakers and feed the MV motors via fused contactors, soft starters and variable speed drives (VSD) at a voltage ranging from 3.3 KV to 6.6 KV.

MV switchgear represents < 30% of the mining power system capital expenditure (CAPEX) but it plays a key role as any failure leads to loss of production. The objective of this white paper is to help mining end users and EPCs understand MV switchgear technologies and guide them in the optimized choices for each application, taking in account the international standards (IEC or ANSI) chosen for the project and Total Cost of Ownership (TCO). WP 04 explains how to optimize cost of pre-fabricated switch-rooms (E-Houses) by correct MV switchgear selection.

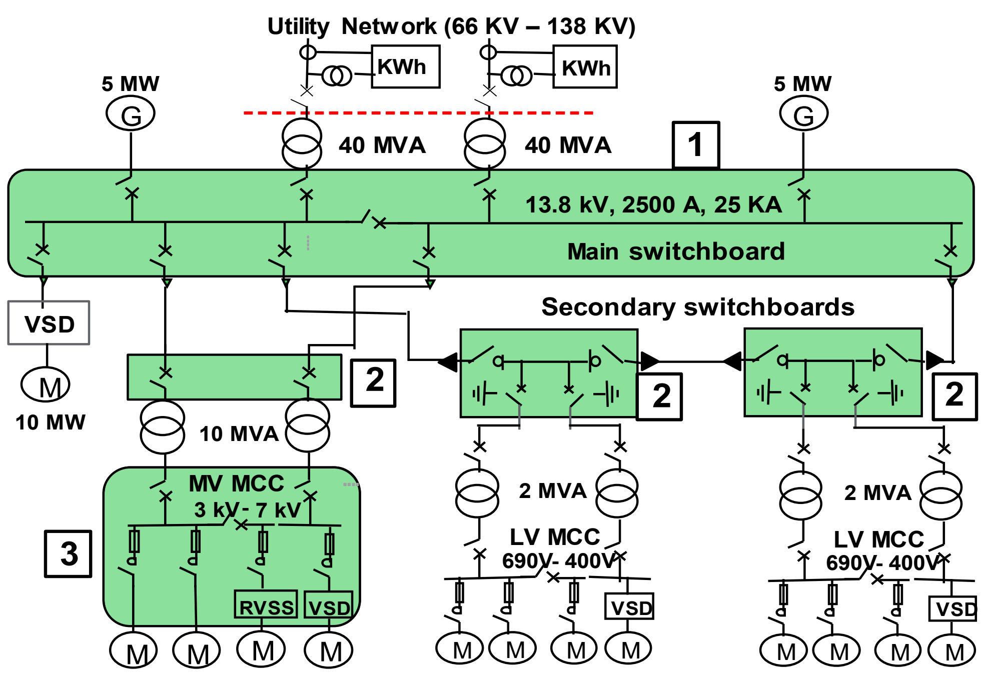

Figure 1

Typical optimized mining power system showing the three key MV applications:

1. *Main switchboard*
2. *Secondary switchboards*
3. *Motor Control center*

MV switchgear standards

The global market for electrical equipment is ruled by international standards. IEC standards apply in all countries except USA and Canada where ANSI/NEMA/IEEE/UL standards are used. MV switchgear main applicable international standard are listed in Table 1.

Table 1

MV switchgear international standards are IEC and North American standards (ANSI/NEMA/IEEE/UL)

MV Switchgear type	US, Canada (all installations) Chile, Peru, Ecuador, Mexico (mining)	Rest of the World
AIS Metal clad	ANSI C37.20.2	IEC 62271-200
AIS Metal enclosed	ANSI C.37.20.3	
AIS MV MCC	NEMA ICS 3 / UL 347	
GIS Metal enclosed	IEEE C37.20.9	
Arc resistant panels	IEEE C37.20.7	

The differences between them are significant leading global manufacturers to have different products to be able comply with each standard. Historically, Chile, Peru, Ecuador and Mexico use ANSI/NEMA standards in their mining installations. This requires mining end users and EPCs to understand how to specify and select MV switchgear for both standards.

"The mining industry in Chile, Peru, Ecuador and Mexico uses ANSI/NEMA standards even if the official country standard is IEC due to historical reasons and long established habits"

MV Air Insulated Switchgear (AIS) have insulators exposed to atmospheric air conditions (e.g. dust, condensation, high altitude). Alternatively, these live parts can be protected by an earthed shield, in the form of metallic tank filled with SF6 gas, known as Gas Insulated Switchgear (GIS) or cast in solid insulation with a conductive surface, known as Shielded Solid Insulated Switchgear (SSIS). MV shielded switchgear are more suitable to the mining environment as it is not affected by atmospheric air condition. GIS and SSIS panels can be used in high altitude mines without any voltage derating as shown in WP 06. They are also the optimal choice for underground pits where ambient air has high humidity and dust.

IEC 62271 standard

IEC 62271 is applicable to MV switchgear components and factory-built enclosures with rated voltages between 1 kV and 52 kV (1). It gives nominal ratings valid for "normal service conditions", which are defined as:

- Minimum Temperature = - 5 °C
- Maximum Temperature= 40 °C
- Maximum altitude= < 1,000 m
- Maximum humidity (24 h) = 95 % with water vapour pressure of 2.2 kPa
- Maximum humidity (1 month) = 90% with water vapour pressure of 1.8 kPa

Table 2 shows IEC 62271 rated voltages (Un), AC power frequency (50/ 60 Hz) withstand voltage (PFWV) and the Lighting Impulse Withstand Voltage (LIWV).

Table 2

IEC 62271 rated voltage levels and associated AC rms power frequency (1 min) withstand voltage and lighting impulse (1.2/50 µs) peak withstand voltage

Un (KV rms)	PFWV (KV rms)	LIWV (KV peak)
3.6	10	40
7.2	20	60
12	28	75
17.5	38	95
24	50	125
36	70	170

IEC 62271 standard defines normal rated current (In) 200 A, 630A, 1250 A, 1600 A, 2000 A, 2500A, 3150A and 4000 A based on maximum conductor temperatures (θ max) and temperature rise (Δθ) for an ambient temperature Tamb = 40°C. Rated short circuit currents are 16 kA, 20 kA, 25 kA, 31.5 kA, 40 kA, 50 kA and 63 kA.

IEC 62271-200 defines the types of segregations between cubicle compartments, partition types and operator access modes. It defines the Loss of Service Continuity (LSC) index that reflects the level of operator safety and power supply availability to be expected during regular equipment maintenance operations. The standard allows the use of metallic barriers (PM) or insulating barriers (PI) to separate compartments. The latter are not safe to touch when the switchboard is energized as there is an electric field gradient on its surface.

Compartment access		Continuity of supply during maintenance
LSC 1		The whole switchboard must be de-energized
LSC2	LSC2A	Busbar compartment can remain energized
	LSC 2B	Busbar and cable compartment can remain energized

IEC 62271-200 standard is based on equipment performance only. Designers have freedom to choose materials, cubicle architectures and insulation technology (AIS, GIS or SSIS). Figure 2 illustrates typical IEC 62271-200 LSC types of MV switchgear panels. AIS can have fixed of withdrawable circuit breakers, while GIS or SSIS have fixed circuit breakers with a series disconnector. All IEC MV switchgear includes integral cable earthing with fault making capacity interlocked with the main switching device to ensure operator safety when accessing cable compartments. All IEC MV switchgear panels are provided with Internal Arc Classification (IAC) that indicates the level of operator protection in case of an internal arc. This is defined by the following letter code A= Authorized Persons, F= Front, L= Lateral, R= Rear. Maximum operator safety level is provided by AFLR class.

