PowerIT MV Air Insulated Motor Control
Featuring Advance™ and SafeGear® Technology
From the generating station switchyard to the residential meter on the home, ABB Inc. provides customers superior quality and reliability in its products, services and systems.

As a single-source supplier, ABB is the largest and most complete supplier of power transmission and distribution equipment and systems in the world. We make the substations, power lines, cables, transformers, network control systems, metering systems and other systems and equipment our customers use to transport electricity efficiently. We strive for operational excellence, lowest cost manufacturing and short cycle times.

ABB’s ability to integrate hardware and software for operational efficiency and data acquisition enables customers to fully optimize their power systems. Whether you need data on power quality, system operating conditions, usage patterns, cost, or pricing, ABB delivers the information you need.

Our aftermarket services are at the core of our philosophy for maintaining strong, lasting business alliances. Ongoing, expert service on installed equipment, as well as continuing support for equipment upgrades and replacement, are key benefits of our service structure. ABB has also launched a unique service and retrofit program that goes beyond conventional service concepts to include network planning, financial and environmental engineering and personnel training.

As a leader in research, development and innovation, ABB has the capability to provide the full scope of products, systems and services that help you meet the energy demands of today and the challenges of tomorrow — whether you are buying, selling or using power. You can always count on ABB.
Electrical power is the lifeblood of any production plant. No other resource affects the bottom line like the availability of reliable power. ABB provides the complete range of engineering expertise to optimize this valuable resource. With pride, we present SafeGear® and Advance™ Medium Voltage Motor Control Centers, an innovation in power distribution from ABB.

ABB’s SafeGear and Advance Medium Voltage Motor Control Centers enhance the link in the electrical power distribution chain. Combining innovative design with field-proven components, SafeGear and Advance Motor Control Centers offer safe, cost-effective and innovative solutions to powering medium voltage motors.

We support our customers and products with local partnerships that are backed with the talent, technology and finance of a global leader. This is yet another example of ABB achieving its mission to contribute to the success of our customers.
TECHNOLOGY REVIEW

A review of relevant electrical power distribution fundamentals and technologies; discussion of common challenges faced when designing and operating a distribution system such as faults in power systems and power quality; and advice from experts at ABB on handling these challenges. This chapter is concluded with a discussion of arc resistant technologies emerging in the ANSI market.

PRODUCT DESCRIPTION

A detailed description of SafeGear® and Advance™ Medium Voltage Motor Control Centers (MVMCC) with pictures and illustrations. This section describes the specific features, functions and benefits of the newly designed conventional and arc resistant motor control.

TECHNICAL SPECIFICATIONS

Specification text describing standards, options and choices for engineering SafeGear and Advance MVMCC. Outline drawings and general arrangements, electrical drawings and tables provide detailed information for you to create your own design and specification.
**Technology Review**

**Introduction**
Power distribution systems are designed based on the following fundamental principles: maximum safety, maximum system reliability, maximum flexibility, maximum power efficiency, maximum power quality, and minimum cost of operation and maintenance.

**Safety**
Safety of personnel operating and installing equipment is the primary objective of any electrical power installation. In any new installation or modification of an existing system, maximized safety of the personnel has to be considered. Electrical equipment can have a direct impact on humans or can affect the structures and facilities surrounding or in contact with the electrical equipment. It can indirectly cause a safety hazard. All these safety factors have to be addressed when designing and installing electrical equipment.

**Reliability**
A reliable system will provide a continuing, uninterrupted electrical service when needed by the load. Distribution system reliability is directly related to cost, so careful consideration has to be given to what reliability is required for a given load. More reliable systems require more elaborate solutions. The judgment has to be made as to how reliable the distribution system has to be. The maximum attainable reliability also depends on the reliability of the primary feeder or incoming power line. A distribution system cannot be more reliable than its incoming power sources. Reliability also relates to power quality.

**Flexibility**
The design of the system should take into consideration possibilities for future expansion or modifications. The nature of the load, changes in its physical location, and diminished or increased load demand all have to be expected. In cases of system expansion or modernization, compatibility with existing equipment and the degree to which changes have to be made at the interface of new and old systems should also be considered.

**Power Efficiency**
A small quantity of power is always lost in the process of power distribution. Heat generated by current flowing in the bus-bars, through connections, contacts, interrupters, current transformers or fuses, can be sufficiently high to be considered. Typically more
efficient, low loss equipment is more expensive so the system
designers and owners have to make an engineering choice about
how the initial higher cost correlates to the increased savings during
the expected lifetime of the equipment.

Power Quality

Today much attention is focused on quality of electric power. The
majority of power quality problems originate from the distribution
system. Transmission systems are relatively free of power pollution.
The choice of a power distribution solution depends on the power
quality required by the loads.

Cost

Minimum cost is often the most important objective of the system
designers and owners. There are three parts to consider in the
overall lifetime cost of the distribution system: initial investment,
maintenance and operating cost.

Initial investment is related to design and engineering costs, cost of
electrical equipment needed (contactors, CBs, CTs), as well as
installation, testing and commissioning costs. Additional special user
requirements for floor space or climate control equipment, for
example, also affect the cost.

The maintenance costs are associated with periodic inspections and
testing. Service costs are related to lubrication, contact inspections
and refurbishment. The operating costs are usually inversely
proportional to efficiency of the system.

There is a relationship between these three cost components. With
higher initial system costs, maintenance and operating costs tend to
be lower. An engineering economic analysis is strongly recom-
manded to evaluate the total cost of ownership of the equipment
over its expected operating life. Equipment with the lowest total
lifetime cost is the optimum solution.

Maintenance

Maintenance can not only be costly, but can also affect the system
due to disruptions to factory processes and nuisances for the users
of electric power. Cost of lost revenue, in most cases, exceeds the
cost of operations and maintenance of the electrical system. Con-
sider all these factors in the overall selection of the final solution.

Today the trend of the power industry is to minimize the mainte-
nance or even provide maintenance-free equipment. Technologies
such as vacuum switching require lower maintenance compared
with older solutions.
Vacuum interrupters have been in commercial use since the late 1950s. The significant advantages of switching with vacuum interrupters—extremely high switching rate, virtually no maintenance, and long lifetime—were immediately apparent. Today, cost-effective vacuum interrupters cover the application range of 600 V to 38 kV and interrupting currents from hundreds of Amperes to 80 kA.

This figure illustrates the design of a typical vacuum interrupter, sometimes called a vacuum bottle.

The two interrupter contacts are immersed in a vacuum-tight, sealed envelope typically made of ceramic or glass. Depending on the voltage rating, the enclosure can be made of either one or two ceramic cylinders (6). Flexible bellows (9) provide a means for mechanical movement of the contact stem (2) within the vacuum. The contacts are surrounded by a vapor shield (4), made of a stainless steel, copper or FeNi to protect the inside of the ceramic from arc metal vapor and preserve the dielectric integrity between the two ends of the switch. A metallic collar between the two ceramic cylinders (6) serves as a seal and as support for the vapor shield (4). The contacts are typically made out of two components. The mechanical strength and means for controlling the arc are
provided by copper elements (3). Special, OFHC (oxygen free, high conductivity) copper is used for vacuum interrupter manufacturing. For higher interrupting current ratings, the contact subsystems (3) can have special geometrical arrangements to generate magnetic fields to control arcing during the arcing phase and to assist the arc interruption at current zero. The contact surfaces (8) are made from a number of specially designed materials, such as CuCr (Copper Chromium), CuBi (Copper Bismuth), AgWC (Silver Tungsten Carbide) to optimize the switching performance, contact life and interrupting ratings.

In the closed position, current flows freely between moving and fixed contacts. When the moving contact is separated from the fixed contact under current, an arc is drawn. The arc vaporizes a small quantity of the metal from the surface contact. Typically the arc voltage is independent of the flowing current and is only of the order of several volts. Therefore the arc energy is very small (product of arc voltage, arc current and time) which allows the vacuum interrupters to be compact and have long life.

When the main power frequency current approaches zero, the arc products (plasma) quickly diffuse due to the ambient vacuum. The recovery of dielectric strength between contacts is very fast. A typical contactor regains its full dielectric strength in a few to several microseconds. It is also significant that in most cases the current can be interrupted in vacuum even when the contact gap is not fully open at the instant of current zero. Even a partial gap, less than a millimeter, can interrupt full current. This makes vacuum contactors fast devices, limited in the interrupting time only by the mechanical drive. Because the contacts are lightweight, the mechanical drive energy required by the vacuum interrupter is low compared to other switching technologies.
Vacuum Contactors

Vacuum contactors are rated to perform a very high number of switching operations before the unit requires maintenance, typically 1-5 million. Durable vacuum interrupter bottles and a simple, solenoid-type driving mechanism allow frequent contactor switching operations with virtually no wear and tear.

Since vacuum contactors are not designed for interrupting currents higher than a few kiloamperes, a fuse in series is required to protect the distribution system against faults. In the figure below three power fuses and the contactor are mounted on a common truck to provide a withdrawable arrangement.

