LV Motor Control Center in Mining Applications - IEC vs ANSI/NEMA

Mining Power Systems Competency Center
White Paper N° 04

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Executive summary

LV motor control centers are key components in mining power systems with high impact on total electrical distribution cost.
This paper describes LV switchgear types used in typical installations compliant with IEC and ANSI/NEMA standards. It analyses advantages and disadvantages of each LV switchgear type for the mining power systems applications. It provides practical advice and recommendations to EPCs and mining end-users involved in power system design.

Introduction

Most countries in the world use IEC standards for their electrical installations except USA and Canada where ANSI and CSA standards are mandatory. However, mining power systems in Chile, Peru, Ecuador and Mexico use equipment compliant with ANSI/NEMA standards, even if officially, these countries apply IEC standard. This is because US companies owned and built most of the mines in these countries until the 1970's and local habits have not changed over time.

Figure 1 illustrates a typical mining power system with main switchgear applications that is LV motor control centers (MCC) feeding LV motors via fused contactors, soft starters and variable speed drives (VSD) at a voltage ranging from 380 V to 690 V.
LV switchgear represents < 30% of the mining power system capital expenditure (CAPEX) but it plays a key role as any failure leads to significant loss of production.

Figure 1

Typical power system of an open pit mine

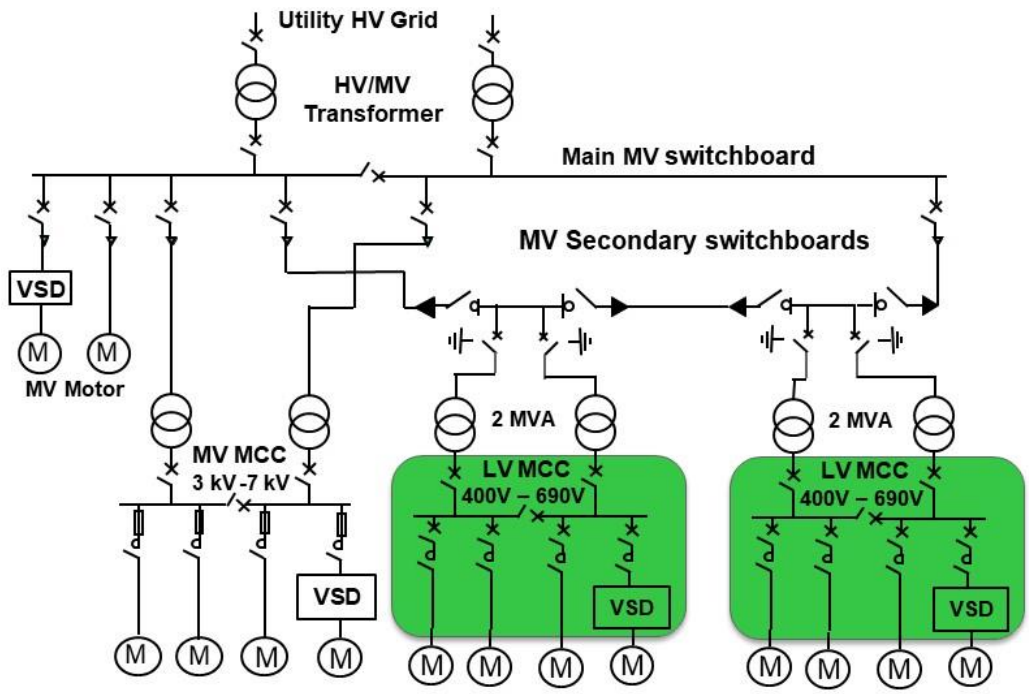
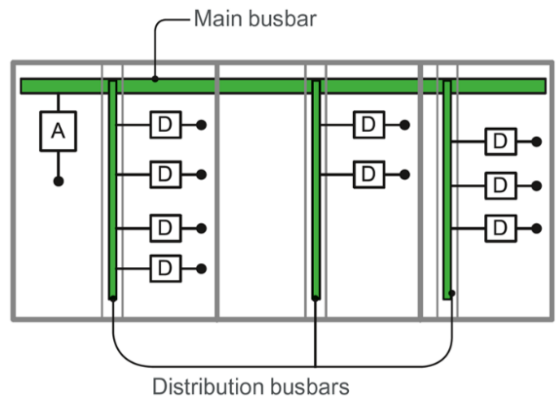


Figure 2 shows a typical MCC consisting of a main busbar that distributes power horizontally between various switchboard columns, and distribution busbars supplying motor starters.

Figure 2

Typical Motor control Center Architecture



The objective of this white paper is to help mining end-users and engineering companies (EPCs) understand LV switchgear technologies and international standards (IEC or ANSI) to select equipment that optimizes the Total Cost of Ownership (TCO).

LV Equipment International Standards

The two prevailing electrical equipment standards bodies in the world are the International Electrotechnical Commission (IEC) and the American National Standards Institute (ANSI). ANSI is applicable in North America, and some select regions, while IEC is used in the rest of the world. Each body takes a different approach to developing and approving standards which affects the design and testing of equipment. Neither standard is better than the other, but understanding their differences is critical for specifying equipment for mining power systems.

In North America, the legal and liability environment drives some minimum criteria for design, installation and performance, leading to ANSI standards being closely tied in with building and safety codes. ANSI is a design-based standard specifying, for example, sheet metal thickness, paint color, barriers and other features to ensure consistency of equipment from various manufacturers. This means that most manufacturers' equipment designed to the same standard vary little from one another.

The IEC standards are legal requirements and market references for all electrical, electronic, and related technologies. Since IEC is applicable worldwide, across many countries where local practices, codes and legal environments vary drastically, the standards are performance-based. IEC standards dictate the intent of the design, and to what test or environment the design must comply. This means manufacturers of IEC equipment have freedom to innovate in their equipment provided that they can demonstrate performance compliance by predefined tests.

LV equipment standards

North American and IEC standards for LV equipment are significantly different. This can be confusing for power system designers who wish to compare them.

IEC standards apply to all LV equipment types regardless of the applications. Equipment is characterized by the following features:

- Power distribution and Motor Control functions are grouped in the same switchboard known as PMCC
- Air Circuit Breakers (ACB), Molded Case Circuit Breakers (MCCBs) and different types of LV motor feeders are mixed in the same switchboard sharing a common busbar.

North American philosophy is to have dedicated standards for each type of application (LV power distribution, MCC and sub-distribution panels). Furthermore, each of these standards are issued by different bodies such as ANSI, IEEE, NEMA and UL (see Appendix A). Table 1 summarizes LV equipment international standards.

Table 1

IEC and North American standards covering LV equipment in mining installations

Equipment Type	USA, Canada (all installations) Chile, Peru, Ecuador, Mexico (mining)	Rest of the World
LV Switchgear	ANSI/IEEE C37.20.1 UL 1558	IEC 61439
LV Switchboard	UL 891	
LV Motor control Center	NEMA ICS 18 UL 845	

IEC Standard for LV Switchgear

IEC 61439-1 & -2

These two standards are the reference for LV equipment construction. They highlight all the requirements for designers and users of LV switchboards: people and equipment safety, availability, long-term reliability, and conformity.