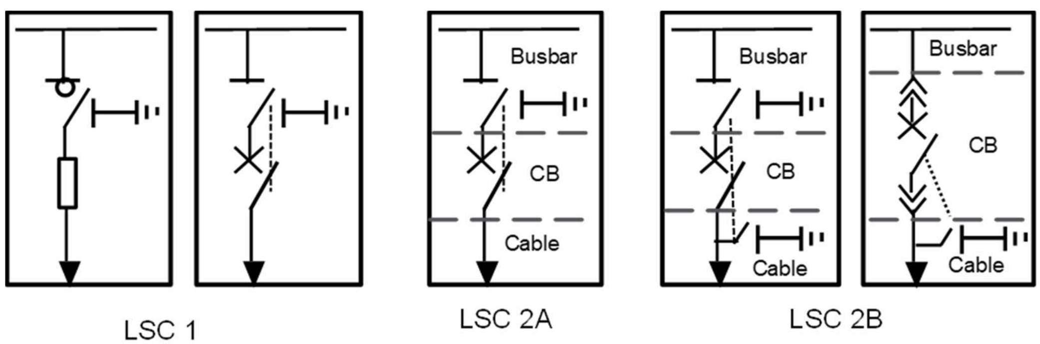

Figure 2

IEC 62271 MV panels with different LSC types and architectures that include interlocked cable earthing function for operator safety

North American Standards

"IEC standards are based on performance to be proven by test, which gives opportunity for innovation. ANSI/NEMA standards are based on fixed design rules and approved materials."

North American standards are issued by several bodies (IEEE, NEMA, UL) and consolidated by the American National Standard Institute (ANSI). MV switchgear standards cover 1 kV to 38 kV rated voltages for three AIS switchgear types

- ANSI C37.20.2- metal clad switchgear (2)
- ANSI C37.20. metal enclosed switchgear (3)
- NEMA ICS 3/UL 347 metal enclosed fused contactors used in MV MCCs (4) (5)
- IEEE C37.20.9 standard for MV GIS, released in 2019 not widely used yet (6)

Table 3 shows rated voltages (Un), AC power frequency (60 Hz) voltage withstand (PFWV) and Basic Insulation Level (BIL) for "normal service conditions":

- Minimum Temperature = - 30 °C

- Maximum Temperature= 40 °C
- Maximum altitude= < 3,000 feet (1,000 m)
- Maximum humidity = not specified

The MV equipment nominal currents defined by ANSI standards are:

- AIS Metal-clad: 1200A, 2000A, 3000 A and 4000 A
- AIS Metal-enclosed: 200 A, 400 A, 600A and 1200A

It also defines rated short circuit currents of 25 kA, 40 kA, 50 kA and 63 kA for metal-clad while metal enclosed is limited to 16 kA, 20 kA and 25 kA.

Table 3

ANSI rated voltage levels and associated AC rms power frequency (1 min) withstand voltage and lighting impulse (1.2/50 µs) peak withstand voltage referred as Basic Insulation Level (BIL)

Un (KV rms)	PFWV (KV rms)	BIL (KV peak)
2.4	15	45
4.16	19	60
15	36	95
27	60	125
38	80	150

North American standards define segregation between compartments, partition types and operator access modes. AIS metal clad panels requires metallic partitions between busbar, circuit breaker and cable compartment, while metal enclosed AIS panels do not require any segregation, as illustrated in Figure 3.

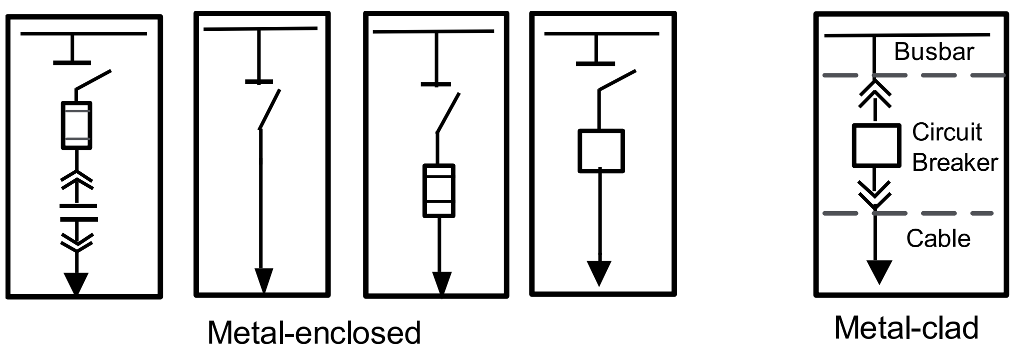

Figure 3

ANSI standards define two types of MV switchgear

- *Metal enclosed*
- *Metal -clad*

Operator safety philosophy adopted by North American standards is based on "visible gap" concept, where the operator must be able to see the disconnector open to ensure that the panel is de-energized. Integral cable earthing is not mandatory. The function is done by a portable grounding device that has to carried by the operator. Internal arc containment is a special version known as Arc Resistant (AR), that is defined in IEEE C37.20.7 (7).

ANSI/NEMA standards define many of the cubicle design parameters such as dimensions, metal thickness, position of busbars, cable connections, instrument transformers, etc. The materials used must be approved by Underwriters Laboratory (UL). These constraints set by ANSI/NEMA/UL standards gives MV switchgear designers little scope for innovation.

Comparison of IEC and ANSI/NEMA Air Insulated Switchgear

Global EPCs working in mining projects in Mexico, Chile and Peru need to be familiar with both standards as these three countries use ANSI/NEMA MV Switchgear even if IEC is the official country standard. Global manufacturers like Schneider Electric design and build both types of panels covering all the ratings. Based on this knowledge it is possible to summarize the key differences that are listed below:

- ANSI/NEMA AIS panels are bigger, heavier and more expensive than IEC ones for similar ratings. WP 04 explains the impact of MV switchgear footprint and weight in the E-house building cost and its transportation to the mine site.
- ANSI/NEMA panels ensure operator safety by providing a “visible gap” when the disconnector is in open position. IEC operator safety is based on indication of voltage presence, indirect indication of disconnector position and interlocked cable earthing switch to allow operator access to the cable compartments.
- IEC panels have internal arc classification (IAC) as standard while ANSI ones have reinforced Arc Resistant (AR) special version that is more expensive

Air insulated switchgear characteristics

AIS dielectric performance is determined by electric field stress (dependent on conductor and insulator geometries), the condition of solid insulator surfaces (dependent on presence of dust, pollution and condensation) and on atmospheric air dielectric withstand (dependent on air density which reduces with altitude). Figure 4 shows the two independent mechanisms cause air insulation breakdown.