A contactor requires a holding current in the solenoid coil to keep it in the closed position. Although the holding current is often quite small, customers are sometimes concerned that the contactor will open during a brief control power outage. Some designs incorporate mechanical latches to keep the contactors in a closed position. However, these latches do not perform all the functions of conventional circuit breakers. A latched vacuum contactor is not a circuit breaker in terms of functionality or in terms of its rating. However, properly utilized it can provide long service and trouble-free operation.
Ride-through capability is another solution for momentary outages of control voltage. A special electronic circuitry provides this short-term ride-through capability to a contactor by maintaining the control voltage at the minimum coil-holding level during momentary sags and voltage dips or a complete voltage dropout of 270 ms of the control voltage. This circuitry improves the performance of a contactor in distribution systems where power quality is a concern.

There are two kinds of power fuses: standard (general purpose) and current limiting fuses. Ratings of standard fuses depend on (1) the normal continuous current and (2) the time it takes for the fuses to respond to the different magnitude of overcurrent. Fusable links, the principle elements of every fuse, can have different lengths and thickness and can be made of different metals or alloys. The interrupting medium of a fuse also influences its operating characteristics. This characteristic of the standard fuse is an inversely proportional time-overcurrent curve, as shown schematically in the figure.

Proper selection of a fuse for an induction motor is very important. An improperly selected fuse can permanently damage the motor and other equipment in the system. Both starting inrush and normal load currents have to be considered.
The function of a current limiting (CL) fuse is to suppress the fault current before it can reach the maximum value. Since in ac power systems the current can peak in a few milliseconds (4.16-8.66 ms for 60 Hz and 5-10 ms for 50 Hz), the CL fuse has to react very quickly to limit this peak. Typically this is accomplished by designing a device that can rapidly develop a voltage higher than the power system source voltage thus providing a reverse net voltage. Since the fault current has an inductive nature in every power system, the developing fault current will actually change from rising to falling if the net voltage changes polarity as indicated in the figure.

Some special devices incorporate a CL fuse, others use bypass devices as well as electronic sensing, logic and control. These “intelligent” devices have a group of characteristics adjustable to more specific customer needs and can perform a variety of different protective functions. Increased price has to be considered in the design process in comparison to increased functionality.
Faults in Power Systems

Different kinds of faults occur in power systems: three-phase, single-phase, single-phase to ground, phase-to-phase, phase-to-phase to ground. The most severe fault is the three-phase fault. If the system is close to balance (i.e., all three phases are almost the same), the calculations of three-phase faults can be done based on a single-phase equivalent.

Fault current results from a number of simultaneous voltage sources in the system. These sources can be either equivalent voltage sources behind the power system (transformers, feeders, incoming power lines) or the electromotive forces (EMF) of spinning magnetic fields inside running motors. The example in the figure below shows three components of the fault current at point F.

Fault in a distribution system with two running motors

Currents $I_1$ and $I_2$ can be calculated assuming that a sudden fault current from the motor is equal to 4-8 times the normal, full load current, approximately the same as the inrush current, $I_{1(2)} = 4-8 \times I_{load M1 \text{ or } M2}$. Current $I_3$ is determined from the impedance of the supply transformer ($Z_{tr}$) and the available fault current upstream from the transformer. If the available fault current upstream is $I_{SYS}$ and the transformer ratio is $N$, current $I_3$ is equal to

\[
I_3 = \frac{1}{Z_{tr}} \left( \frac{V_{LV}}{I_{SYS} \cdot N} + \frac{1}{I_{SYS}} \right) \quad \text{(in actual units)}
\]

\[
I_3 = \frac{1}{Z_{tr} + \frac{1}{I_{SYS}}} \quad \text{(in per unit)}
\]
Example

Transformer: 13.8 kV / 4.16 kV, 5%, 1000 kVA

System fault current on the high voltage side of the transformer: 10,000 A

Motor 1: 500 kVA, 4.16 kV

Motor 2: 100 kVA, 4.16 kV

I₃ calculation in per unit (pu) values:

\[ I₃ = \frac{1}{0.05 \text{ pu} + 1/240 \text{ pu}} = 18.45 \text{ pu} \quad \text{(or 2561 A)} \]

Assuming \( I_{sys} = \text{infinity} \)
\[ I₃ = \frac{1}{0.05} = 20 \text{ pu} \quad \text{(or 2776 A)} \]

Note that in typical systems the fault current I₃ is primarily dependent on the impedance of the transformer, i.e., the fault current upstream of the transformer is infinite. Such calculation will be more conservative and will provide an extra security margin for selection of the downstream equipment.

Motor contributions to the fault:
\[ I₁ = 6 \times 69.4 \text{ A} = 416 \text{ A} \]
\[ I₂ = 6 \times 13.9 \text{ A} = 83 \text{ A} \]

Total fault current:
\[ I_F = I₁ + I₂ + I₃ = 3060 \text{ A} \]

Effects of Faults

Faults can have severe impact on power system operations. The most important effects of faults are:

- Direct damage to the equipment (transformers, cables, circuit breakers and motors).
- Loss of power service. Depending on system configuration and fault location, one feeder or the entire system can lose power.
- Safety hazard to humans. By nature faults are unplanned and uncontrolled events. Faults are often accompanied by arcing that releases high energy. Potential burning, fire, and injuries can result.
- Voltage dips or sags. Faults can be viewed as power quality problems. They affect the quality of power and can cause flicker, momentary interruptions and/or equipment malfunctioning.

The first three aspects of faults are well-known. Recently the power quality issues have also been recognized.
Power Quality

Power quality is an important consideration in designing any power system. Distribution systems are especially vulnerable to power quality problems. These problems should be taken into account when selecting and purchasing the equipment. Power quality issues are perhaps more pronounced in the USA (ANSI market) than in Europe (IEC market) because of the differences between the two systems, namely, distances for power delivery, density of loads, and customer concentrations.

Power quality problems can be summarized as:

- Voltage sags and dips
- Momentary interruptions (flicker)
- Harmonics (harmonic current and/or harmonic voltages)

Voltage Sags

Voltage sags and dips are associated with switching or fault events in the power system that cause the voltages on adjacent or neighboring circuits to partially collapse. These events can last anywhere from a few milliseconds up to a second or more.

Momentary Interruptions

Momentary interruptions correspond to the same type of power system events, like switching or faults, but can also be caused by lightning and other transients. The most significant difference is that momentary interruptions occur primarily in the circuits directly involved in the event rather than the adjacent circuit. Momentary interruptions are more severe power quality problems than voltage sags and dips.

Harmonics

Harmonics are primarily caused by non-linear loads. The non-linear nature of power equipment causes a perfectly sinusoidal 50/60 Hz voltage waveform to result in currents containing other frequencies. Conversely, a sinusoidal current can cause generation of non-sinusoidal voltages. Non-linear power equipment can include saturated transformers, motors, and generators, but is primarily associated with power electronics. The act of triggering, or switching an SCR, a diode, IGBT, or a GTO in many cases is a non-linear operation. Power electronic devices such as adjustable speed drives (ASD) can sometimes exhibit a high level of harmonics, often more than 100% total harmonic distortion (THD). In case of ASDs this level of harmonics varies with the selected rpm of the motor, and mechanical load on the shaft.

Harmonics are unwanted events in distribution systems. They can cause excessive heating and damage to neutral connections and cables and can saturate distribution transformers. Harmonics may also precipitate from the
original location of the non-linear equipment to other locations like feeders and loads. They also may cause false tripping or malfunctioning of equipment, especially sensitive relays, computer loads, other ASDs and PLCs.

There are a variety of techniques to mitigate and control the level of harmonics and there are industry standards regulating the harmonics (see IEEE 519, Standard Practices and Requirements for Harmonic Control in Electrical Power Systems, or IEC 555/ 1000-3). Possible mitigation procedures include reconfiguring the system, resizing the cables or transformers to include additional loading due to harmonic currents, or installing filters and harmonic blockers. It is important to remember that these measures often work for some but not for all harmonics. Often, a comprehensive study has to be performed to determine the level of harmonic currents, their impact on the power system and possible suppression measures.

Power system studies to determine solutions to these and other power problems are one of our most important services at ABB. An expert staff can help you to solve system problems using a variety of tools and methodologies.

**Transient Recovery Voltage**

Transient Recovery Voltage (TRV) is a voltage that occurs across the contacts of a contactor immediately after the interruption of main frequency current. This voltage results from the system and cannot be avoided. In industrial power circuits, TRV from switching an inductive load (such as a motor) is illustrated on the following page. A typical analytical expression for the inductive load TRV waveform is:

\[
TRV = 1 - e^{-t/\tau} \cos(\omega_n t)
\]

where \(\omega_n = 2\pi f_n\), \(f_n\) is a natural frequency of the circuit, typically in the range between 500 Hz - 20 kHz, \(t\) is time, and \(\tau\) represents the damping of the circuit at high frequencies.

When switching capacitor banks for power factor correction or for harmonic filtering for example, the TRV is different due to a significant electric charge trapped in the capacitor at the time of current interruption. Typical TRV for capacitive load is illustrated on the following page. Analytical expression for a capacitive TRV is

\[
TRV = 1 - \cos \omega t
\]

where \(\omega\) is a power frequency (50/60 Hz).
In the case of resistive loads (power factor equals unity) TRV per se does not appear since there is no transient associated with the transition from ON to OFF state. The voltage across the contactors when switching OFF resistive loads is equal to the normal system voltage, therefore,

\[ TRV = \sin \omega t \]

where \( \omega \) is a main power frequency. Typical TRV for a resistive circuit is shown in the figure below.