IEC 61439-1 defines normal service conditions, construction requirements, technical characteristics, and verification tests. It is based on the concept of "assembly", which includes a metallic enclosure housing a combination of busbars, LV switching devices (ACBs, MCCBs, contactors, fused switches) and control gear (relays, trip units, power meters).

IEC 61439-1 uses the concept of functional unit (FU) which is defined as a part of an assembly comprising all the electrical and mechanical elements including switching devices that contribute to the fulfilment of the same function.

The standard considers the LV switchgear market structure by defining the split of responsibilities between the original manufacturer (e.g. Schneider Electric) and the panel builder, which are often different companies. The original manufacturer is responsible for the design and associated verification of an assembly system. The assembly Manufacturer (Panel Builder) is responsible for routine verifications on each panel produced, according to the standard.

Nominal voltage rating

IEC 61439 defines LV switchgear rated voltage values:

- Ue: rated operational voltage
- Ui: rated RMS insulation voltage used to test creepage distance
- Uimp: rated impulse voltage used to validate clearance

Overvoltage category (OVC) defines transient overvoltage depending on neutral earthing system (TN, TT, IT) and location of the equipment in the installation.

IEC 61439 refers to IEC 60664 standard for LV equipment insulation coordination. This standard defines the LV equipment insulation characteristics: (minimum clearances and creepage distances) in relation with the expected voltage stress (transient and temporary overvoltage). Table 2 gives the correlation between system voltages and the corresponding Uimp for TT/TN neutral earthing systems.

Table 2

Correlation between supply system voltages and rated impulse withstand voltage Uimp

Network Voltage Ue	Overvoltage Category			
TN/TT neutral earthing	I	II	III	IV
380 V, 400 V, 480 V	1.5 kV	2.5 kV	4 kV	6 kV
600 V, 690 V	2.5 kV	4 kV	6 kV	8 kV
1000 V	4 kV	6 kV	8 kV	12 kV

Minimum clearances to withstand rated Uimp up to 2000 m are indicated in Table 3.

Table 3

Minimum clearances to withstand rated Uimp

Uimp	Clearance for altitudes up to 2000 m
4 kV	3 mm
6 kV	5.5 mm
8 kV	8 mm
12 kV	14 mm

The dielectric properties are also validated by a power frequency test at a voltage of 1890 V for equipment with 300 V < Ui < 690 V.

IEC 60664 recommends minimum creepage distances to withstand a given Ui, considering the pollution degree (PD) and the type of insulation material. Pollution is defined as the introduction of solid, liquid or gaseous foreign bodies that can reduce the dielectric strength or resistivity of the insulator surface.
IEC 61439-1 defines 4 degrees of pollution. Assemblies for industrial applications are generally for use in a pollution degree 3 environment (conductive pollution due to regular condensation). Table 4 shows creepage distances for group 3 insulation material (175 < CTI < 400) at different Ui values.

Table 4

Minimum creepage distances or different LV network rated voltages

Network Voltage (Ue)	Rated insulation voltage (Ui)	Minimum Creepage Distance	
		Pollution degree 2	Pollution degree 3
380 V, 400 V	400 V	4 mm	6.3 mm
440 V, 480 V	500 V	5 mm	8 mm
600 V, 690 V	690 V	8 mm	12.5 mm
1000 V	1000 V	10 mm	16 mm

Temperature Limits

The temperature of the LV devices and that of touchable parts are important factors with respect to operational reliability, life span and operator safety. Table 5 shows the maximum temperatures and temperature rise limits defined by IEC 61439 for LV electrical equipment for an ambient temperature of 35 °C.

Table 5

Temperature limits defined by IEC 61439

Equipment Type	Temperature rise	Temp. max
Busbar bare copper contacts	105°K	140°C
Incorporated components	90°K	125°C
Terminals for external insulated conductors	70°K	105°C

IEC 614391-2

IEC 61439-2 covers power switchgear and control gear (PSC) assemblies. A PSC is used to distribute and control energy for all types of loads, intended for industrial, commercial and similar applications where operation by ordinary persons is not intended. A PSC includes Functional Units such as ACB, MCCB and motor starters

IEC 61439-2 defines the types of electrical connections of functional units with a three-letter code as illustrated in Figure 3:
W = Withdrawable D = Disconnectable F = Fixed

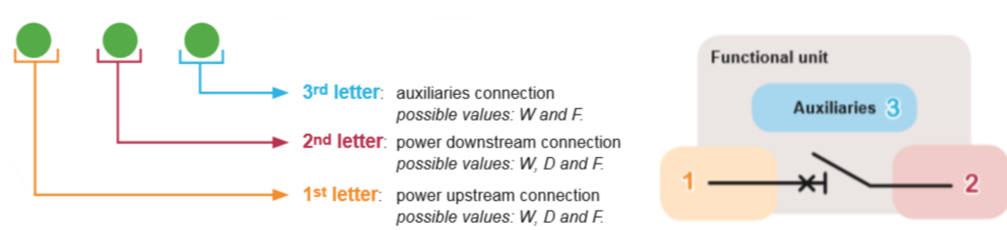


Figure 3

Type of electrical connections according defined in IEC 61439-2

IEC 61439-2 defines the forms of internal separation: operator access to a FU with other parts energized, including risk of accidental contact and passage of objects (e.g., tools) from one FU to another (see Table 6 and Figure 4).

Table 6

Forms of Separation defined by IEC 61439-2

Main Criteria	Sub-criteria	Form of Separation
No internal separation	None	**Form 1**
Functional units separated from the busbars	Terminals for external conductors not separated from the busbars	**Form 2a**
	Terminals for external conductors separated from the busbars	**Form 2b**
Functional units separated from each other and from the busbars. Terminals for external conductors separated from the functional units	Terminals for external conductors not separated from the busbars	**Form 3a**
	Terminals for external conductors separated from the busbars	**Form 3b**
Functional units separated from the busbars and from each other including the terminals for external conductors	Functional units not separated from the terminals for external conductors	**Form 4a**
	Functional units separated from the terminals for external conductors	**Form 4b**

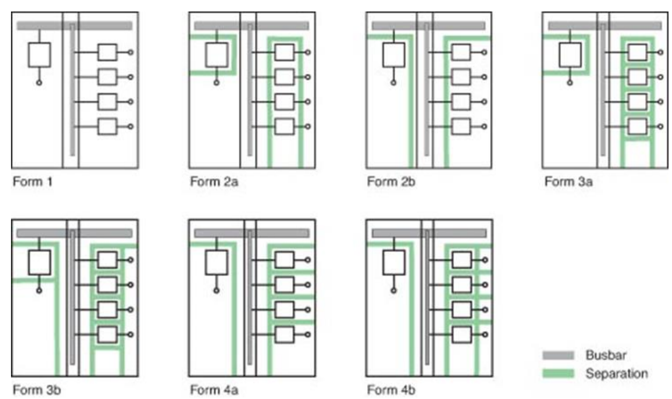


Figure 4

Forms of Separation to define operator access to Functional Units according to IEC 61439-2

To answer the installation needs, the degree of operator safety and the service continuity required, Table 7 shows the different options related to mechanical parameters such as the form of separation and the type of electrical connections.