- Flashover across the minimum clearance (airgap between conductors), is determined by the LIWV or BIL and not the power frequency test voltage
- Tracking along the insulator creepage distance depends on PFWV (50/60 Hz)

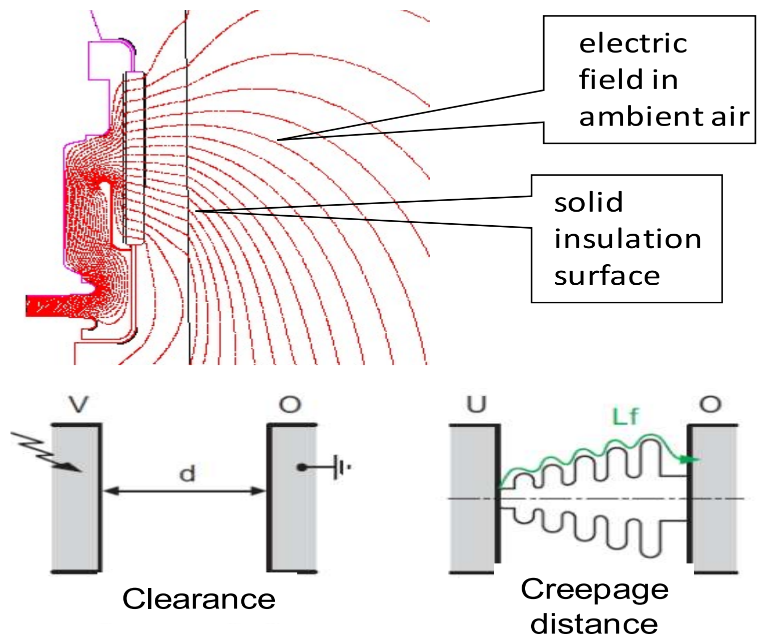

Figure 4

Air insulation dielectric withstand is affected by:

- *Air density that reduces with altitude (flashover across clearances)*
- *dust and condensation on insulator surfaces (tracking discharge)*
- *electric field distribution in ambient air determined by the geometrical shapes of insulators and conductors (e.g. sharp edges)*

LIWV (BIL) across minimum clearance is proportional to atmospheric air density which drops with altitude at a rate of 10%/1,000 m, for which all MV AIS panels have a lower LIWV (BIL) rating above 1,000 m as explained in WP 06.

The risk of surface discharges (tracking) in MV AIS insulators (e.g. busbar supports) increases with the presence of dust and condensation. For this reason they should not be used in underground mines.

MV shielded insulation characteristics

MV switchgear designs with shielded insulation have live conductors “shielded “from ambient air by an earthed screen. Effective earth shields must be continuous and include MV cable connectors and voltage transformers (see Figure 5).

MV shielded insulation designs can be achieved two different technologies and often a combination of both in the same equipment:

- Gas Insulated Switchgear (GIS): live parts are placed in a sealed tank filled with high dielectric strength gas (e.g. SF6) and connected to earth.
- Shielded Solid Insulation Switchgear (SSIS) : live parts are cast in solid insulation (e.g. epoxy resin) with metallic paint surface connected to earth

GIS and SSIS panels have several advantages compared to AIS designs, including:

- Dielectric performance unaffected by atmospheric air condition (e.g. altitude)
- High operator safety as live parts are not accessible
- Significantly reduced footprint as conductors can be placed closer together
- No need for routine maintenance (e.g. insulator cleaning) giving reduced OPEX

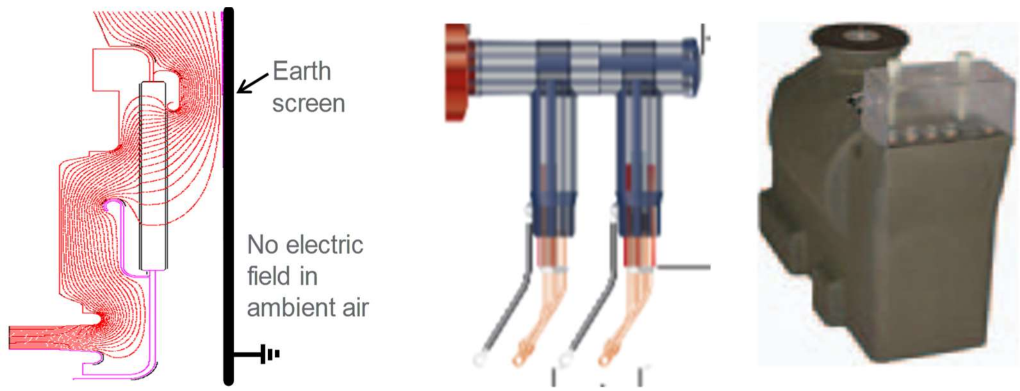

Figure 3

MV switchgear with shielded insulation has all live conductors protected by insulation with a continuous earthed screen, including cable connectors and voltage transformers

MV GIS and SSIS designs use fixed circuit breakers with integral isolation and cable earthing. This is compatible with IEC 62271 standard, which allows many panel architectures provided that electrical and safety performance tests are met.

Up until 2019 ANSI did not have a standard dedicated to GIS. Global manufactures like Schneider Electric have adapted their IEC GIS and SSIS fixed circuit breaker designs to meet ANSI C37.20.3 standard. The adaptations include adding viewing windows or cameras to enable operators to visualize disconnector contact position and changing labels in line with US practices.

The SF6 gas issue

Sulphur Hexafluoride (SF6) is a synthetic gas used by the electrical industry since the 1960's, initially in HV GIS (> 132 KV) and then in MV switchgear during the 80's. SF6 gas unique properties such as high dielectric strength (3 times that of air), high thermal conductivity and current interruption ability make it a "perfect" gas for electrical use. Unfortunately, SF6 is one the most powerful greenhouse gases (8).

Although it is still legal to use SF6 in HV and MV switchgear, industry leaders investigating alternative gases (9) with less Global Warming Potential (GWP). Schneider Electric Premset Shielded Solid Insulated Switchgear provides an SF6 free alternative up to 17.5 KV, 1250 A, 25 kA (10). Until a widely accepted "SF6 free" insulation system is found, end users should work closely with GIS suppliers to ensure that the SF6 gas is recovered at the end of life to avoid its release into the atmosphere.

MV Switchgear by applications

The mining power systems applications shown in Figure 1 can be implemented with AIS, GIS or SSIS technologies depending on required electrical ratings (Un, In and Isc) and the standards selected by the designer. The typical product options shown for each application are based on Schneider Electric current MV switchgear offers. However, similar equipment can be found in other MV switchgear manufacturers catalogues as they all must comply with the relevant IEC or ANSI standards.

MV Main Switchboard Application

These are “all circuit breakers” MV switchboards, with electrical ratings that depend on HV/MV transformer rated power, MV network rated voltage (Un) and the busbar normal current (In). Short circuit current rating (Isc) depends on the HV/MV transformer short circuit impedance (Zsc) and the selected operating mode when two HV/MV transformers are used.

The most common MV main switchboard architecture has two incomers and a bus section circuit breaker, known in North America as “Main-Tie-Main”. Optimized designs avoid MV network architectures with HV/MV transformers operating in parallel by keeping bus section circuit breakers open, which is feasible when voltage drop caused by large MV motor starting is within acceptable limits. More details on these topics can be found in WP 01 and WP 02.

MV main switchboards typical ratings are shown in Table 3.