If it is determined that the transients generated as a result of the interaction of a switching device in a particular system application are not acceptable, various means of surge protection or suppression can be used. Two factors determine the level of criticality of various surges: (1) magnitude and (2) rate of rise. Motors are sensitive to both the magnitude and the rate of rise of the surge. However, the extent of the potential impact depends on the different designs of motors.
As a rule of thumb, surge protective devices should be mounted as closely as possible to the equipment (motors) being protected. Minimizing stray inductance and stray capacitance of the connections is essential. The right solution for the suppression of surges depends on economics, criticality of the equipment being protected, cost of failure (COF) analysis and the probability of over-voltage occurring in the given system.

**ZnO Arresters**
Zinc-oxide arresters are commonly installed on transformers and motors to suppress the voltage magnitude. ZnO arresters do not modify the rate of rise of the voltage transients.

**Surge Capacitors**
Surge capacitors can reduce the rate of rise of the surge voltages generated in the system but do not directly limit the magnitude of the surge.

**R-C Circuits**
A combination of a resistor (R) and a capacitor (C) in series provides a way to reduce the rate of rise of the transients and at the same time dissipate the transient energy, providing more significant damping for higher frequency components of the surge. R-C circuits however, do not insure limiting the absolute magnitude of the voltage transients to a certain level.

**ZORC**
ZORC is a combination of ZnO arrester with an R-C circuit. The figure below represents one possible connection. This provides the most comprehensive protection system for limiting both voltage magnitude and rate of rise of surge voltages.

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**ZORC Circuit**

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Grounding and Shielding

The most neglected form of surge management for switchgear is grounding and shielding. Frequently surges are created by the interaction between vacuum switchgear and the system. Therefore shielding and grounding against high frequencies may often prove to be sufficient to reduce transients to a safe level.

To date, research concerning grounding practices for surge protection and propagation has not produced consistent conclusions. When subjected to problems concerning vacuum switching transients, application and design engineers often face a dilemma; how, where, and what to ground for best system performance. A common example of the grounding dilemma is shown in the figure below.

From the high frequency point of view, Option C seems to be more effective than Options A and B. However, this introduces a danger of inducing significant circulating currents at 60 Hz due to the ground loop between (1) the cable shield, (2) the ground return path (wherever this might occur— shown in the figure as a dotted line) and (3) the two grounding points. Options A and B change the pattern of the traveling waves resulting from the high frequency transients generated at the breaker end.

System studies may be needed to understand the vacuum switchgear transients as well as to determine the most suitable means for transient prevention and suppression.

Various options for grounding of a shielded cable

A - at the motor entrance

B - at the switchgear

C - at both ends of the cable

VCB - Vacuum Circuit Breaker
IM - Induction Motor
Motor Inrush Current

When an induction motor is energized but the rotor is at rest, a large current will flow. This large current is called motor inrush current or locked-rotor current. By nature the inrush current is similar to a short-circuit current of a transformer where the primary winding corresponds to the stator winding and a shorted secondary winding represents the rotor at rest. Typical values of an inrush current can reach up to 8.0 pu of a full normal rated current. This current is primarily inductive, i.e., of a very low power factor. Under normal operating conditions this inrush current does not represent a problem to motor starters, especially when a reduced voltage technique is used (see sections below on autotransformer or resistor starting).

Voltage Surge

When full voltage starting is used and the starting process is aborted, due to some unforeseen circumstances, interruption of such a large inductive current has a severe effect on a switching device. In rare cases, when the vacuum contactor is opened on inrush current and the instant of contact parting happens to be just before the natural 60 Hz current zero, reignitions inside vacuum interrupters can result. When aborted starts are a concern and the potential interaction between the power circuit and the vacuum contactor is unknown, surge protection is advisable to minimize the possibility of motor insulation damage. Aborted starts also create severe mechanical stresses on the motor windings and the rotor shaft.

Voltage Regulation

Starting large motors can have a significant effect on the power supply system. During starting, the inrush current may cause the system voltage to sag and fall below the minimum allowable limit. The voltage drop caused by the starting motor can create a power quality problem—flicker of lights, for example—and may have serious negative consequences. Voltage drops are directly proportional to the equivalent impedance of the system as measured at the location of the motor. This equivalent system impedance also determines the short-circuit current (such as current I3 in the preceding section on fault calculations). The lower the impedance of the system, the better the voltage regulation and the higher the fault current supplied by the system. Unfortunately, good voltage regulation also increases the available fault current at this location which in turn increases the demand on the switchgear and the total cost of the system. Some compromises have to be reached between performance and cost.

Voltage regulation is defined in percentage as

\[
REGULATION = \frac{V_{\text{NO LOAD}} - V_{\text{FULL LOAD}}}{V_{\text{FULL LOAD}}}
\]
Motor Starting
Motor Starters and Controllers

The four common techniques for starting induction motors are:

- Across-the-line starting
- Autotransformer starting
- Resistor or reactor starting
- Star-delta starting

Each method has advantages and disadvantages which are considered in relation to the cost of the motor controllers.

Across-the-line Starting

Across-the-line starting (full voltage) is the least expensive and the most commonly used method. It involves energizing the squirrel-cage motor with full voltage directly from the feeding power lines. The acceleration characteristic of the induction motor at starting speeds from rest to the rated rpm, however, is not satisfactory. At rest (locked rotor condition), the induction motor draws a high inrush current similar to a transformer with a short-circuited secondary winding. Inrush current can reach 4 to 8 times the full rated current and is primarily dependent on the air gap and the leakage inductance of the windings. In cases of large HP machines this creates voltage dips, can severely disturb operation of other parts of systems and also causes serious power quality problems for both the industrial customer and the electric energy provider.

Autotransformer Starting

Autotransformer starting involves reducing the voltage applied to the motor windings at starting, for a short time, until the motor gains a speed close to its rating. Starting current (inrush) is almost directly proportional to the starting voltage. For example, a 0.5 pu voltage applied to the motor will produce an inrush current equal to half the value of across-the-line starting. The starting torque varies with the square of the current, so in the example just mentioned, the torque would reduce to 0.25 pu of full voltage value. Torque might be insufficient for some mechanical loads that might require higher starting torque. A compromise has to be reached. The following figure shows a simple strategy for selecting the most appropriate voltage to start induction motors.
In this example, a four pole (4 on the first horizontal axis) induction motor (1750 rpm, 60 Hz) has an across-the-line starting inrush current of about 5.2 times the normal full load current at 100% mechanical loading on the shaft (blue arrow pointing to the solid curve labeled 100% M). At this current level the machine also generates a starting torque of ~1.7 pu (blue arrow pointing to the thick-line torque curve). At lower loads the inrush current and starting torques are reduced accordingly (other solid curves).

Autotransformer starting is represented by the dashed curves. Assuming the same machine with the autotransformer set up for 65% rated voltage, the inrush current from the line side is reduced to 2.5 pu (red arrow to 65% L curve). The motor inrush current of ~3.4 pu (magenta arrow to the 65% M curve) corresponds to the starting torque of 0.8 pu.

A sample circuit for the autotransformer starter follows.
To start the motor, contactor S which consists of 5 poles closes first. The two autotransformers, AT1 and AT2, connected in open-delta provide reduced voltage to the motor windings. The closer the winding taps are located to the common point P, the lower the starting voltage. After the motor acquires speed close to the rated value, the contactor R closes and contactor S opens simultaneously.

The advantages of autotransformer starting are low line inrush current, modest cost, and low power consumption from the supply lines. However, autotransformer starting has a distinct “jump” between the starting torque (lower value) and the normal running torque (high value). The mechanical and electrical transient produced by this switching might not be suitable for some loads.

A modified version of the autotransformer starting is known as a Korndorfer circuit where part of the autotransformer windings are used as series reactors for a short time during switching after the S contactor opens and before the R contactor closes. This way the transient from start to run can be reduced.
Resistor or Reactor Starting

The concept of reducing the voltage during the low motor rpm used for resistor starting is similar to that of the autotransformer. Inrush current to the motor creates a voltage drop across the resistor (or reactor) and thus limits the starting transient. Since the resistors are connected in series with the motor, the line current is the same as the motor current. When the motor reaches its rated rpm, the resistors are bypassed. At no time during start-up are the motor terminals de-energized.

Resistor starting is the smoothest way to energize induction motors. Since inrush current during starting decreases with the increasing speed of the rotor, the voltage drop across the resistors decreases, and the motor terminal voltage increases accordingly. The torque also varies smoothly, providing soft starting as indicated by the dashed line in the figure below.

Typical torque and speed relationship at various voltages for an induction motor

Resistor switching is the least expensive method for smaller horsepower motors. For larger sizes, resistors may be considered if the requirements of large power dissipation can be met. Otherwise, reactors should be used. For heavier loads, two steps of resistor switching might be implemented.
Another advantage of the resistor start-up is an improved power factor because resistance improves the equivalent motor circuit that is otherwise inductive. If a series reactor is used instead of the resistor, the power factor at start is very low and the advantage is lost.

If all six leads of the three-phase windings of the motor are accessible, it is possible to start the motor with windings connected in a Wye (star) and reconnected in delta when a certain speed is reached. With a Wye connection a lower voltage per winding is applied \((1/\sqrt{3} \approx 58\%)\). This is therefore another reduced-voltage starter. The inrush current is reduced and the torque is held to lower values, which provides a good starting technique especially for high-inertia, heavy mechanical loads.