Table 7

Types of Connections and levels of Service

	Withdrawable	Disconnectable	Fixed
			
Access to Functional Units	Only the concerned FU must be turned off	Only the concerned FU must be turned off	Switching off the whole switchboard
Maintenance	15 min < T	15 min< T < 60 min	T > 60 min
Minimum form required	3b	2b	1

IEC TR 61641 - Guide for testing under Internal Arc conditions

LV switchgear internal arc test is not mandatory in IEC 61439-2 standard. Test guidelines and criteria are given in IEC Technical Report (TR) 61641 (see annex C).

North American Standards for LV Equipment

Type of equipment in North American standards

North American philosophy is to have dedicated standards for each type of application (LV power distribution, MCC and sub-distribution panels).

Switchgear, in North America, refers to LV enclosures with withdrawable ACBs and metallic partitions (equivalent to IEC Form 4b) defined by ANSI C37 standard. Safety aspects are complemented in UL 1558 standard.
Electrical switchgear regulates, protects, and isolates a power system with a variety of controls housed in a metal enclosure. It is a vital system in industries that experience electrical faults or those that need to regularly de-energize equipment for maintenance, such as industrial environments and electrical utilities.

Switchboard is the term used for free standing, fixed MCCB panels defined by UL 891 standard. They are mainly used in LV distribution in buildings and can sometimes include a few motor feeders for building loads (e.g. HVAC).
Switchboards are used to transmit power to one or more sources, most often in commercial settings.

Motor Control Center is a specific LV panel construction defined by NEMA ICS18 and UL 845 standards to control motors. NEMA ICS 2 defines « NEMA Size xx » starters and its components (e.g. contactors, circuit breakers, relays).
Motor control centers were first used in auto manufacturing to control the many electric motors used in process lines. Now MCCs are used all over the world, across many applications, such as wastewater treatment, mining and the oil and gas industry.

North American LV equipment types and associated standards are illustrated in Figure 5. In LV industrial networks that use North American practices, the MCCs are connected via LV cables or LV busways to LV metal enclosed switchgear compliant with ANSI/IEEE C37.20.1. Nominal voltage ratings are 480 V (popular in USA) and 600 V (mainly used in Canada).

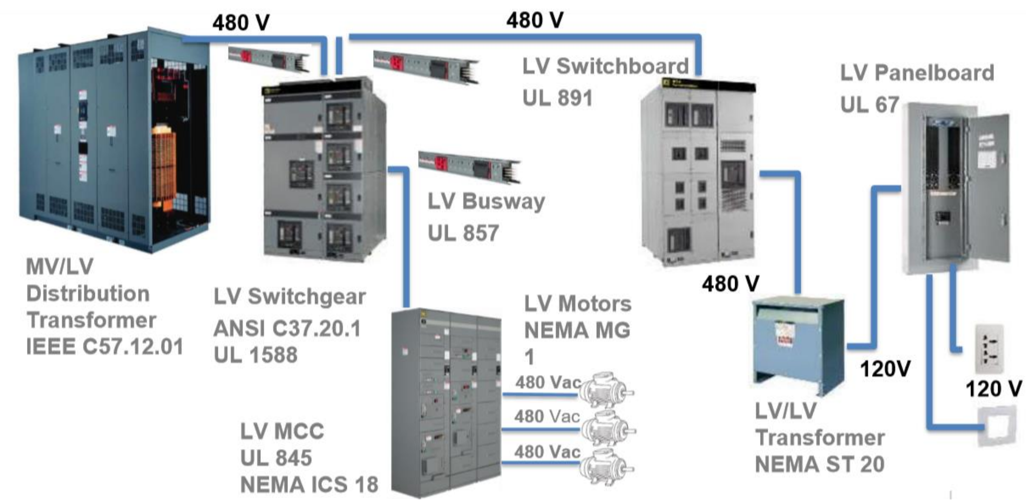


Figure 5

North American LV equipment types and associated standards

North American Standards for LV Metal Enclosed Switchgear

IEEE C37.20.1 - Standard for Metal-Enclosed Low-Voltage Power Circuit Breaker Switchgear

This standard covers metal-enclosed LV switchgear assemblies containing devices as power circuit breakers, other interrupting devices, switches, control, instrumentation, and metering, protective and regulating equipment.
IEEE C37.20.1 standard deals with service conditions, rating, temperature limitations, and classification of insulating materials.
LV metal-enclosed switchgear, compliant with IEEE C37.20.1 and UL 1558 standards, can contain either stationary or draw-out, manually or electrically operated LV Power Circuit Breakers (PCBs), which conform with ANSI C37.13 and UL 1066 standards, in individual grounded metal compartments.

Rated maximum voltage levels can be 254 V, 508 V, or 635 V. The preferred continuous current ratings of the main busbar are 1600 A, 2000 A, 3200 A, 4000 A, 5000, 6000 A, 8000 A or 10 000 A. Table 8 shows ANSI C37.20.1 temperature rise limits used to determine nominal currents at ambient temperature Tamb= 40°C.

Table 8

Temperature limits from ANSI C37.20.1

Equipment Type	Temperature rise	Temperature max
Busbar bare copper contacts	30°K	70°C
Busbar tin/silver plated copper contacts	65°K	105°C
Insulated cable unplated contacts	30°K	70°C
Insulated cable tin/silver plated contacts	45°K	85°C

The standard defines the panels structure, which consists of columns with separate compartments for PCBs, busbars and power cable terminations, separated by earthed metallic barriers. Each column can stack up to four PCB units with associated protection relays, control and instrumentation devices and Control Power Transformers (CPTs). Power cable terminations are rear access only, which requires additional E-House footprint.
ANSI C37.20.1 standard defines short-circuit current ratings of 85 kA (typical), 100 kA, 150 kA and 200 kA. The panel mechanical structure must withstand the passage of rated fault current during 1 sec, which results in a strong mechanical structure and large conductor cross sections.

UL 1558 - Safety Standard- LV Metal-Enclosed Power Circuit Breaker Switchgear

UL 1558 standard complements ANSI/IEEE C37.20.1 and compliance is required to meet the safety requirement of the US National Electrical Code (NEC). UL 1558 defines the safety features of LV metal enclosed switchgear such as ground fault protection schemes, interlocks and safety labels. It also defines minimum spacings between conductors (see Table 9) including clearances (referred to as “through air spacing”) and creepage distances (referred to as “over surface spacing”).

Table 9

Minimum spacing for LV metal-enclosed Switchgear according to UL 1558

LV Switchgear section	Minimum spacing between live parts of opposite polarity		Minimum spacing between live conductors and grounded surface
	Through air	Over surface	Through air and over surface
Busbars and enclosure	25.4 mm	50.8 mm	25.4 mm
Control circuit terminals	9.5 mm	12.7 mm	12.7 mm

North American Standards for LV Motor Control Centers

Motor Control Center (MCC) is a specific LV panel construction, that groups all the functions required to monitor, control and protect LV motor loads. The concept of “modular MCC” was first introduced in the USA during the 1950’s in response to the needs of the car manufacturing industry. The first UL standard for MCC was issued in the 1970’s to address safety and testing related issues.

NEMA ICS 18 defines MCC nominal ratings and constructional features. UL 845 standard includes NEMA ICS 18 content plus all safety requirements for compliance with the NEC.