Table 3

Typical electrical ratings for MV Main Switchboards depend on HV/MV transformer parameters and MV network configurations

<table>
<tr><td colspan="2" rowspan="3"></td><td rowspan="3">Un (KV)</td><td colspan="2">In (A)</td><td colspan="2">Isc (KA)</td></tr>
<tr><td rowspan="2">Feeder</td><td rowspan="2">Incomer & Bus Section</td><td colspan="2">Bus Section Position</td></tr>
<tr><td>Open</td><td>Closed</td></tr>
<tr><td rowspan="3">HV/MV transformer rated power</td><td>20 – 50 MVA</td><td>11-15</td><td>630</td><td>1200 - 3150</td><td>20 – 31.5</td><td>31.5 - 50</td></tr>
<tr><td>40– 80 MVA</td><td>20-27</td><td rowspan="2">1200</td><td>1200 - 2000</td><td rowspan="2">20 - 25</td><td rowspan="2">31.5 - 40</td></tr>
<tr><td>60- 100 MVA</td><td>33-38</td><td>1200 - 2000</td></tr>
</table>

IEC 62271- AIS Panels for Main Switchboards

Figure 4 illustrates Schneider Electric MCset, a typical IEC 62271 AIS LSC2B-PM panel with draw-out vacuum circuit breaker cassette and integral interlocked earthing switch. MCset maximum electrical ratings are:

<table>
<tr><td colspan="2"></td><td>In max</td><td>Isc max</td></tr>
<tr><td rowspan="3">Un</td><td>12 KV</td><td rowspan="2">4000 A</td><td rowspan="2">50 KA</td></tr>
<tr><td>17.5 KV</td></tr>
<tr><td>24 KV</td><td>2500 A</td><td>31.5 KA</td></tr>
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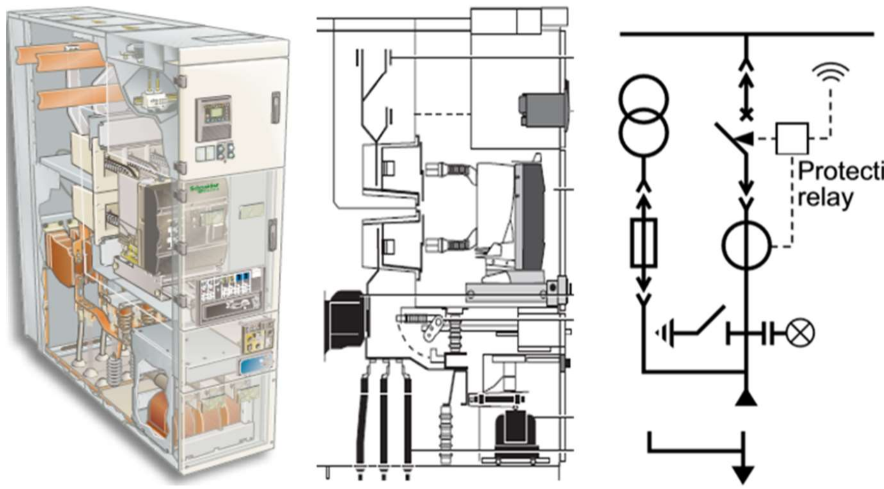


Figure 4

Schneider Electric MCset MV AIS with withdrawable vacuum circuit breakers compliant with IEC 62271 class LSC2-PM Maximum ratings are :

- *17.5 kV, 4000 A, 50 kA*
- *24 kV, 2500 A, 31.5 kA*

Figure 5 illustrates Schneider Electric F-400, a typical IEC 62271 AIS LSC2B-PM 36 kV panel with draw-out SF6 circuit breaker in a rolling truck and integral interlocked earthing switch. F400 maximum electrical ratings are:

Un	In max	Isc max
36KV	2500 A	40 kA

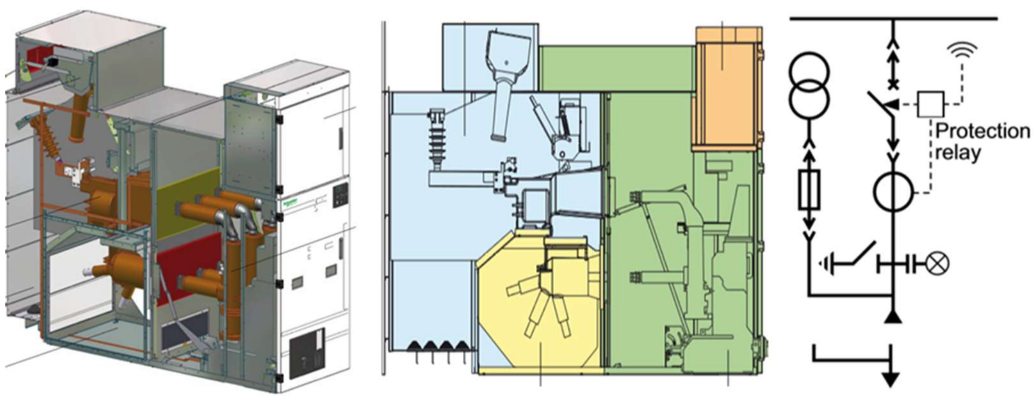


Figure 5

Schneider Electric F400 36 kV AIS with draw-out SF6 circuit breaker compliant with IEC 62271 class LSC2-PM Maximum ratings are :

- *36 kV, 2500 A, 40 kA*

IEC 62271- GIS/SSIS Panels for Main Switchboards

Figure 6 illustrates Schneider Electric GHA, a typical IEC 62271 GIS LSC2B-PM 36 kV panel with fixed vacuum circuit breaker and three position serial disconnector. Busbars are inside the SF6 filled metal tank, but their connection does not require gas work on site. GHA is available in single and double busbar configuration with these maximum electrical ratings:

	Un	In max	Isc max
Double Busbar	36 KV	2500 A	40 KA
Single Busbar			

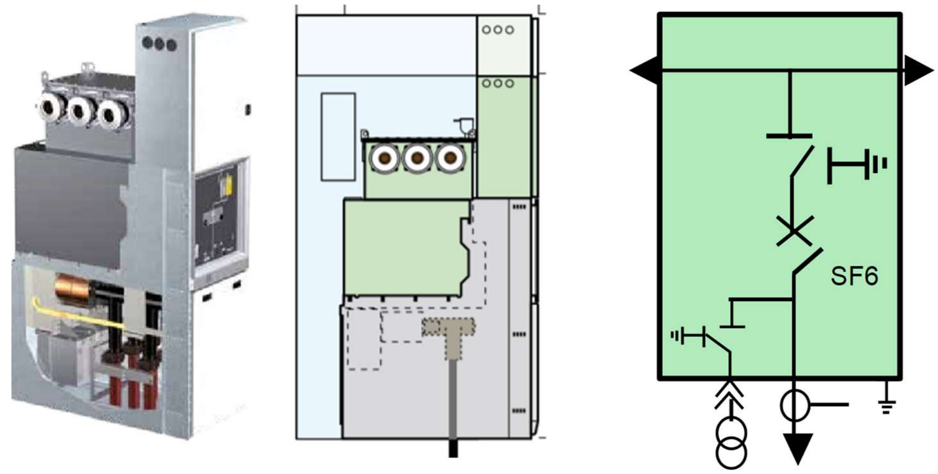


Figure 6

Schneider Electric GHA 36 kV GIS with fixed vacuum circuit breaker and serial 3 position disconnector compliant with IEC 62271 LSC2-PM Maximum ratings are:

- *36 kV, 4000 A, 40 kA*

Figure 7 illustrates Schneider Electric CBGS-0, an IEC 62271 LSC2B-PM 36 kV GIS panel with fixed SF6 circuit breaker and three position serial disconnector. This design uses shielded solid insulated busbars (EPDM rubber with a conductive earthed surface). As the busbars are outside the SF6 filled metallic tank their connection on site is quick and simple. CBGS-0 maximum electrical ratings are:

Un	In max	Isc max
36 KV	1600 A	31.5 KA

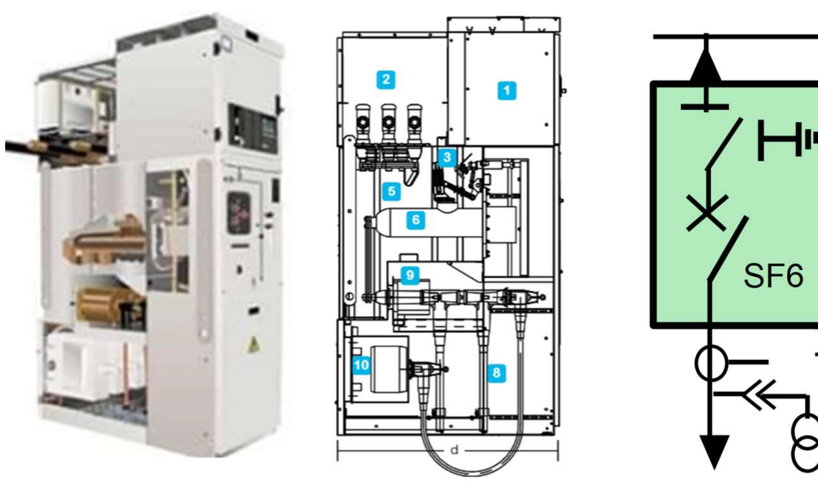


Figure 7

Schneider Electric CBGS-0 36 kV GIS with fixed SF6 circuit breaker and serial 3 position disconnector compliant with IEC 62271 LSC2-PM Maximum ratings are :

- *36 kV, 1600 A, 31.5 kA*

Figure 8 illustrates Schneider Electric Premset , an IEC 62271 LSC2B-PM 17.5 kV SSIS panel with fixed vacuum circuit breaker disconnector and two position earthing switch. Busbars use EPDM rubber with a conductive surface. Vacuum bottles are cast in epoxy resin with conductive paint. The earthing switch is housed in an epoxy resin tank coated with metallic paint, which provides “controlled air” insulation.

Premset is an “SF6 free” shielded vacuum circuit breaker panel with small footprint and operator safety. Premset can be used in main MV switchboards if the HV/MV transformer rated power is < 20 MVA and network voltage is 17.5 kV. This is illustrated in Recommended Power System Design for High Altitude Lithium Mine. Premset is available in IEC or ANSI versions with the following maximum ratings:

Un	In max	Isc max

17.5 KV	1250 A	25 KA

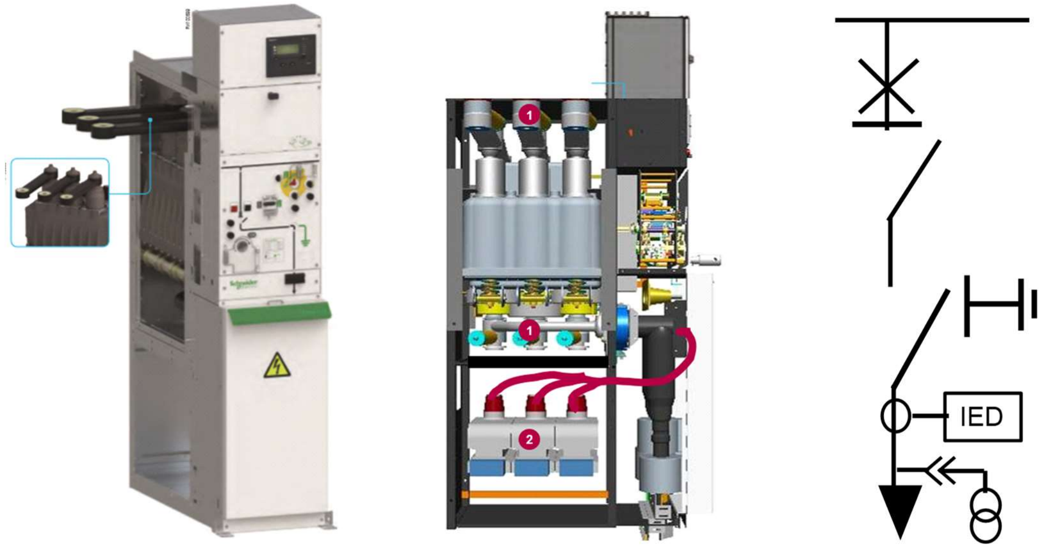


Figure 8

Schneider Electric Premset 17.5 kV SSIS with fixed vacuum circuit breaker disconnector and 2 position earthing switch compliant with IEC 62271 LSC2-PM
Maximum ratings are :

- *17.5 kV, 1250 A, 25 kA*

ANSI metal clad- AIS panel for MV Main Switchboards

Figure 9 illustrates Schneider Electric Masterclad range, a typical ANSI C37.20.2 metal clad AIS panel with withdrawable vacuum circuit breaker on a rolling truck. Cable earthing is done using an external earthing truck. The same architecture is used for 15 kV and 27 kV. Cabling is from the rear and feeder circuit breakers be double stacked. Masterclad AR is the arc resistant version which has reinforced structure to contain the arc. Masterclad electrical ratings are:

	Un	In max	Isc max
Masterclad Standard	15 KV	4000 A	63 KA
	27 KV	2000 A	40 KA
Masterclad AR Arc Resistant	15 kV	3000 A	50 kA
	27 kV	Not available	

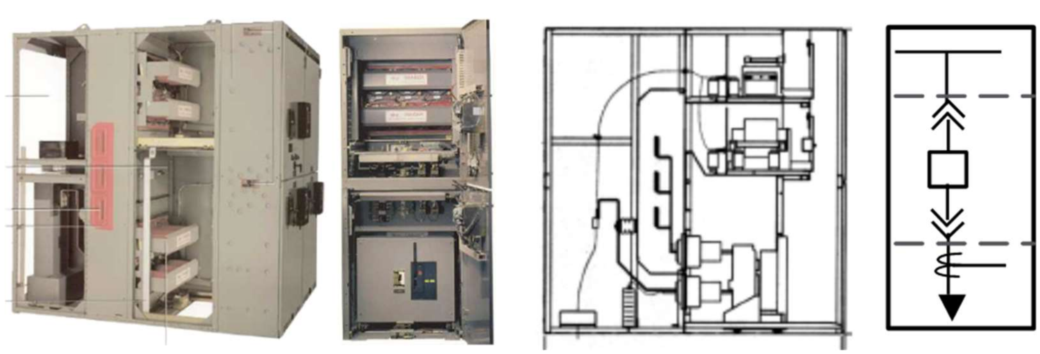


Figure 9

Schneider Electric Masterclad ANSI metal clad MV AIS with draw-out vacuum circuit breaker compliant with ANSI C37.20.2 standard
Maximum ratings are :

- *15 kV, 4000 A, 63 kA*
- *27 kV, 2000A, 40 kA*

ANSI Metal Enclosed GIS/SSIS Panels for Main Switchboards

Most global MV switchgear manufacturers have adapted their IEC MV GIS panels to comply US and Canadian standards and obtained UL certification to be able to offer these product ranges to North American customers. Schneider Electric certified GHA (Figure 6), CBGS-0 (Figure 7) and Premset (Figure 8) to various ANSI, IEEE, NEMA and CSA standards. Hence these GIS/SSIS panels can be used in USA and Canada as well as mining installations in Chile, Peru, Ecuador and Mexico when ANSI/NEMA standards are requested.

MV Secondary Switchboards Applications

MV secondary switchboards have mixture of switches and circuit breakers used to control and protect MV/LV transformers feeding LV MCCs, as explained in WP 01. Ring Main Unit (RMU) are a specific type of secondary switchboards with 3 or 4 switching devices used to connect transformers to the MV ring. MV secondary panels are mainly used in MV public distribution utility network. They are very cost effective but their electrical ratings are limited to In < 630 A and Isc < 25 kA. Typical MV secondary switchgear ratings are

Un (kV)	In (A)	Isc (kA)
11-15	200 - 1250	20- 25
20-27		
33-38	200- 630	

Traditional mining power system designs use radial MV networks with Isc > 25 kA with MV circuit breaker panels (LSC2B-PM or metal clad type). Using “dual radial” or “open ring” MV networks architectures with Isc < 25 kA it is possible to achieve significant cost savings introducing MV secondary switchboards. This is illustrated in Recommended Power System Design for Mid-size Iron Ore Mines.