The wound-rotor motor operates on the same principle as the induction motor except the rotor is made out of an actual winding rather than short-circuit squirrel-cage bars. Since rotor terminals are accessible from the outside, it is possible to control the level of induction and therefore the motor speed by switching between different values of resistance in the rotor circuit. A typical controller for the wound-rotor motor includes the stator winding and rotor winding contactors (see figure below). Depending on the starting requirements and the mechanical load, one or more switched resistances may be implemented in the rotor circuit. In the figure below, the motor is first energized with the contactor \(R\) closed and contactors \(S1\) and \(S2\) open. Then the \(S1\) contactor closes. When the motor gains more speed, contactor \(S2\) closes completing the start-up process.
Synchronous Motor Starting

Synchronous motors are usually started as wound-rotor induction motors, i.e. with a resistor connected to the field winding. This is similar to the procedure described in the preceding section. In the figure below contactor S and RR are closed. When the motor reaches sufficient speed, close to the rated rpm for a comparable induction motor, contactor S opens and R closes to energize the field winding with dc power. The motor then gains synchronism with the main power frequency.

The R and S contactors are also used when the motor loses its synchronism (out-of-step condition). In such a case, the contactor R opens and contactor S closes, protecting the stator winding from extreme swing currents and possible motor damage. During the out-of-step mode the motor can run as an induction machine. When the swing diminishes, the motor can be resynchronized with S open and R closed.
In recent years Adjustable Speed Drives (ASD), also called Variable Speed Drives (VSD), have gained popularity in power systems. These are power electronic devices capable of inverting ac main frequency power (50/60 Hz) into a variable frequency power. In order to keep the magnetic flux inside the machine within the limits of the motor design at any given frequency of output, most ASDs maintain a constant relationship between the voltage and the frequency, so called “constant volts per hertz” control, i.e.,

\[
\frac{V}{f} = \text{const (magnetic flux)}
\]

The lower the speed, the lower the voltage applied to the motor.

There are three distinct types of ASD design:

- Voltage source inverter
- Current source inverter
- Pulse width modulation (PWM) inverter.

In all three types the principle of operation includes converting the main frequency of the line voltage into dc using power electronics rectifiers, and then inverting the resultant dc into variable frequency ac output. The figure below shows simplified block diagrams of the three drives.

**Three types of adjustable speed drives**

A - Voltage source inverter

B - Current source inverter

C - PWM inverter
The voltage source inverter is based on the fact that a fixed voltage is maintained across a capacitor (C). This voltage is commutated through an inverter to the winding of the machine. The voltage level changes with the different frequencies of the inverter commutation according to the constant volts per hertz principle. The current source inverter uses a large inductance (L) to maintain a fixed current from the rectifier to the inverter.

The PWM inverter uses a principle similar to the voltage source inverter but the commutation circuitry is based on the modulation of the width of the pulse rather than changing the magnitude of the capacitor voltage to synthesize different frequencies to the motor. Refer to the three waveforms in the accompanying block diagrams on page 23.

Sensitive loads such as VSDs or other power electronic driven devices will require cleaner power and thus a more sophisticated power distribution system. However, it is often the case that such sensitive loads also generate harmonics and other 60 Hz wave distortions, such as sags and dips. The higher the power quality requirement, the more sophisticated the distribution system, and thus the higher the cost of the system. As a result, careful balance has to be achieved between the required quality of power and the cost associated with the installation and maintenance of the distribution system.

MCCs can be installed in a variety of different environmental conditions that may vary from installation to installation. ANSI standards define various aspects of normal service conditions for operating indoor electrical equipment. However, these definitions are not exact and allow for interpretation. Typically, usual service conditions exist when:

- Temperature of the air is within -30°C to +40°C
- Altitude of the installation does not exceed 1000 m
- The effect of solar radiation is not significant
- Unusual service conditions do not apply

Definitions of unusual service conditions include exposure to fumes, vapors, steam, excessive humidity and temperature, but do not provide any specific threshold values. It is important to realize that the combination of multiple factors has a different effect on electrical equipment than do individual conditions considered separately.
It is therefore up to the customer and personnel specifying the equipment to recognize and consider all possible environmental effects that the equipment will be exposed to during its operating lifetime.

Moisture condensation and excessive humidity are the most common contributors to equipment problems. It is a good practice to include properly rated and located space heaters to mitigate the moisture problems. ABB strongly recommends space heaters and can assist customers in finding the most efficient and economical solution.

Arc Resistant Switchgear

A Demand for Greater Safety for Personnel and Equipment

In the last several years the issue of safety has been increasingly important. Power systems are becoming more complex. More electrical equipment is being installed in factories as well as rural and urban areas like shopping malls. Consequences from fatal faults and electrical failures are greater than ever. From an economic point of view, the extra cost of special protective clothing for workers or the specification of electrically fail safe switchgear equipment is seen as a good investment that can translate into real savings.

The most common and detrimental fault to switchgear equipment is an internal arc inside the switchgear enclosure. When ignited, this arc is uncontrolled and can burn freely in air or other medium developing extremely high pressure and generating high temperature gases (plasma). In a matter of milliseconds the internal arc releases all available fault energy. Conventional enclosures will rupture under the mechanical stress causing damage to objects in the vicinity.

There are many causes for internal arcing faults inside switchgear. Some of these include improper maintenance, mechanical and interlock failures, gradual component deterioration or insulation breakdown, improper environmental conditions such as excessive moisture, excessive operating voltage beyond maximum rated values and the presence of foreign objects or live animals inside the equipment. The history of incidents shows that improper environmental conditions and the presence of foreign objects and live animals are the most frequent causes of internal arcing faults.
Most of the existing design practices and ANSI standards address many measures to prevent internal arcing faults in electrical equipment. However, they do not fully address the damaging effects and other consequences of internal arcing faults.

Switchgear equipment can be designed to protect against the consequences of internal arcing faults and virtually eliminate exposure of personnel to internal arc faults.

Typically, a free burning arc in air generates ionized plasma at temperatures of 10,000-20,000 K. This plasma generation depends on the energy input to the arc, based on arc current, voltage and duration.

The left graph below shows an example of arc energy released inside a switchgear enclosure during an internal three-phase fault of 40 kA. In less than 10 ms the arc energy can reach 5 MJ and in 60 ms can exceed 20 MJ. The possible pressure build up, inside the switchgear compartment, due to arcing is high. The exact pressure also depends on the dimensions of the enclosure. This amount of thermal energy cannot be contained. In order to provide safe passage for the hot gases to escape, the cubicle compartment can be designed to vent the plasma externally either through the roof or at the back of the switchgear assembly.

The right graph illustrates the calculated pressure developed in a sample MCC enclosure and shows the advantage of arc resistance. The upper curve corresponds to the internal pressure build-up without arc resistance, and the lower curve with arc resistance.
without arc resistant design that will lead to an eventual rupture and destruction of the gear. The lower curve demonstrates safe and successful handling of excessive pressure due to the arc resistant design. In about 5 ms the safety vents in the switchgear operate and safely release the pressure of arc gases and plasma.

Complex gas thermodynamics and the theory of arc plasmas are used to solve the problem of venting the arcing faults safely and reliably. The figure at left illustrates a sample design for a motor controller compartment, providing a pressure vessel with safety flaps that will operate in a precise, controlled manner during internal arcing.

Some of the critical design considerations for an arc resistant assembly include:

• Relative volumes of different compartments: contactor compartments, intermediate venting compartments
• Opening speed of the flaps versus pressure build up during arcing
• Separation of compartments to prevent plasma intrusion into adjacent chambers where required
• Cross-sectioning of exhaust channels to prevent local pressure build up
• Structural strength of walls, doors and partitions to withstand the pressure and temperature rise

In ABB’s continuing effort to improve safety in the workplace and commercial environments, the addition of Arc Resistance for Medium Voltage Motor Control Centers is a significant step. ABB is committed to increase awareness for arc resistant design in power distribution systems and expects demand for this type of product to increase in the near future.
Standards and Testing

IEC 298-1981 is the current international standard describing arc resistant switchgear. CENELEC and EEMAC in Canada have developed similar standards. ANSI C37.20.7 provides a Guide for Testing Metal-Enclosed Switchgear for Internal Arcing Faults.

The ANSI standard provides the following:

• Identifies the problem of arc resistance
• Defines arc resistant switchgear
• Establishes ratings for levels of protection against internal arcing
• Defines test procedures and criteria to verify the ratings of arc resistance
• Suggests design, application, and maintenance of arc resistant switchgear

ABB intends to stay at the forefront in promoting protection for personnel and equipment from internal arc faults. Our most important goal remains as our commitment to customers through the best technology and most complete service.
Medium Voltage Motor Control Center

Product Description

Advance™ Medium Voltage Motor Control Centers (MVMCC) incorporates the newest in metal-enclosed switchgear design. Attributes new and unique to motor control centers optimize their operation and simplify handling and maintenance.

Additionally, the ABB MVMCC design greatly improves maintenance simplicity. The enhancements in this product provide a superior solution for motor control. Advance supports the latest customer requirements for increased worker safety, enhanced reliability and ease of use.
SafeGear® Medium Voltage Motor Control Center is the first product to offer arc resistance. All the design improvements of Advance are included in SafeGear, making this the product with the best protection available today.