NEMA ICS18 (2007) - LV Motor Control Center

NEMA ICS 18 defines recommended electrical ratings that are:

- Nominal voltage of 480 V and 600 V
- Horizontal busbars nominal current ratings are 600A, 800A, 1200A, 2000 A, 2500A and 3200 A (1200 A is most common). Vertical busbar can be 300 A, 600 A, 1000 A or 1200 A
- Short circuit current ratings are 42 kA, 65 kA, 85 kA and 100 kA
- No short time current rating is specified as the upstream protection trips instantaneously.

NEMA ICS 18 recommends the use of some constructional features, such as:

- NEMA Type 1 enclosures with standard height of 90” (2.29 m) and metal barriers with a level of segregation equivalent to Form 4b as per IEC 61439-2
- Withdrawable drawers (also referred as “buckets”) to house combination motor control devices (circuit breakers, fuse-switch, contactor, relays, VSDs, RVSS, etc.)
- Position and dimensions for control wiring channels
- Panel interlocks

Table 10 refers to NEMA ICS 2 for the definition of « NEMA sizes » for combination motor control units defined by their rated current in Amps and motor rated power in hp. NEMA standardization philosophy is to simplify the selection process as users only need to know motor rated power in hp and voltage (480 V or 600 V). To achieve this, it accepts some over-rated components, particularly for small motors.

Table 10

Motor starters defined by NEMA ICS2

NEMA Size	Continuous current (A)	Max motor hp 480 V – 600 V
00	9	2
0	18	5
1	27	10
2	45	25
3	90	50
4	135	100
5	270	200
6	540	400
7	810	600
8	1215	900
9	2250	1600

UL 845 (2018) - Standard for Safety - LV Motor Control Centers

Compliance to UL 845 is necessary to meet safety requirement of National Electrical Code (NEC), compulsory in US installations. UL 845 defines all the electrical tests (temperature rise, short-circuit and dielectric) and mechanical test (number of operations, dimensions, etc.) that must be passed to obtain the “UL label”.

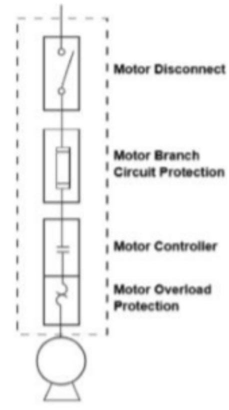
NEMA ICS18 requires temperature rise limit of 65 °C for an ambient temperature of 40°C. However, to comply with UL 845, the copper section has to be increased because UL 845 limits temperature rise to 50°C and maximum temperature to 90°C.

UL 845 defines material type and thickness of metallic and insulating barriers, control wiring spacing, connector types, wire sizes and wiring loom construction as well as four types of combination motor controllers as indicated in table 11.

Table 11

Combination motor controllers defined by UL 845

		Electrical Function			
	Device	Circuit disconnection	Short circuit protection	Motor load controller	Overload protection
Type A	Disconnector	*			
	Fuse		*		
	Contactor			*	
	Overload relay				*
Type C	Circuit breaker Inverse time trip	*	*		
	Contactor			*	
	Overload relay				*
Type D	Circuit breaker Instantaneous trip	*	*		
	Contactor			*	
	Overload relay				*
Type E	Self-protected Control device	*	*	*	*



UL 845 establishes minimum clearances (through air spacing) and creepage distances (over surface spacing) that define the dielectric withstand in air, but it does not define any impulse voltage withstand (equivalent to Uimp in IEC 61439).
UL 845 defines AC 60 Hz (1 min) insulation test voltage as: 1,000 V + 2 * Un
The minimum spacings for nominal voltage < 600 V ac are shown in Table 12.

Table 12

Minimal clearance and creepage distances defined by UL 845 for 600 V

LV MCC section	Minimum spacing between live parts of opposite polarity		Minimum spacing between live parts and grounded metal parts
	Through air	Over surface	Through air and over surface
Busbars and enclosure	25.4 mm	50.8 mm	25.4 mm
	Minimum spacing between uninsulated live parts of opposite polarity		Minimum spacing between uninsulated live parts and the walls of a metal enclosure
Within motor control units	Through air	Over surface	Through air and over surface
	9.5 mm	12.7 mm	12.7 mm

Internal Arc Withstand

Today there is no recognized standard in North America for arc resistant LV MCCs that also meet UL 845. Manufacturers like Schneider Electric that wish to develop arc resistant designs have to test according to Annex H of IEEE C37.20.7 ‘Guide for Testing Metal-enclosed Switchgear Rated up to 38 kV for Internal Arcing Faults’.

Table 13 highlights the main design difference between IEC and ANSI/NEMA standards for LV equipment.

Main differences between IEC and ANSI/NEMA standards

Table 13

Differences between IEC and ANSI/NEMA

Characteristics	ANSI/NEMA	IEC
External Conductor Connections Temperature Rise (Max.)	Switchgear: 45°C rise over a 40°C ambient MCC: 50°C rise over a 40°C ambient for 80% rated device	70°C rise over a 40°C ambient but may be lower if limited by material in contact according to manufacturer.
Plated Bus Temperature Rise (Max.)	65°C rise over a 40°C ambient	105°C rise over a 40°C ambient but may be lower if materials in contact with bus are limited to lower temperature
Through Air Clearance (min.)	Phase to Phase: 25.4mm/1” Phase to Ground: 25.4mm/1”	Phase to Phase: 14mm/0.55” Phase to Ground: 14mm/0.55
Over Surface Creepage (min.)	Phase to Phase: 50.8mm/2” Phase to Ground: 25.4mm/1”	Phase to Phase: 16mm/0.63” Phase to Ground: 16mm/0.63”
Impulse voltage	No	Depend on OVC
AC test	1000 V + 2 Un	1890 V for 300 V < Ui < 690 V
Motor starter	Size defined by NEMA ICS2 Simple selection but conservative ratings	No standard frame sizes but different utilization categories resulting in more optimized solution
Segregation	Segregation equivalent to form 4b for switchgear No segregation for MCC	Form 1 to 4
Withdrawability	For power connections	FFF to WWW
Enclosure (see Annex B)	Nema type per NEMA 250	IP code per IEC 60529
Internal Arc withstand	IEEE C37.20.7	IEC 61641

LV Equipment for Mining Power Systems

Typical LV equipment ratings

LV networks found in mining are mainly 3 phase 4 wire systems with nominal voltage ranging from 380 V to 690 V. The choice of LV network voltage is important as it will impact nominal current ratings and equipment cost, particularly at high altitudes as the dielectric performance of the LV equipment is reduced.

The main types of Low Voltage equipment used in mining power systems are:

- Power distribution panels used to connect power sources (MV/LV transformer, LV back-up generator) and large non-motor loads such as power factor correction (PFC) equipment, active filters and LV/LV transformers for ancillary loads.
- Motor Control Centers (MCC) for control and protection of all 3 phase LV motor loads with rated power ranging from 10 kW to 1 MW. They are supplied from MV/LV transformers with nominal power ratings between 1 MVA to 2.5 MVA.
- Sub-distribution panels for lighting, HVAC and ancillary functions

IEC 61439 LV Power Motor Control Center Equipment

Figure 6 illustrates a typical IEC network with a redundant power supply. The motor feeders and power distribution feeders are mixed in the same switchboard known as PMCC. The most typical voltage rating is 400 V, 3150 A and 50 kA. VSDs controlling motors > 50 kW are usually connected in a separate wall mounted or free-standing panel connected to the PMCC via LV cables.