IEC 62271- AIS Panels for Secondary Switchboards

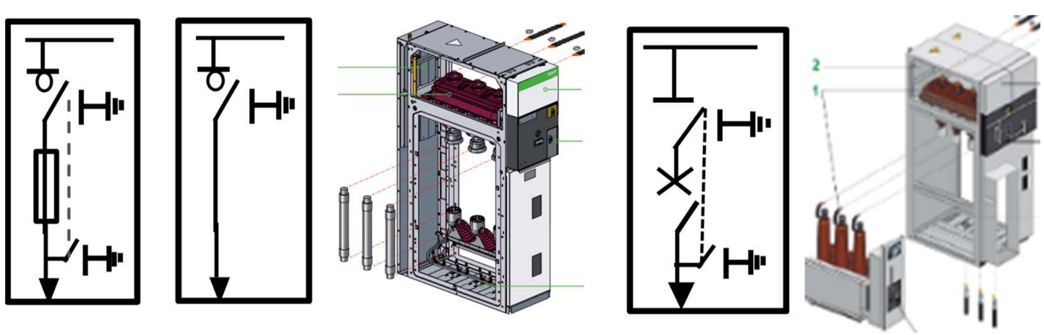
Figure 10 shows Schneider Electric SM6, a typical IEC AIS LSC2A-PI panel with switches, fused switches and fixed SF6 circuit breakers. The same architecture is used for 17.5 kV, 24 kV and 36kV. SM6 fixed circuit breaker panels can be used as lower cost alternative to LSC2B-PM draw-out circuit breaker panels in main MV switchboards if nominal ratings allow it. SM6 maximum electrical ratings are:

Un	In max	Isc max
17.5	1250 A	25 kA
24 KV		20KA
36 KV		

Figure 10

Schneider Electric SM6 AIS range of switches, fused switches and circuit breakers compliant with IEC 62271 (LSC2A -PI) with ratings

- *17.5 kV, 1250 A, 25 kA*
- *24 kV, 1250 A, 20 kA*
- *36 kV, 1250 A, 20 kA*



IEC 62271- GIS Panels for Secondary Switchboards

Figure 11 illustrates Schneider Electric DVCAS, a typical IEC LSC2A-PM 36kV range of GIS panels. They include 3 position 630 A, 25 kA switches (On-Off-Earth) and fixed vacuum circuit breaker that be configured as a multi-panel switchboard. Switching devices and busbars are in a stainless-steel tank filled with SF6 gas. DVCAS maximum electrical ratings are:

DVCAS panels typical configurations	Un	In max	Isc max
Single circuit breaker (cable in and out)	36 KV	630 A	25 KA
Two switches & circuit breaker (RMU)			

Figure 11

Schneider Electric DVCAS 36 kV GIS range of switches and circuit breakers compliant with IEC 62271 (LSC2A – PM type) with maximum ratings

- *36 kV, 630 A, 25 kA*

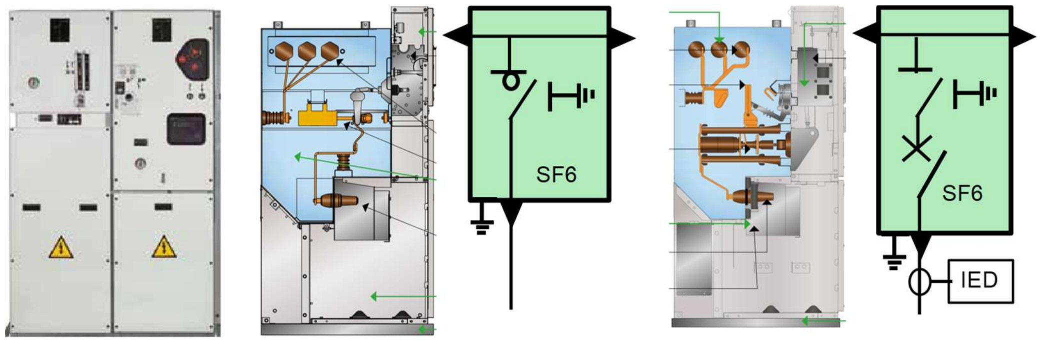


Figure 12 illustrates Schneider Electric RM6 a typical IEC LSC2A-PM GIS range of 3 position 630A switches (On-Off-Earth), fused switches and fixed SF6 circuit breaker disconnectors. RM6 can be configured as single panels with extensible shielded busbars or as multi-function unit with up to five devices in an earthed stainless-steel tank filled with SF6 gas. A typical configuration has two 630 A switches and a 200A circuit breaker (11) known as Ring Main Unit (RMU). The circuit breaker short circuit interrupting capacity varies according to the rated voltage (25 KA @12 KV or 20 KA @ 24 KV). RM6 maximum electrical ratings are:

RM6 panels typical configurations	Un	In max	Isc max
Circuit breaker (cable in and out)	12 kV 24 kV	630 A	25 KA 20 kA
Two switches & circuit breaker (RMU)			

Figure 12

Schneider Electric RM6 MV GIS range of switches , fused-switches and circuit breakers compliant with IEC 62271 (LSC2A – PM type) with maximum ratings

- *12 kV, 630 A, 25 kA*
- *24 kV, 630 A, 20 kA*

ANSI- Metal Enclosed Panels for Secondary Switchboards

Figure 13 shows Schneider Electric HVL and HVLcc (an adapted version of SM6) that are typical ANSI AIS metal enclosed range with switches and fused switches. HVL and HVLcc maximum electrical ratings are

	Un	In max	Isc max
HVL	15 kV	1200 A	

	38 kV	600 A	
HVLcc	15 kV	1200 A	25KA
	38 kV	400 A	

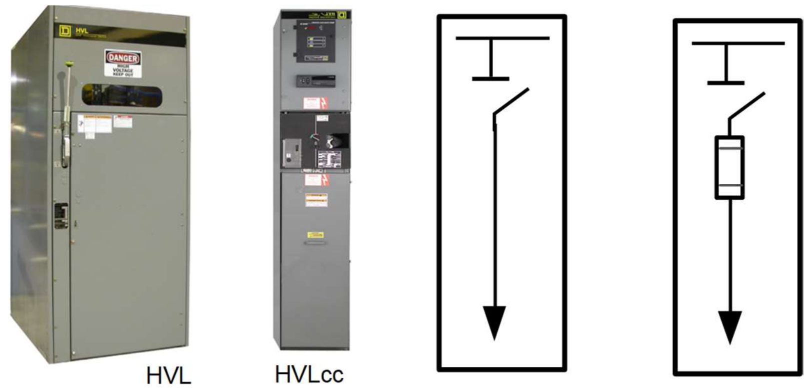


Figure 13

Schneider Electric HVL and HVLcc AIS metal enclosed range of switches , fused-switches compliant with ANSI C37.20.3 with maximum ratings

- *15 kV, 1200 A, 25 kA*
- *38 kV, 600 A, 25 kA*

Schneider Electric also offers shielded MV metal enclosed switchgear certified under ANSI C37.20.3 that can be used in MV secondary switchboards. This include ANSI/UL certified versions of Premset SSIS panel (see Figure 8) and DVCAS GIS panels (see Figure 11).

North American common design practice for mining power system use Main-Tie-Main MV network architectures with the tie circuit breaker closed. This results in short circuit current levels > 40 kA, which restricts the useof MV metal enclosed switchgear as their short circuit current rating is ≤ 25 kA.