Arc resistance protects the operator from harm and limits damage to equipment in the event of an internal arc fault. Arc resistance was developed utilizing decades of ABB experience with medium voltage power systems.


As shown in the figure, type B arc resistance specifies protection from objects or hot gases that might be ejected during an arc fault on all accessible sides of the enclosure. Vents and flaps are located on top of the enclosure to release the pressure.

Arc resistance significantly reduces operator risk during the handling and operation of the equipment. Installation, maintenance and operations personnel recognize the sturdiness and benefit of the design.
Operator safety is a prime concern for ABB development and engineering teams. The design of SafeGear and Advance MVMCC was derived from ABB switchgear. ABB has a long-standing tradition and reputation in the design and manufacture of distribution switchgear equipment.

Safe handling is supported by closed door racking, automatic primary and secondary disconnects and safety interlocking inside the cell. All significant components are mounted on the withdrawable truck simplifying maintenance and handling. The clean design used in the contactor module grants easy access to all parts inside the cell. ABB uses a reliable vacuum contactor, field proven for more than 10 years.

Motor control is available in one-high and two-high design. Indoor and outdoor enclosures as well as placement in power distribution centers allow installation in any environment.

The standardized cubicle sizes and modular design allow for simplified engineering. All units are 30" wide and 95" high, made up of compartment blocks 19", 38", or 57" tall.

All products are UL listed and CSA approved and conform to the appropriate NEMA standards.

ABB offers a comprehensive line of starter types for voltage levels from 2.2 kV to 7.2 kV and contactor ratings at 400 A and 720 A. The main bus can carry from 1200 A up to 3000 A of continuous current.

**Starter types:**

1. Full voltage nonreversible starters for squirrel-cage motors which will also allow switching and protection for transformer and capacitor loads
2. Full voltage nonreversible starters for synchronous motors
3. Reduced voltage starters with autotransformer or reactor for synchronous and squirrel-cage motors
4. Full voltage reversible starters for synchronous and squirrel-cage motors
5. Starters for wound-rotor induction motors

Transition and incoming sections are available for easy connections to ABB's SafeGear or Advance products or any existing switchgear or motor control center lineup.

Well-known A&E firms and clients from the petrochemicals, and oil and gas industries worldwide employ this product because of its ruggedness and simplified design.
The vacuum contactor module is a new design with operator and maintenance personnel in mind. It incorporates distinctive features for ease of installation, operational safety and maintenance simplicity.

**Ratings**

Contactors are rated at 400 A and 720 A and comply with UL 347 temperature rise requirements. Two-high design can be accomplished using 400 A contactors with no derating.

**Unique Racking System**

The racking system is unique and features a two-position, (Connected-Test/Disconnected) closed-door system for all contactors. It also includes a fully automatic secondary disconnect system. The racking system is integral to the contactor. The contactor/enclosure system includes all necessary interlocks to assure proper sequencing and safe operation. For improved safety, the interlocking system prohibits racking while the door is open. The contactor can only be racked into the Connected position with the door closed while maintaining the integrity of arc resistance. The contactor enclosure includes stationary support bushings and primary contacts for engagement with the contactor. Standard padlock provisioning is provided for securing the contactor in place. Additional padlocking provisions available (optional).
**Product Description**

**Toc Actuator**
Optional TOC contacts (Run & Test Service) are actuated by the front of the panel as the contactor moves in and out of the connected position.

**Contactor Grounding**
A stationary ground contact interacts with the ground contact of the controller unit. Ground connection is made prior to coupling of the primary or secondary contacts and is continuous during the racking operation.

**Interference Blocking**
The contactor enclosure has interference blocking to prevent the insertion of improperly rated controllers.
Polycarbonate Shutters

Transparent polycarbonate shutters block access to primary contacts when the controller is in the Test/Disconnected position or withdrawn from the system. Contact stabs can be visually inspected without de-energizing the system. The motion of the withdrawable contactor opens and closes the shutter automatically and does not depend on gravity but a spring return system. Shutters are driven simultaneously from both sides for smooth, balanced operation.

Interlocks prevent accidental opening of the shutters and access to energized contact stabs.

Power Cable Hookup

Two grounded metal ducts allow connection of power cables with top or bottom entry (front access). The system is designed to connect one cable rated at up to 500 mcm per phase (non-shielded, 100% insulated and without stress cones). Multiple cables that do not exceed this dimension may also be used. (Please contact your ABB sales representative for other alternatives for power cable connections.) Higher rated cables can be installed from the top or the bottom in the one-high design. No cable extensions are needed due to the open design of the contactor compartment. Easily accessible cable lugs simplify power cable installation.

Secondary Disconnect System

A single, (25-pin) self-aligning secondary disconnect for control circuitry is provided as a standard feature. This system, which is fully-automatic, reduces the number of steps during contactor insertion thus simplifying the operating procedure. The female portion of the disconnect system is mounted over a slide bar, so the contacts remain engaged to the contactor when racking it out from the Connected to the Test/Disconnected position. Potentially energized control contacts are recessed and remain “touch safe.”
Product Description

Vacuum Contactor Truck Assembly

The vacuum contactor and power fuses are mounted on a fully-withdrawable truck assembly similar to the ADVAC™ circuit breaker used in SafeGear and Advance metal clad switchgear. The truck assembly eliminates the need for an isolation switch thereby reducing the number of moving parts and simplifying the handling. The operation is identical to MV switchgear.

A lifting device latches to the contactor module for simple and safe extraction of the contactor. The height of the tray on the lifting device can be adjusted to fit the compartment height. Maintenance work, such as exchange of fuses, can be conducted with the contactor locked in place on the lifting device.

Other maintenance is simple and safe because all parts requiring service are mounted on the truck for inspection away from energized equipment. These parts include the vacuum bottles, power fuses, the control power transformer and its fuses, auxiliary switches and the ground contact.

The blown fuse indicator on each fuse is visible from the front of the assembly with the contactor in the Test/Disconnect position and with the door open (see technical specifications for more information).
Low Voltage Instrument Module

All protection and control devices are mounted in a dedicated low voltage compartment. Each low voltage instrument module is **completely isolated and segregated** from high voltage compartments. This ensures safety for operations and maintenance personnel while they work on control and auxiliary circuits.

Devices and control switches are mounted on the door for easy readability and convenient access. Those devices that do not require immediate access are mounted inside the compartment.

Main Bus Ratings

Main bus ratings are available in 1200 A, 2000 A and 3000 A.

Bus Bars and Supports

Bus supports and insulation materials are flame-retardant, track-resistant and nonhygroscopic. Bus bars are made of copper and have fully round edges. Connection joints, as well as bus bars, are silver-plated.

Main Bus Access

The main bus compartment can be accessed from the front through the low voltage compartment by unbolting the rear barrier.

Insulated and Isolated Bus Option

Epoxy-insulated bus bars are also available. Bus joints can be covered with reusable boots. These can be removed for field inspection and maintenance.
Materials and Construction

Both SafeGear and Advance MVMCC use 14-gauge precoated Galvalume® material throughout. Galvalume does not require painting due to its superior resistance to corrosion and self-healing characteristics.

Hem bends create a rigid self-supporting structure, reduce sharp edges inside the cubicle and diminish the risk of injury.

The bolted modular design and double-side wall construction allow for easy system extension and maintenance.

Excellent product quality results from the best materials and design (arc resistant door construction shown).

Standardized Frame Sizes

Simplified engineering is possible due to standardized frame sizes. Frame size for one-high and two-high construction is identical. Because of modularity, MCCs can be easily designed and assembled for varied applications.
Product Description

Auxiliary Primary Modules

Potential Transformer

ABB's standard PT modules accommodate industry-leading type VIY-60 kV BIL type potential transformers and can be mounted in a 19" module. Each standard module accepts up to three transformers with line-to-line (L-L) or line-to-ground (L-G) connections. The optional 75 kV BIL type potential transformers accepts up to two transformers and will be mounted in a 38" module. PT's are automatically grounded on withdrawal to discharge residual current.

Accessories

The accessory group for SafeGear and Advance MVMCC and the ABB vacuum contactor includes a complete array of required and optional special tools for proper handling, operation and maintenance. For maximum convenience, all withdrawable assemblies - vacuum contactors, PTs, CPTs, and fuses - use the same accessories.

Required accessories include a racking crank for inserting and removing primary assemblies. A standard 16 mm socket wrench with a swivel adapter can be conveniently used for racking.
Lift Truck

A lift truck is required for all primary devices. The lift truck docks with the MVMCC, allowing a primary device to be raised or lowered to the appropriate height and safely rolled into the compartment. The lift truck has wheels for easy maneuvering in restricted aisle space common to MVMCC installations. A motor lift is available as an option.

All primary devices have self-contained wheels for easy floor rolling.

Test Jumper

A “test jumper” is an extension cord. It allows connection of secondary contacts on a vacuum contactor to the MVMCC while outside a contactor compartment. This enables the contactor to be electrically operated using controls in the MCC, or electrically charged after manual operation of the contactor in a MCC aisle.