Figure 6

Typical IEC 61439 standard LV Power Motor Control (PMCC) switchboard

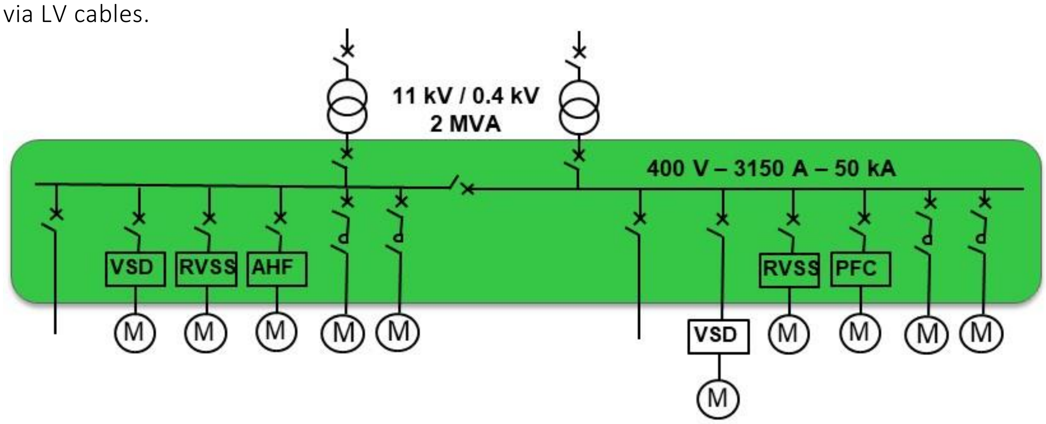


Figure 7 shows Schneider Electric Blokset, a typical IEC LV PMCC switchboard.

Figure 7

Schneider Electric Blokset LV PMCC panel

Table 14 summarizes the Blokset electrical ratings and construction features.

Table 14

Blokset LV PMCC main characteristics

Equipment Ratings	
Un	380 V, 400 V, 480 V, 690 V
Ui / Uimp	1000 V / 12 kV
Degree of pollution	3
Rated Isc	50 kA, 65 kA, 100 kA
Main busbar In	Up to 7000 A
Vertical busbar	Up to 2100 A
Degree of protection	IP20, IP31, IP42, IP54
Form of separation	2b, 3b, 4a, 4b
Withdrawability	FFF/WFD/WFW/WWW
PCC Fu	Incomer & feeder up to 6300 A
MCC Fu	DOL feeder up to 250 kW, VSD up to 160 kW
Cabling	Front or rear access, top or bottom entry
Arc Resistance	100 kA, 400 ms, IEC 61641 class C

A complete PMCC assembly is made of different types of columns, fitted with power cable and auxiliary wiring compartments. Each column can accept different type of LV devices arranged in standard drawers according to their function. Figure 8 shows the different types of LV motor feeder drawers available in Blokset.

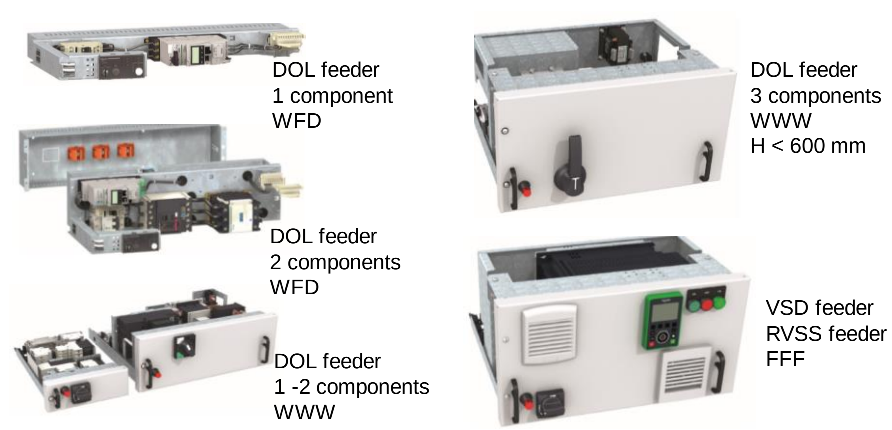


Figure 8

Different types of LV motor feeder drawers available in Blokset PMCC

The LV devices integrated in Blokset include:

- Masterpact ACB used for incomers and bus section
- Compact NSX MCCB used for power feeders
- Fully integrated DOL Motor Starter (Tesys U)
- Motor circuit breakers (Tesys GV2, GV3, GV4, GV5 and GV6)
- Contactors of different ratings (Tesys D and F)
- Motor relays (Tesys LR9, LRD) and Intelligent Protection Relay (Tesys T)

Blokset FUs also integrate motor feeders with VSD and RVSS.

Blokset PMCC design has a high level of operator safety, with the following features:

- Form 4b separation and « finger safe » IP2X live part protection
- Withdrawable unit fully interlocked to avoid on load disconnection
- Intuitive operation to minimize operator error
- Drawer padlocks in every operating position (ON, TEST, OFF)
- Internal arc resistant (Class C) up to 100 kA @ 415V, 0.4 sec
- Arcing energy reduction using VAMP optical arc detection system (optional)

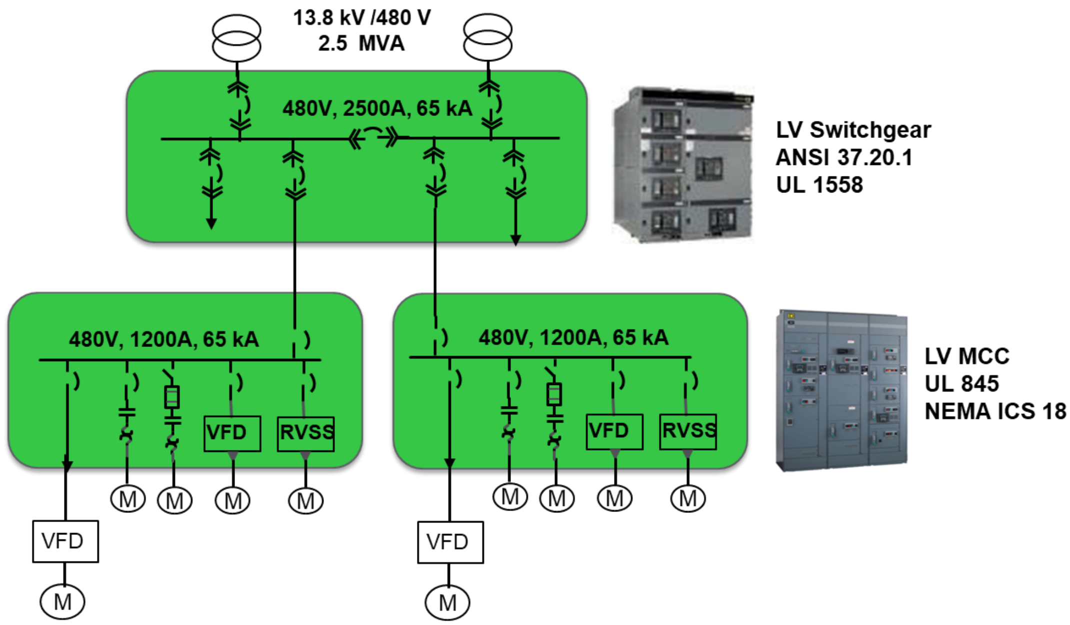
North American LV equipment

Figure 9 shows a typical North American LV network architecture with main-tie-main power supply. The MV/LV transformer typical rating is 13.8 kV/ 480V, 2.5 MVA. The transformer secondary feeds an ANSI/IEEE C37.20.1 LV metal-enclosed switchgear with draw-out ACBs, typically rated 480 V, 3000 A and 85 kA.