MV Motor Control Center Applications

MV MCCs are AIS switchboards that feed MV motor loads, using:

- MV AIS circuit breakers panels for incomers and bus section
- MV AIS fused contactor panels as motor feeders, that can be either Direct on Line (DOL), Autotransformer (RVAT), Soft starter (RVSS) or Variable Speed Drives (VSD)

MCCs are usually fed by dual MV/MV transformers, often connected in parallel to minimize voltage drop during MV motor DOL start. MV MCCs switchboard ratings depend on MV/MV transformer rated power and short circuit impedance. Nominal voltage and minimum size of motor connected depend on country habits. US, Canada Mexico, Brazil, Peru and Chile use 4.16 kV to feed motors > 300 kW while the rest of world uses mainly 6.6 kV to feed motors > 1 MW. Typical ratings for IEC and ANSI/NEMA MV MCCs are

		Un (KV)	In (A)		Isc (KA)
			Feeder	Incomer & B/S	
MCC transformer rated power	5 to 15 MVA	4.16 or 6.6	200-400	1200 - 2000	25 –40

Figure 14 illustrates a typical IEC 6.6 kV MCC switchboard with draw-out LSC2B-PM circuit breakers as incomers and bus section and fixed or draw -out LSC2A fused contactors as motor feeders, all connected to the same busbar.

Figure 15 shows a typical ANSI/NEMA/UL 4.16 kV MCC architecture with one ANSI C.32.20.2 metal clad circuit breaker switchboard feeding several NEMA ICS3/UL 347 metal enclosed switchboards with fused contactor panels via MV cables.

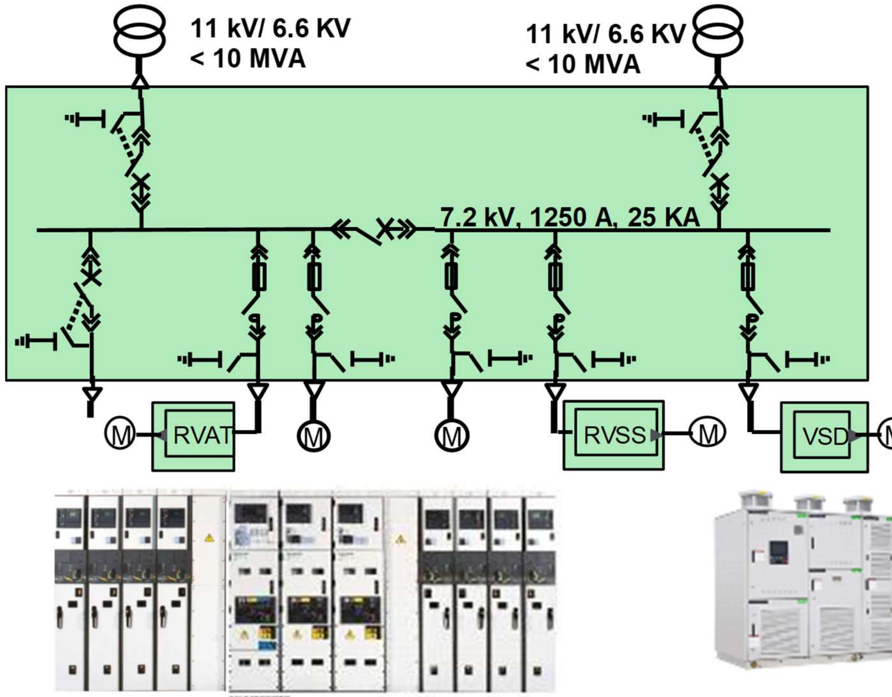


Figure 14

Typical IEC 6.6 kV MCC mixed switchboard using Schneider Electric MV AIS panels:

- *MCset incomers & bus section*
- *Motorpact for motor feeders*

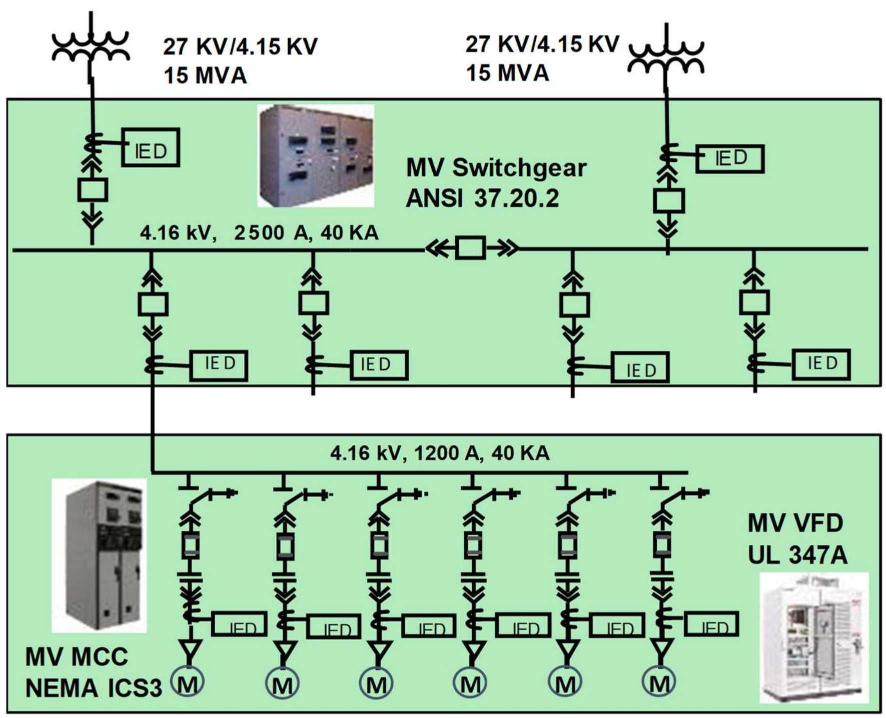


Figure 15

Typical ANSI/NEMA 4.16 kV MCC using Schneider Electric MV AIS panels:

- *Masterclad incomers, bus section and cable feeders*
- *Motorpact motor feeders*

IEC 62271- AIS Panels for Motor Control Centers

Figure 16 shows Schneider Electric Motorpact a typical IEC LSC2A-PI 7.2 KV AIS draw-out fused contactor DOL motor feeder panel. Motorpact range includes a Reduced Voltage Soft Starter (RVSS) panel that uses MV thyristors to control the voltage applied to the motor during the start (see Figure 17). A transition panel is used to connect Motorpact and MCset onto a common busbar. Motorpact ratings for DOL and RVSS panel are:

	Un	In max	Isc max
DOL	7.2 KV	3150 A (busbars)	50 KA
RVSS		400 A (feeders)	

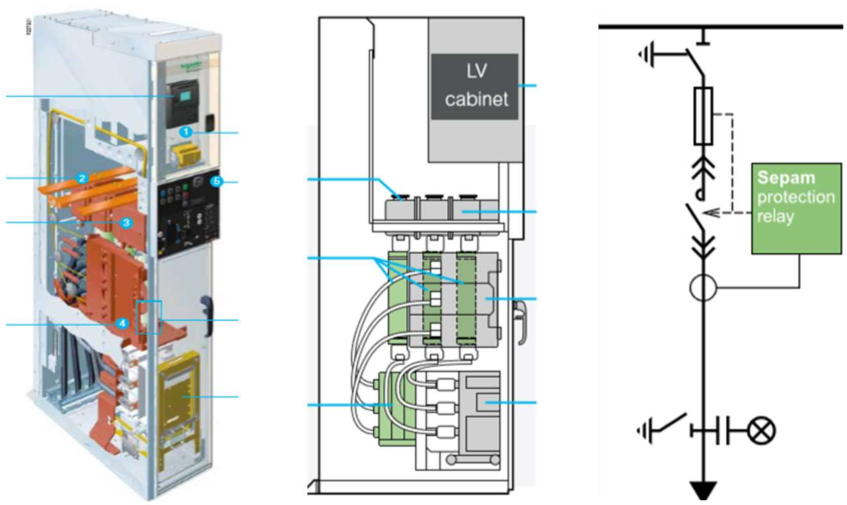


Figure 16

Schneider Electric Motorpact 7.2 kV AIS draw-out fused contactor motor feeder panel used DOL starter for motors up to 4 MW, compliant with IEC 62271 standard LSC2A-PI type; Busbar transition panel allows connection with MCset AIS range of draw out circuit breaker panels