Test Cabinet

A “test cabinet” is a wall-mounted control cabinet connected to a separate power source and containing switches to open and close a contactor. The test cabinet has a female connector and an umbilical cord (stored inside the cabinet) for connection to the contactor, and serves as an aid to contactor inspection and maintenance in MCC aisles or work areas.

Ground Device

A Ground device is a drawout assembly compatible with MCC compartments. The Ground device provides a means to selectively ground deenergized primary load circuits to the MCC ground bus to support maintenance activity.

The racking system of the Ground device can then be padlocked or Kirk Key interlocked in the Connected position in accordance with lock-out and tag-out safety procedures.
Medium Voltage Motor Control Center
Technical Specifications

**Introduction**
This specification text describes standard and optional features of ABB’s SafeGear and Advance Medium Voltage Motor Control Centers. All references to arc resistance relate to SafeGear only. All other features are common between the two products.

Tables and drawings detailing electrical and dimensional information are located under the heading Technical Data. Dimensions shown are identical for SafeGear and Advance MVMCC. Some details depict arc resistant construction.

The text below can also be used as a standard design specification for proposal or bid requests by following a simple procedure.

1. Select the applicable paragraph from those marked as “Choice” and erase those that do not apply.
2. Delete undesired paragraphs marked as “Option.”
3. Remove the sidebars: “Choice” or “Option.”

The specification is available in electronic format as a word processing file from our web site [http://www.abb.com/mediumvoltage](http://www.abb.com/mediumvoltage) or from ABB. Please contact your ABB sales representative or the Power Technology Medium Voltage Group at 1-800-929-7947.
Specifications

These specifications cover the general requirements for medium voltage metal-enclosed motor control centers.

The specific requirements are given on data sheets and the one-line diagram(s). In general, when resolving conflicting information, the following order of precedence shall apply:

1. One-line diagram(s)
2. Data sheets
3. This specification
4. Purchase order
5. Other referenced specifications

The medium voltage motor controller shall be of modular construction with one-high and two-high arrangements and include the following design features: a two-position (Connected-Test/Disconnected) closed door racking system; withdrawable and removable contactor with automatic secondary disconnect system; and isolated, segregated low voltage compartment. A separate isolation switch shall not be required. The contactor and enclosure will include all necessary interlocks to assure proper sequencing and safe operation.

MCC design shall be inherently of NEMA 1 (indoor) construction.

MCC design shall be inherently of NEMA 3R (outdoor) construction.

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<thead>
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<th>UL</th>
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<th>High Voltage Industrial Control Equipment</th>
</tr>
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<tbody>
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<td>Requirements for Instrument Transformers</td>
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<td>NEMA</td>
<td>250</td>
<td>Enclosures for Electrical Equipment (1000 Volts Maximum)</td>
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<td>Industrial Control and Systems: General Requirements</td>
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<tr>
<td>EEMAC</td>
<td>G14-1</td>
<td>Procedure for Arc resistant Testing the Resistance of Metal-clad Switchgear Under Conditions of an Internal Fault</td>
</tr>
</tbody>
</table>
Technical Specifications

Arc Resistance (SafeGear only)

The medium voltage motor controller shall be designed to meet the arc resistance Type B testing requirements of EEMAC G14-1 (burn-through test only at 0.5 seconds) or ANSI C37.20.7, Draft 8 to prevent injury to personnel or damage to external equipment in the event of an internal arc fault.

All exterior air circulation vents facing the front, rear or sides of the medium voltage motor controller shall automatically seal closed in the event of an internal arc fault.

Pressure shall be relieved through vents and flaps leading to the roof of the unit.

Materials and Construction

The medium voltage motor controller frame will be of modular construction and fabricated primarily from 14-gauge pre-coated Galvalume material (zinc-aluminum over cold-rolled carbon steel) and shall not require painting due to superior resistance to corrosion.

Those components which require welding or which require greater than 14-gauge Galvalume material shall be constructed of standard carbon steel and painted. Where painting is required, standard color shall be ANSI #61 (gray).

Option:

The external surfaces of doors and panels shall be painted in color ANSI #______.

Hem-bends (rigid overlap bending) shall be consistently used to enhance strength and to minimize potential exposures to sharp steel edges during installation and maintenance.

Each contactor shall consist of a 3-pole drawout vacuum type contactor, continuous ratings: 400 or 720 A, 2.4 to 7.2 kV as specified on the one-line diagram or in the data sheets. The contactor shall be electrically operated and UL listed.

Vacuum contactor, power fuses, control power transformer (CPT) and all auxiliary contacts shall be mounted on a truck assembly and completely removable from the cell to allow maintenance outside the cell and away from energized primary and secondary circuits. No moving parts for operation of the truck assembly shall reside in the contactor compartment.

Contactor grounding shall occur when the truck assembly is inserted into the compartment and shall be continuous during racking operation.

ABB CPT standard is 500VA, optional 1kVA (one module) or 2kVA (2 CPT’s of 1kVA each) can be located in the available CPT compartment.
Low voltage 3ph window type current transformers (CT) shall be bushing-mounted and exchangeable from the front. Bushing design shall allow for up to two standard accuracy three-phase CTs for all ratings.

**Option:** Zero sequence 3ph window type CTs shall be provided.

Current limiting power fuses shall be installed in a truck-mounted fuse box and be suitable for use with motor, capacitor or transformer applications. The blown fuse indicator on each fuse is visible from the front of the assembly with the contactor in the test/disconnect position and with the door open.

Power fuses for motor protection (type R) shall be equipped with bolted-type connection.

**Choice**

Power fuses for feeder or transformer protection (type E) shall be equipped with clip type connection.

Single-phasing shall be prevented by means of electronic relaying only. Blown fuse trip system can actuate a limit switch that will energize an indicating lamp located on the instrument compartment door.

Contactor will trip.

**Racking System and Disconnect**

A racking system shall be integral to the contactor. Racking shall only be possible with the door closed. The racking system shall have two positions (Connected and Test/Disconnected). In the connected position both primary and secondary contacts shall be engaged. In the test/disconnected position, primary contacts are separated from the bus contacts while the secondary contacts remain engaged to the contactor to be tested.

The connection of secondary circuits shall be completely automatic. It shall not depend on operator interaction.

**Option:** Padlock provisions shall allow the contactor assembly to be locked in the Connected or Test/Disconnected position. Padlocks are not to be included.

Interference blocking shall prevent insertion of a lower rated contactor into a higher rated compartment.

Interlocks shall prevent: (1) insertion or removal of a closed contactor, (2) closing of the contactor unless it is in a positive Connected or Test/Disconnected position and (3) opening of the contactor cell door while the contactor is in the connected position or during racking.

Other interlocks or tagging shall be provided as required by UL 347.
Technical Specifications

Shutters
Shutters shall be non-metallic and transparent, and shall block access to primary contacts when the controller is in the Test/Disconnected position or withdrawn from the cell.

Shutter opening and closing motion shall be driven automatically by the contactor, and not depend on gravity but spring return systems. Shutters shall be driven from both sides simultaneously for smooth, balanced operation.

Shutters shall be interlocked in the closed position. Interlocks shall prevent accidental opening of shutters when the contactor is in the Test/Disconnect position or removed from the compartment.

Relays, Instruments and Controls
As specified in the one-line diagram or the data sheets, secondary equipment such as protective relays, auxiliary relays, indicating instruments, recording instruments, indicating lights, transducers and control instruments shall be installed in low voltage compartments only. No relay or control devices are applied to the doors of any high voltage compartment.

Bus Compartment
The main bus compartment shall be accessible from the front through the low voltage compartment. Bus bar material shall be solid copper. Both connection joints as well as bus bars are silver-plated.

Bus bar continuous current ratings shall be 1200 A, 2000 A, or 3000 A as specified in the one-line diagrams or data sheets. Current ratings shall comply with ANSI temperature rise requirements.

Primary bus conductors shall be insulated utilizing an epoxy coating or as a shrinkable cover. Removable and reusable rubber boots shall cover bus joints.

A continuous rigid copper ground bus shall extend throughout the entire assembly and shall ground the stationary structure and equipment.

Cable Compartment
Two grounded metal ducts allow connection of power cables with top or bottom entry. The system is designed to connect as shown on the attached Cable Data Table for 5kV applications. For 7.2 kV applications please consult the factory

Note:
Please contact your ABB sales representative for other alternatives for power cable connections.
Test and Inspection

The following test and inspection acceptance shall be performed in accordance with the applicable standards.

1. Visual inspection for workmanship
2. Dimensional check
3. Verification of correct wiring
4. Electrical test (per ICS 3 Part 2):
   - High-pot test to bus bar (UL-347) and control wiring
   - Continuity of wiring
   - Mechanical operating test
   - Electrical operation and sequence test

Technical Data

LOAD DATA - HORSEPOWER RATINGS

<table>
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<th>Application</th>
<th>Contactor Rating (A)</th>
<th>Load Data</th>
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<tr>
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<td>2,000</td>
<td>2,000</td>
</tr>
</tbody>
</table>

Two high arrangements with 400 A contactor only, no derating of upper compartment.