This switchgear feeds several NEMA ICS18/UL 845 MCCs with typical ratings 480 V, 1200 A and 65 kA. They are connected by LV cables, either directly to the MCC busbar or sometimes via an MCCB incomer. VSDs controlling motors > 50 kW are usually connected in a separate wall mounted or free-standing panel connected to the MCC via LV cables.

Figure 9

Typical US LV network configuration with ANSI LV switchgear and NEMA LV MCC



ANSI/IEEE C37.20.1 LV Metal-Enclosed Switchgear

Figure 10 shows Schneider Electric PowerZone 4, a typical ANSI Metal Enclosed LV switchgear panel architecture.
Power Zone 4 is fully compliant with ANSI/IEEE C37.20.1 standard and UL 1558 listed. It integrates Masterpact ACB range, which complies with ANSI/IEEE C37.13 and UL 1066. PowerZone 4 panel architecture allows to stack up to 4 Masterpact ACBs in one column.

Figure 10

PowerZone 4 Metal-Enclosed LV switchgear panel

The main electrical ratings are summarized in Table 15.

Table 15

PowerZone 4 electrical ratings and technical characteristics

Equipment Ratings	
Un	380 V, 400 V, 480 V, 600 V
Network type	3 ph/3 wire, 3 ph/4 wire
Rated Isc	42 kA, 65 kA, 85 kA, 200 kA @480 V
Main busbar In	1200 A, 2000 A, 3000 A, 4000 A, 5000 A, 6000 A
Vertical busbar In	800 A, 1200 A, 2000 A
Compartment	ACB, Busbar, Cable termination with metallic partition
Enclosure	NEMA Type 1
Power Cables	Rear access, top or bottom entry
Control cables	Front access
Arc Resistance	Available with ArcBlok technology

PowerZone 4 provides a high level of operator safety including features such as:

- Arc resistance in accordance with ANSI C37.20.7 Type 2B
- Insulated busbars
- ACB remote racking
- Automatic shutter mechanisms
- Instantaneous trip “maintenance setting” for arc flash energy reduction
- Comprehensive range of padlocks and key interlocks.

UL 845 LV Motor Control Center

Figure 11 shows Schneider Electric Model 6, a typical LV MCC compliant with NEMA ICS 18 and UL 845 standard.

Figure 11

Model 6 UL 845 LV MCC panel (arc resistant version)

The main electrical ratings are summarized in Table 16.

Table 16

Model 6 MCC main electrical characteristics

Equipment Ratings	
Un	380 V, 400 V, 480 V, 600 V
Network type	3 ph/3 wire, 3 ph/4 wire
Rated Isc	42 kA, 65 kA, 85 kA, 100 kA
Main busbar In	600 A, 1200 A, 2000 A, 2500 A, 3200 A
Vertical busbar In	300 A, 600 A, 1200 A
Enclosure	NEMA Type 1, 1A, 12 and 3R
Power Cables	Font access, top or bottom entry
Arc Resistance	Optional 65 kA – 100 ms @ 600 V

The components used to configure the DOL motor starter standard NEMA sizes are mainly the same IEC components that have been tested and certified to be listed under UL standard. Motor starters in Model 6 MCC include:

- NEMA Type A-D Combination DOL Starters
- NEMA Type F self-protected and coordinated DOL starters
- Intelligent Motor Starter based on Tesys T IMPR
- VSD and RVSS motor feeders.

Model 6 provides a high level of operator safety including optional features such as:

- Arc resistance in accordance with ANSI C37.20.7 Type 2A
- Closed door racking to disengage bucket from busbar before opening door
- Absence of Voltage Test to check de-energized circuit before opening panel door
- Automatic Bus Shutter to minimize risk of accidental contact with live busbar
- Instantaneous trip "maintenance setting" for arc flash energy reduction
- Comprehensive range of padlocks and key interlocks.

Model 6 MCC can also be configured in a "Main-Tie-Main" configuration (2 incomers and bus section in IEC terminology) illustrated in Figure 12. The panel integrates Masterpact ACBs up to 3200 A with a maximum rating of 100 kA @ 480V and 85kA @ 600V. The main benefit is lower footprint compared to the classic configuration.

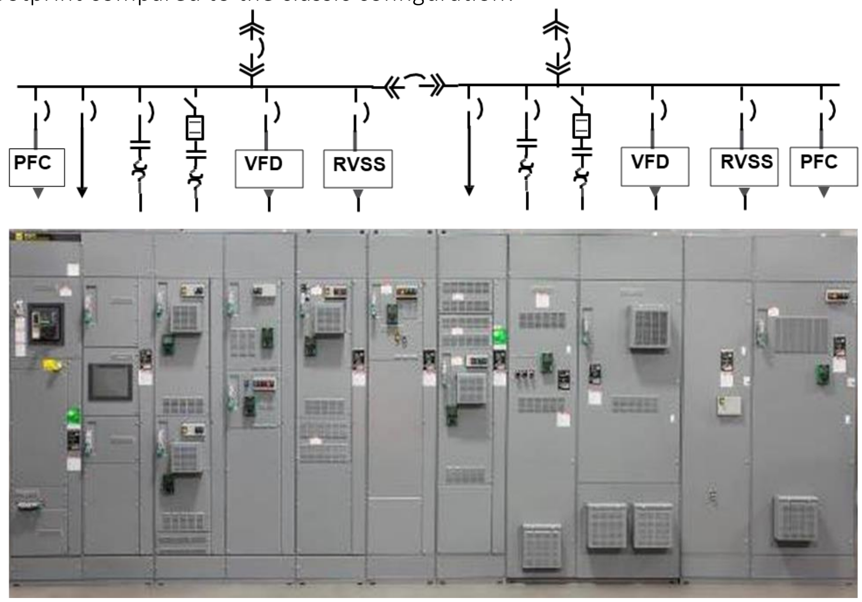


Figure 12

Model 6 Main-Tie Main panel configuration integrating Masterpact ACBs

Case Study

The example described hereafter comes from an open pit mining site located in South America. The main characteristics of the LV MCCs are indicated in table 17.