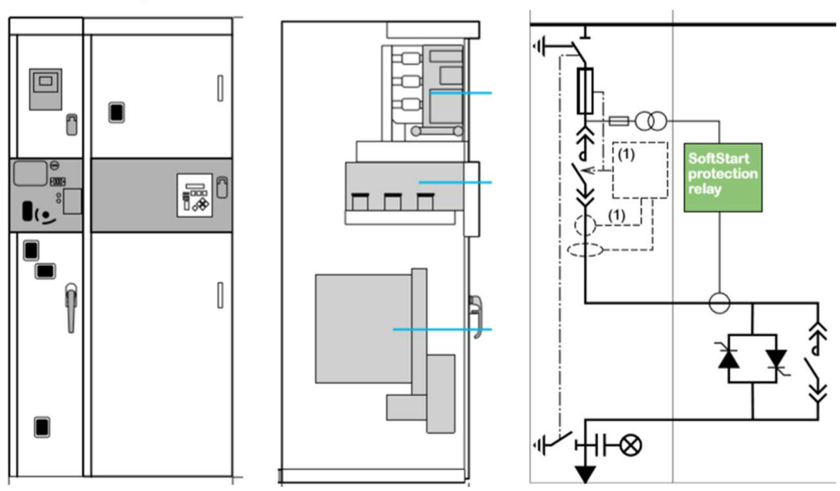


Figure 17

Schneider Electric Motorpact 7.2 kV AIS draw-out fused contactor panel and thyristor panel with by-pass contactor to provide a Reduced Voltage Soft Starter motor feeder

- *Motorpact for motor feeders*

Motorpact also has version compliant with NEMA ICS 3 and UL 347 standard. This panel is sold in USA and Canada, as well as mining segment in countries that specify North American standards such as Chile, Peru, Ecuador and Mexico.

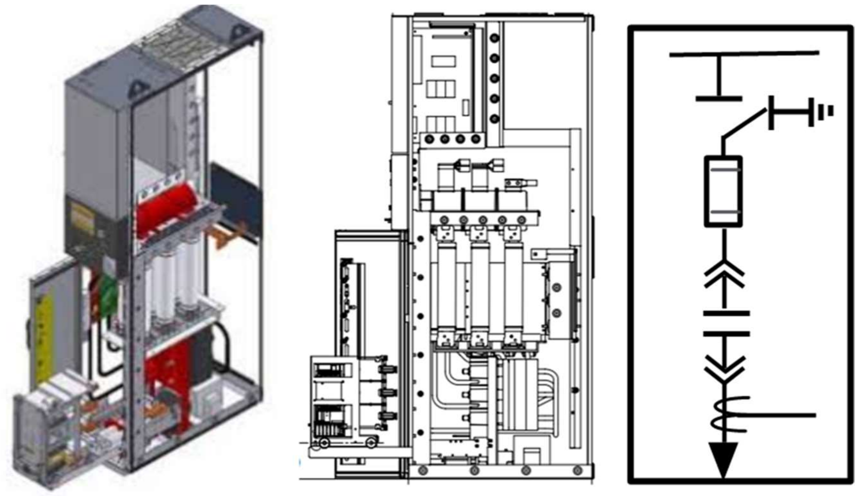


Figure 18

Schneider Electric Motorpact 7.2 kV AIS draw-out fused contactor motor feeder panel used DOL starter for motors up to 4 MW, compliant with INEMA ICS3 standard; Busbar transition panel allows connection with Masterclad ANSI metal clad range of draw out circuit breaker panels

Conclusion

MV switchgear represents < 30% of mining power system CAPEX but their choice is critical as any failure results in lost production. The mining environment is one of the toughest for AIS as it combines high levels if dust as well as high altitude and underground pit installations.

Optimization of MV installations starts with the correct choices of network voltages, MV switchgear nominal current and short circuit current level. Designs should avoid exceeding 2500 A nominal current in main MV switchboard and 25 kA fault current by correct selection of HV/MV transformer short circuit impedance. This will allow to use cost effective GIS and SSIS panels that are better adapted to the mining environment, have lower footprint, weight and cost and provide greater operator safety than traditional AIS panels.

The choice of standard, either IEC or ANSI, also has an impact on total MV installation cost, including the E-House. ANSI AIS panels are bulkier and more expensive than IEC AIS panels for equivalent electrical ratings. The difference is less marked in MV MCC applications.

Schneider Electric has one of the most complete MV switchgear offers in the market for IEC and ANSI/NEMA standards, as well as the expertise to help end users and EPCs optimize their mining power system during the project design stage.

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(3) ANSI/IEEE C37.20.3-2013 -Standard for Metal-Enclosed Interrupter Switchgear (1-38 kV)

(4) IEEE C37.20.9 (2019)- IEEE Standard for Metal-Enclosed switchgear rated 1 kV to 52 kV Incorporating Gas Insulating Systems.

(5) IEEE C37.20.7 (2017)- IEEE Guide for Testing Switchgear Rated up to 52 kV for Internal Arc Faults

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Acknowledgements

Special thanks to Jean-Marc Lupin, Delcho Penkov and Tifenn Perron for reviewing the original content of this white paper and providing valuable feedback.

Glossary

AIS	Air Insulated Switchgear
ANSI	American National Standards Association
AR	Arc Resistance (ANSI term equivalent to internal arc containment)
CAPEX	Capital Expenditure (also called “first cost”)
CSA	Canadian Standards Association
E-House	Electrical House (factory built switch-room delivered directly to site)
EPC	Engineering Procurement Contractor
GIS	Gas insulated Switchgear
GWP	Global Warming Potential of a gas compared to CO_2
HV	High Voltage (Un > 52 kV)
IAC	Internal Arc Classification (according to IEC 62271 standard)
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronic Engineers (USA)
LV	Low Voltage (Un < 1 kV)
MCC	Motor Control Center
MV	Medium Voltage (1 kV < Un < 52 kV)
NEMA	National Electrical Manufacturers Association (USA)
OPEX	Operational Expenditure (includes maintenance and outages cost)
RMU	Ring Main Unit (MV switchgear panel with 3-4 functions in one tank)
SSIS	Screened Solid Insulated Switchgear
TCO	Total Cost of Ownership (CAPEX + OPEX)
UL	Underwriters Laboratory (USA)
Zsc	Transformer short circuit impedance

Resources

Schneider Electric MV Switchgear IEC Standard Offer Panorama
https://www.se.com/ww/en/product-category/87897-medium-voltage-switchgear/

Schneider Electric MV Switchgear ANSI Standard Offer Panorama
https://download.schneider-electric.com/files?p_enDocType=Brochure&p_File_Name=SE-1986_ANSI+Panorama+%5B998-1186690_US_A%5D+0508.pdf&p_Doc_Ref=998-1186690_US_ANSI

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