CABLE DATA

Cable Rating = 5kV Un-Shielded, 100% Insulated

<table>
<thead>
<tr>
<th>Construction</th>
<th>10/0 Frame Extension</th>
<th>Cable Rating = 5kV Un-Shielded, 100% Insulated</th>
<th>10/0 Frame Extension</th>
<th>Cable Rating = 5kV Shielded, 100% Insulated</th>
</tr>
</thead>
<tbody>
<tr>
<td>400A</td>
<td>2x 350</td>
<td>2x 350</td>
<td>2x 350</td>
<td>1x 350</td>
</tr>
<tr>
<td>400A</td>
<td>1x 350</td>
<td>1x 350</td>
<td>1x 350</td>
<td>1x 350</td>
</tr>
<tr>
<td>720A</td>
<td>2x 350</td>
<td>2x 350</td>
<td>2x 350</td>
<td>N/A</td>
</tr>
<tr>
<td>720A</td>
<td>1x 350</td>
<td>1x 350</td>
<td>1x 350</td>
<td>2x 350</td>
</tr>
</tbody>
</table>

Cable Rating = 5kV Shielded, 100% Insulated

<table>
<thead>
<tr>
<th>Construction</th>
<th>10/0 Frame Extension</th>
<th>Cable Rating = 5kV Un-Shielded, 100% Insulated</th>
<th>10/0 Frame Extension</th>
<th>Cable Rating = 5kV Shielded, 100% Insulated</th>
</tr>
</thead>
<tbody>
<tr>
<td>400A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>720A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>
### Technical Specifications

#### Contactor Ratings

<table>
<thead>
<tr>
<th>Rating</th>
<th>400 A</th>
<th>720 A</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Interrupting ratings at 2.4, 5.0 &amp; 6.6 kV</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NEMA unfused</td>
<td>25 / 50 / 60 MVA</td>
<td>30 / 60 / 85 MVA</td>
</tr>
<tr>
<td>NEMA fused</td>
<td>200 / 400 / 570 MVA</td>
<td>200 / 400 / 570 MVA</td>
</tr>
<tr>
<td><strong>Short time current</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 sec</td>
<td>2,400 A</td>
<td>4,320 A</td>
</tr>
<tr>
<td>1 sec</td>
<td>6,000 A</td>
<td>10,800 A</td>
</tr>
<tr>
<td>10 ms</td>
<td>85 kA (peak)</td>
<td>85 kA (peak)</td>
</tr>
<tr>
<td><strong>Mechanical life, latched/unlatched</strong></td>
<td>250,000 / 2,500,000</td>
<td>250,000 / 1,000,000</td>
</tr>
<tr>
<td><strong>Switching frequency (per hour)</strong></td>
<td>300 / 12000</td>
<td>300 / 600</td>
</tr>
<tr>
<td><strong>Latched/unlatched</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Electrical life</strong></td>
<td>250,000</td>
<td>250,000</td>
</tr>
<tr>
<td><strong>Impulse withstand</strong></td>
<td>60 kV</td>
<td>60 kV</td>
</tr>
<tr>
<td><strong>Dielectric strength</strong></td>
<td>22 kV – 1 minute</td>
<td>22 kV – 1 minute</td>
</tr>
<tr>
<td><strong>Maximum voltage level</strong></td>
<td>7200 V</td>
<td>6900 V</td>
</tr>
<tr>
<td><strong>Contactor close time (max)</strong></td>
<td>4.8 cyc 60 Hz (80 ms)</td>
<td>4.2 cyc 60 Hz (70 ms)</td>
</tr>
<tr>
<td><strong>Contactor open time (max)</strong></td>
<td>1.5 cyc 60 Hz (25 ms)</td>
<td>2.1 cyc 60 Hz (35 ms)</td>
</tr>
<tr>
<td><strong>Control ratings:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contactor control voltage (ac/dc, levels)</td>
<td>Std: 120 V ac 50/60Hz</td>
<td>115-240 V ac / 125-250 V dc</td>
</tr>
<tr>
<td></td>
<td>Option: 240 V ac / 125 V dc 250 V dc</td>
<td></td>
</tr>
<tr>
<td>Pickup voltage ac or dc</td>
<td>85% (hot) – 70% (cold)</td>
<td>85% (hot) – 70% (cold)</td>
</tr>
<tr>
<td>Dropout voltage ac or dc</td>
<td>50% (hot) – 40% (cold)</td>
<td>50% (hot) – 40% (cold)</td>
</tr>
<tr>
<td>Burden closing</td>
<td>670 VA (ac) – 700 W (dc)</td>
<td>840 VA (ac) – 875 W (dc)</td>
</tr>
<tr>
<td>Burden holding</td>
<td>85 VA (ac) – 85 W (dc)</td>
<td>48 VA (ac)</td>
</tr>
<tr>
<td><strong>Auxiliary Contact</strong></td>
<td>3NO, 3NC 2NO, 3NC (latched)</td>
<td>3NO, 3NC</td>
</tr>
<tr>
<td>Max voltage</td>
<td>600 V</td>
<td>600 V</td>
</tr>
<tr>
<td>Continuous current</td>
<td>10 A</td>
<td>10 A</td>
</tr>
<tr>
<td>Making capacity</td>
<td>7200 VA</td>
<td>7200 VA</td>
</tr>
<tr>
<td>Breaking capacity</td>
<td>720 VA</td>
<td>720 VA</td>
</tr>
<tr>
<td><strong>Ambient Ratings</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Altitude without derating</td>
<td>6600 ft</td>
<td>6600 ft</td>
</tr>
<tr>
<td>Temperature</td>
<td>-5 to 40°C</td>
<td>-5 to 40°C</td>
</tr>
<tr>
<td>Humidity</td>
<td>45-85%</td>
<td>45-85%</td>
</tr>
<tr>
<td>Vibration</td>
<td>20 Hz – 1G</td>
<td>20 Hz – 0.5G</td>
</tr>
<tr>
<td><strong>Frames per shipping split</strong></td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

*Maximum required for testing. Actual life is greater under normal operations and conditions.*
WARNING!

SIDE ELEVATION

WARNING!

TYPICAL ARRANGEMENT FOR SAFE GEAR AND ADVANCE VERSION

MOTOR CONTROL / GENERAL ARRANGEMENT

Measurements: Inches (MM)

WARNING!

SAFE GEAR

_MEDIUM VOLTAGE MOTOR CONTROL_

SIDE ELEVATION

FRAME DEPTH

95.000 [2413.0]

BASE

FRAME HEIGHT

30.000 [762.0]

DEPRESS LEVER TO BEGIN RACKING

OPERATION (IN/OUT)

ALWAYS COMPLETE

EACH RACKING

WARNING!

L. V. COMPARTMENT

CONTACTOR 400A

MOTOR PROTECTION

MULTILIN 239 RELAY

SIDE ELEVATION

(1200 A, 2000 A & 3000 A Main Bus)

FRONT ELEVATION

(1200 A, 2000 A & 3000 A Main Bus)

SIDE ELEVATION

(1200 A & 2000 A Main Bus)

SIDE ELEVATION

(3000 A Main Bus)

FLOOR PAN

( X=40.00 inches (1016 mm) for 1200 A & 2000 A Main Bus)

( X=46.00 inches (1219 mm) for 3000 A Main Bus)

SEE PAGE 57 FOR OTHER POSSIBLE ARRANGEMENTS IN ADVANCE VERSION
MOTOR CONTROL / ONE-HIGH
Contactor: 400 A
Main Bus: 1200 or 2000 A
Measurements: Inches (MM)
Technical Specifications

MOTOR CONTROL / ONE-HIGH MODIFIED
Contactor: 720 A
Main Bus: 1200 or 2000 A
Measurements: Inches (MM)

Contactor: 720 A
Main Bus: 1200 or 2000 A
Measurements: Inches (MM)

WARNING!
Verify all door and panel bolts are fully seated before operating this equipment.
Refer to Instruction Book for detailed instructions.
Turn off power supply when working inside.

A LWAYS COM P L E TE O PERATI ON (IN/ OUT) WITHOUT STOPPING.

EACH RACKING

RELAY

MULTILIN 239
OPENING FOR CONTROL

FLOOR PLAN

INSTRUMENT COMPARTMENT

SIDE SECTION

CONTACTOR

CONTACTOR COMPARTMENT

FRONT VIEW

CABLE/CONDUIT OPENING FOR POWER

STANDARD CABLE/CONDUIT TOP AND BOTTOM

VENT FLAPS OR COVER

CABLE DUCT

VENT FLAPS OR COVER

INSTRUMENT COMPARTMENT

CABLE DUCT

30.00
30.00
95.00
30.00
30.00
30.00
30.00
30.00
30.00
1.17
42.27
3.05 (77)
0.07 (2)
3.05 (77)
10.00
5.38 (137)
10.00
5.68 (144)
21.50 (546)
2.00 (51)
.38 (10)
.07 (2)
3.05 (77)
10.00
5.38 (137)
10.00
5.68 (144)
21.50 (546)
2.00 (51)
.38 (10)
.07 (2)
MOTOR CONTROL / TWO-HIGH
Contactor: 400 A
Main Bus: 3000 A
Measurements: Inches (MM)

Technical Specifications

Contactor: 400 A
Main Bus: 3000 A

Contactor Compartment

Opening for Control
Opening for Power
Cable Duct
Contactor

Floor Plan

Front View

Side Section

WARNING!
Verify all door and panel bolts are fully seated before operating this equipment. Refer to Instruction Book for detailed instructions before operating this equipment.