Table 17

Comparison of IEC and ANSI/NEMA equipment

Equipment Ratings	
Un	400 V
Rated Isc	65 kA
Main busbar In	2000 A
Enclosure	NEMA Type 12 – IEC IP 54
Power Cables	Font access
Incomer	2000 A
Power Feeder	2 x 60 A – 2 x 150 A – 2 x 250 A – 1 x 400 A
DOL Feeder	10 x 7.5 kW (10 hp) – 5 x 18.5 kW (25 hp) 4 x 37 kW (50 hp) – 1 x 75 kW (100 hp)
VSD Feeder	2 x 22 kW (30 hp)
Arc Resistance	Y

IEC 61439 LV Power Motor Control Center Equipment

The recommended Schneider Electric LV PMCC switchboard is Blokset. The general arrangement of the switchboard is shown in figure 13.
The components used in the switchboard FUs are:

- **Incomer:** MasterPact MTZ ACB - Micrologic 6.0 X with Ethernet interface
- **Power feeder:** Compact NSX MCCB with Micrologic 5/6E
- **DOL motor feeder**: TeSys GV or Compact NSX MCCB, TeSys D contactor and motor protection relay TeSys T, all-in-one starter TeSys U
- **VSD feeders**: Compact NSX MCCB, ATV 600/900

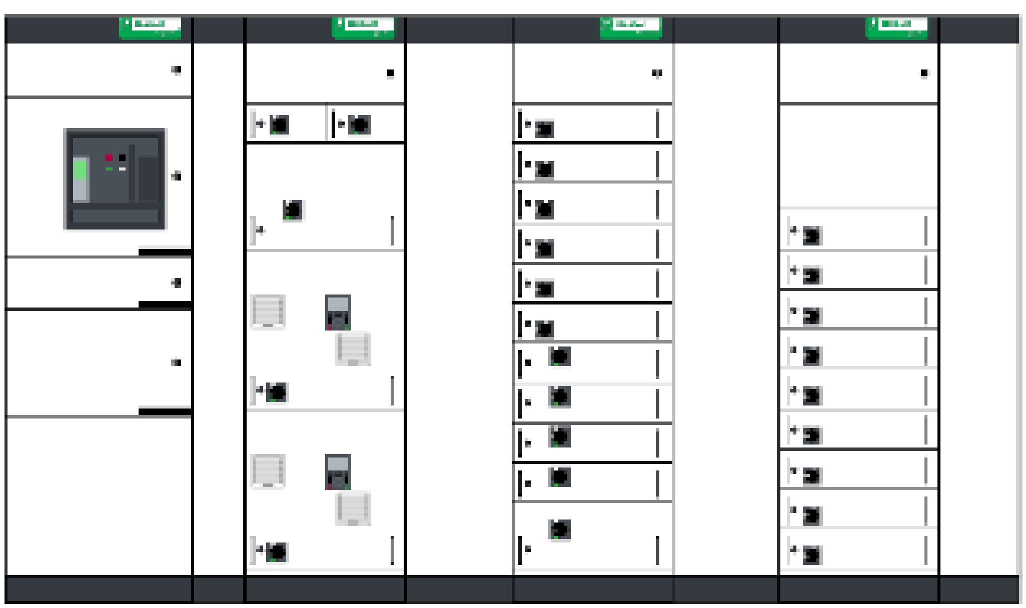


Figure 13

Blokset LV PMCC panel

UL 845 LV Motor Control Center

The recommended Schneider Electric LV MCC is Model 6. The general arrangement of the MCC is shown in figure 14.
The components used in the switchboard are:

- **Incomer:** MasterPact ACB - Micrologic 6.0 X with Ethernet interface
- **Power feeder:** PowerPact MCCB
- **DOL motor feeder**: PowerPact MCCB, TeSys D contactor and TeSys T relay
- **VSD feeders**: PowerPact MCCB and ATV 600/900

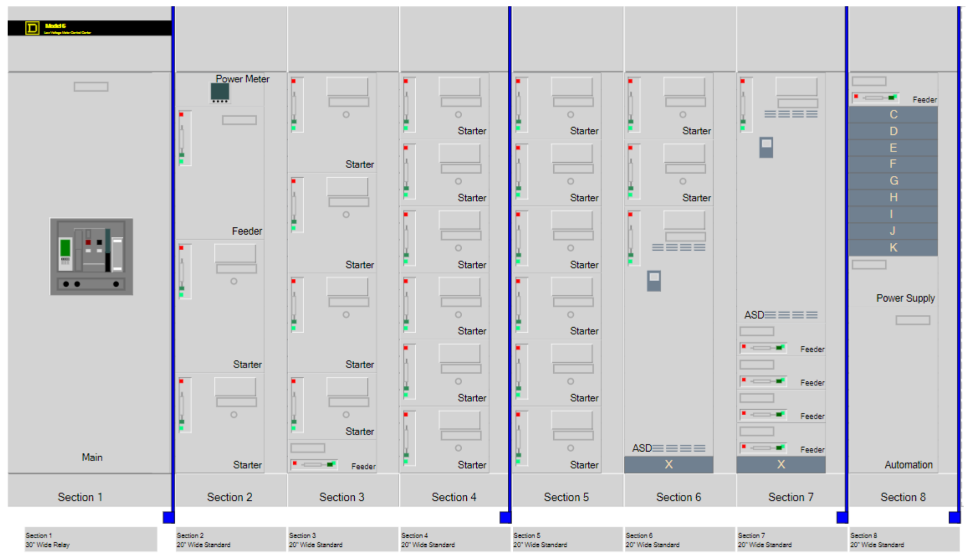


Figure 14

Model 6 MCC panel

Table 18**Error! Reference source not found.** shows the dimensions and relative cost of the two solutions. As indicated, the footprint and the cost are relatively similar.

Table 18

Comparison of IEC and ANSI/NEMA equipment

Equipment Type	IEC	ANSI/NEMA
Schneider Electric Range	**Blokset**	**Model 6**
Total Width	3.8 m	4.3 m
Total Depth	0.6 m	0.508 m
Height	2.2 m	2.286 m
Footprint	2.28 m2	2.18 m2
Cost	100 %	110 %

Conclusion

The choice of LV switchgear is critical for the operation of mining operations as any failure results in major production losses. The choice of standard, either IEC or ANSI/NEMA, has an impact on total LV installation cost, including the E-Houses.

LV MCC can be specified according to IEC 61439-1&2 or UL 845 standards. Both equipment types are well adapted to mining applications and provide high level of operator safety. Any comparative analysis between both offers should be based on customer values which can vary widely between end-user, EPCs, panel builders and installers. Mining end-users could consider the following values in their decision:

- Operator's competency, established habits and level of operational safety
- Installation cost, including LV switchgear, E-house and cabling
- Cost of ownership, including maintenance and spare parts availability.

Schneider Electric has one of the most complete LV 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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Glossary

ACB	Air Circuit Breaker
ANSI	American National Standards Association
CAPEX	Capital Expenditure
CSA	Canadian Standards Association
DOL	Direct on Line
EPC	Engineering Procurement Contractor
FU	Functional Unit
HV	High Voltage (Un > 52 kV)
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronic Engineers
IMPR	Intelligent Motor Protection Relay
LV	Low Voltage (Un < 1 kV)
MCC	Motor control Center
MCCB	Molded Case Circuit Breaker
MV	Medium Voltage (1 kV < Un < 52 kV)
NEC	National electrical Code
NEMA	National Electrical Manufacturers Association
OPEX	Operational Expenditure
PFC	Power Factor Correction
RVSS	Reduced Voltage Soft Starter
SCADA	Supervisory Control and Data Acquisition
TCO	Total Cost of Ownership (CAPEX + OPEX)
UL	Underwriters Laboratories
VSD	Variable Speed Drive

Resources

Electrical installation guide Schneider Electric
https://www.electrical-installation.org/enwiki/Main_Page

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Mining Power Systems Competency Center-
White Paper 06–Power Factor Correction and Harmonic Mitigation in Mining Power Systems

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

Appendix A Standards Organization

In the world, there are two prevailing standards bodies for electrical technologies: The International Electrotechnical Commission (IEC) and the American National Standards.