Contactor Compartment

Vent Flaps or Cover

Cable Duct

Contactor

Depress Lever to Begin Racking Without Stopping.

Operation (In/Out)

Each Racking Must Be Open!

WARNING!

Shock or Burn Working Inside This Equipment Before Turning Off Power Supplying Hazard of Electrical

Verify all door and panel bolts are fully seated Multilin 239

Contactor

Contactor Compartment

1.1730 50.27
38.00 95.00
2.00 (51)
.38 (10)
3.05 (77)
48.00 14.84
5.38 (137)
1.50 (38)
5.68 (144)
.07 (2)
19.00
21.50 (546)
354
1.10
30.00
18.00 30.00
18.00 30.00
Technical Specifications

MOTOR CONTROL / ONE-HIGH

Contactor: 400 A
Main Bus: 3000 A
Measurements: Inches (MM)

WARNING!
Contactor Must Be Open In Contactor Compartment

WARNING!
Refer to Instruction Book for detailed instructions before operating this equipment.

Verify all door and panel bolts are fully seated

HAZARD OF ELECTRICAL WORKING IN SIDE
Turn Off Power Supply Before Shock or Burn

INSTRUMENT COMPARTMENT
OPENING FOR POWER CABLE/CONDUIT
STANDARD
TOP AND BOTTOM
CABLE DUCT
FRONT VIEW
SIDE SECTION
FLOOR PLAN

30.00
57.00
95.00
38.00
1.1730
50.27
95.00
21.50 (546)
5.38 (137)
48.00
3.05 (77)
.07 (2)
18.00
3.05 (77)
30.00
30.00
1.1024
14.84
18.00
3.00
.07 (2)
21.50 (546)
Technical Specifications

MOTOR CONTROL / ONE-HIGH MODIFIED
Contactor: 720 A
Main Bus: 3000 A
Measurements: Inches (MM)

INSTRUMENT COMPARTMENT

CONTACTOR COMPARTMENT

FLOOR PLAN

WARNING!
Verify all door and panel bolts are fully seated
Refer to Instruction Book for detailed instructions before operating this equipment.

INSTRUMENT COMPARTMENT
MULTILINE 239
HAZARD OF ELECTRICAL SHOCK OR BURN
WORKING INSIDE TURN OFF POWER SUPPLYING

CABLE DUCT

VENT FLAPS OR COVER

CONTACTOR

SIDE SECTION

FRONT VIEW

38.00
95.00
30.00
21.50
5.68
1.50
5.38
48.00
50.27
18.00
1.1730
105.00
44.00
2.36
4.07
5.10
2.00
1.50
1.10
90.00
30.00
14.84
2.00
2.00
2.00
1.10
1.10
30.00
30.00
3.05
.07
3.8 (10)
1.5 (38)
5.68 (144)
5.38 (137)
14.84 (376)
2.36 (137)
2.00 (51)
.07 (2)
3.05 (77)
5.68 (144)
MOTOR CONTROL / RVNR
Contactor: 400 A & 720 A
Main Bus: 1200, 2000 & 3000A
Advance Only
Measurements: Inches (MM)

Table:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>200-3000</td>
<td>6.6</td>
<td>400</td>
</tr>
<tr>
<td>200-3000</td>
<td>4.16</td>
<td>400</td>
</tr>
<tr>
<td>200-1500</td>
<td>2.3</td>
<td>400</td>
</tr>
<tr>
<td>1750-3000</td>
<td>2.3</td>
<td>720</td>
</tr>
</tbody>
</table>

Note:
- These values are considered when motor is at 100% load
- For more information, please contact your ABB sales representative
MOTOR CONTROL / NEMA 3R (Outdoor) STD.
Contactor: 400A & 720A
Main Bus: 1200, 2000 & 3000A
Advance Only
Measurements: Inches (MM)
MOTOR CONTROL / NEMA 3R (Outdoor) STD.

Contactor: 400A & 720A
Main Bus: 1200, 2000 & 3000A
Advance Only
Measurements: Inches (MM)

MCC Nema 3R suitable to fit an Advance Nema 3R Switchgear
Technical Specifications

MOTOR CONTROL / INCOMING AND TRANSITION SECTION
(This module looks the same from the front for all variations.)
Measurements: Inches (MM)

* MV MCC Recommended Aisle Space: Front: 72" - Rear: 48" - MCC Top to Ceiling: 48"
### MV MOTOR CONTROL

**Typical Frame Weights**

<table>
<thead>
<tr>
<th>Frame/Style</th>
<th>Main Bus Amps</th>
<th>Advance MCC kg (lbs)</th>
<th>SafeCenter MCC kg (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>One High Contactor 400A</td>
<td>1200</td>
<td>760 (1674)</td>
<td>845 (1861)</td>
</tr>
<tr>
<td></td>
<td>2000</td>
<td>790 (1740)</td>
<td>875 (1927)</td>
</tr>
<tr>
<td></td>
<td>3000</td>
<td>900 (1982)</td>
<td>995 (2192)</td>
</tr>
<tr>
<td>Two High Contactor 400A</td>
<td>1200</td>
<td>1000 (2203)</td>
<td>1120 (2467)</td>
</tr>
<tr>
<td></td>
<td>2000</td>
<td>1030 (2269)</td>
<td>1145 (2522)</td>
</tr>
<tr>
<td></td>
<td>3000</td>
<td>1140 (2511)</td>
<td>1265 (2786)</td>
</tr>
<tr>
<td>One High Contactor 720A</td>
<td>1200</td>
<td>820 (1806)</td>
<td>920 (2026)</td>
</tr>
<tr>
<td></td>
<td>2000</td>
<td>850 (1872)</td>
<td>945 (2081)</td>
</tr>
<tr>
<td></td>
<td>3000</td>
<td>960 (2115)</td>
<td>1065 (2346)</td>
</tr>
<tr>
<td>Transition Section</td>
<td>1200</td>
<td>650 (1432)</td>
<td>720 (1586)</td>
</tr>
<tr>
<td></td>
<td>2000</td>
<td>730 (1608)</td>
<td>810 (1784)</td>
</tr>
<tr>
<td></td>
<td>3000</td>
<td>790 (1740)</td>
<td>885 (1949)</td>
</tr>
<tr>
<td>Incoming Section</td>
<td>1200</td>
<td>325 (716)</td>
<td>360 (793)</td>
</tr>
<tr>
<td></td>
<td>2000</td>
<td>350 (771)</td>
<td>390 (859)</td>
</tr>
<tr>
<td></td>
<td>3000</td>
<td>420 (925)</td>
<td>470 (1035)</td>
</tr>
<tr>
<td>Contactor 400A</td>
<td>135 (297)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contactor 720A</td>
<td>165 (363)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**

1) Contactor weights are included in the cells above.
2) Typical electrical equipment is considered.
3) Weights do not include shipping bases.
4) Arc resistant side panel weight is not considered.
TYPICAL CIRCUIT DIAGRAM, FULL VOLTAGE NON-REVERSING STARTER
FEEDER / TRANSFORMER PROTECTION

[Diagram of typical circuit diagram]
<table>
<thead>
<tr>
<th></th>
<th>AMERICAN STANDARD DEVICE FUNCTION NUMBER (C37.2 - 1979)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Master Element</td>
</tr>
<tr>
<td>2</td>
<td>Time-Delay Starting or Closing Relay</td>
</tr>
<tr>
<td>3</td>
<td>Checking or Interlocking Relay</td>
</tr>
<tr>
<td>4</td>
<td>Master Contactor</td>
</tr>
<tr>
<td>5</td>
<td>Stopping Device</td>
</tr>
<tr>
<td>6</td>
<td>Starting Circuit Breaker</td>
</tr>
<tr>
<td>7</td>
<td>Anode Circuit Breaker</td>
</tr>
<tr>
<td>8</td>
<td>Control Power Disconnecting Device</td>
</tr>
<tr>
<td>9</td>
<td>Reversing Device</td>
</tr>
<tr>
<td>10</td>
<td>Unit Sequence Switch</td>
</tr>
<tr>
<td>11</td>
<td>Reserved for Future Application</td>
</tr>
<tr>
<td>12</td>
<td>Over-Speed Device</td>
</tr>
<tr>
<td>13</td>
<td>Synchronous-Speed Device</td>
</tr>
<tr>
<td>14</td>
<td>Under-Speed Device</td>
</tr>
<tr>
<td>15</td>
<td>Speed or Frequency Matching Device</td>
</tr>
<tr>
<td>16</td>
<td>Reserved for Future Application</td>
</tr>
<tr>
<td>17</td>
<td>Shunting or Discharging Switch</td>
</tr>
<tr>
<td>18</td>
<td>Accelerating or Decelerating Device</td>
</tr>
<tr>
<td>19</td>
<td>Starting-to-Running Transition Contactor</td>
</tr>
<tr>
<td>20</td>
<td>Electrically Operated Valve</td>
</tr>
<tr>
<td>21</td>
<td>Distance Relay</td>
</tr>
<tr>
<td>22</td>
<td>Equilizer Relay</td>
</tr>
<tr>
<td>23</td>
<td>Temperature Control Device</td>
</tr>
<tr>
<td>24</td>
<td>Reserved for Future Application</td>
</tr>
<tr>
<td>25</td>
<td>Synchronizing or Synchronization-Check Device</td>
</tr>
</tbody>
</table>
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