IEC Standards

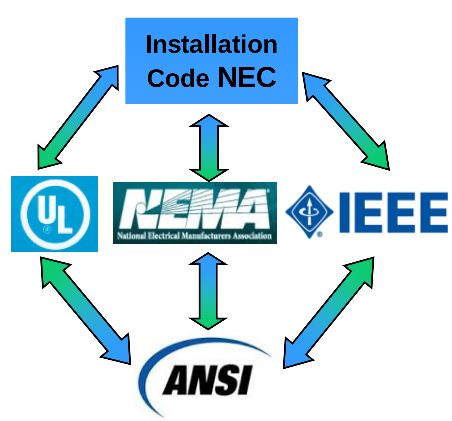
The philosophy of IEC standards is to define electrical, mechanical and environmental performance that have to be demonstrated by test by the manufacturers. This gives designers freedom to innovate by bringing new technologies and materials, while at the same time reducing cost. The end-user needs a certain level of competency to be able to select the right product for its application form the wide offer available. Manufacturers can self-certify many of the claimed performances. Furthermore, the MV and LV equipment is often designed by one of the global companies and manufactured by panel builder partners.

North American Standards

In the USA, the main standards bodies are American National Standard Institute (ANSI). National Electrical Manufacturers Association (NEMA), Institute of Electrical and Electronics Engineers (IEEE) and Underwriters Laboratory (UL). All these standards bodies issue interact between them. Canadian Standards Association (CSA) issues its own standards which are similar to ANSI/NEMA/IEEE/UL. The rest of the world uses International Electrotechnical Commission (IEC) standards.
North American standards (ANSI/NEMA/IEEE/UL and CSA) are very prescriptive and do not allow designers freedom of choice of equipment architecture, dimensions and materials.

Relationships between Standardization Bodies in USA
US standards are legal documents covering design, construction, and certification of electrical equipment to ensure people safety according to the National Electrical Code (NEC)
The US standards are written by three different bodies:

- Institute of Electrical & Electronic Engineers (IEEE): experts from end-users, consultants, manufacturers and universities
- National Electrical Manufacturers Association (NEMA): experts from equipment manufactures that are members of NEMA, dealing with MV and LV MCC enclosures, devices and wiring
- Underwriters Laboratories (UL): writes standards for equipment testing, provides third party certification, issues list of approved products and follows up manufacturing to ensure compliance
- American National Standard Institute (ANSI): accepts proposals from IEEE, NEMA and UL to be adopted as national standard and represents the USA in the IEC



Appendix B Enclosure NEMA type vs IEC IP Code

Enclosure Types

IEC 60529 defines degree of protection against ingress of solid objects and water using the 2 figures IP code.
NEMA 250 defines construction detail and materials. Table xx gives an equivalent IP rating for the most common NEMA enclosures. This table is indicative, only for comparison purposes.

NEMA Enclosure Type Per NEMA 250 standard	Nearest IEC Equivalent Per IEC 60529 standard
NEMA 1 General purpose protection of people from live part protection against falling dirt Test: 1/8" to 1/2" (3.175 - 12.7mm) rod empty test and rust resistance test	IP10 protected against solid objects greater than 50mm Test: 50mm rod entry test No rust resistance test
NEMA 12 Dust-tight and drip-tight Test: drip, dust, gaskets and rust resistance tests	IP52 Dust protected and protected against dripping water Test: dust and rain simulator rests No rust resistance test
NEMA 3R Rainproof and sleet resistant Test: rod entry 1/8-1/4 (3.175-6.35mm) rain, external icing, gaskets and rust resistance tests	IP14 Protected against solid objects greater than 50 mm. Protected against splashing water Test: 50 mm rod and oscillating sprinkler tests. No rust resistance or icing test
NEMA 4X Watertight, dust tight and corrosion resistant Test: hose down, corrosion resistance, gaskets and external icing tests	IP56 Dust protected. Protected against water jets Test: dust and spray nozzle tests. No rust resistance or external icing test

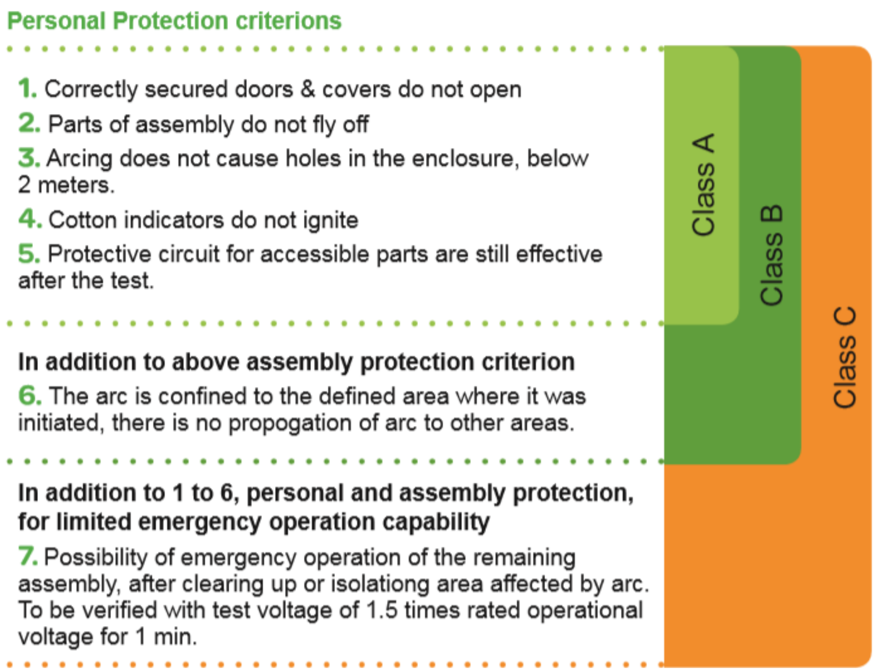
Appendix C Internal Arc Withstand

IEC TR 61641 - Guide for testing under Internal Arc conditions

Test guidelines and criteria to pass are given in IEC Technical Report (TR) 61641, which defines:

• Electrical parameters: arcing current (kA), arcing time (ms) and voltage (V)
• Test conditions: arc initiation by fuse-wire, laboratory set-up (e.g. distance to indicators)

Under specified arcing conditions, switchboard must fulfill following seven acceptance criteria to receive agreement for internal arc.



Arc Flash protection with Vamp system

The Vamp arc protection units detects an arc flash in an installation and trips the feeding breaker. Arc flash protection maximizes personnel safety and minimizes material damage to the installation in the most hazardous power system fault situation.