Welcome to Module 27, which is about *medium voltage switchgear assemblies*.

**FIGURE 1. TYPICAL MEDIUM VOLTAGE SWITCHGEAR ASSEMBLY (SHOWN AS FIVE STRUCTURES)**

We recommend that you complete Module 5, Fundamentals of Circuit Breakers; and Module 6, Medium Voltage Power Circuit Breakers before beginning this module.

Like the other modules in this series, this one presents small, manageable sections of new material followed by a series of questions about that material. Study the material carefully, then answer the questions without referring back to what you’ve just read.

You are the best judge of how well you grasp the material. Review the material as often as you think necessary. The most important thing is establishing a solid foundation to build on as you move from topic to topic and module to module.

**A Note on Font Styles**

*Key points are in bold.*

*Glossary terms are underlined and italicized the first time they appear.*

**Viewing the Glossary**

You may view definitions of glossary items by clicking on terms and words that are underlined and italicized in the text. You may also browse the Glossary by clicking on the Glossary bookmark in the left-hand margin.
### MEDIUM VOLTAGE SWITCHGEAR ASSEMBLY

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This module will discuss the medium voltage switchgear assembly: what it is, how it is used, what its components are, and how it interfaces with a medium voltage circuit breaker.

When we say “medium voltage,” we are referring to a range of 1000 volts to 38 kV. This is the voltage range discussed in Module 6, Medium Voltage Power Circuit Breakers.

Module 6 discussed two circuit breaker technologies: vacuum interrupter and SF₆. The emphasis was on vacuum. Likewise, this module will emphasize vacuum switchgear assemblies. This is the worldwide application trend for medium voltage assemblies.
**WHAT IS A MEDIUM VOLTAGE SWITCHGEAR ASSEMBLY?**

*Switchgear* is a generic term. The industry uses it to cover “assemblies of switching and interrupting devices, along with control, metering, protective and regulating equipment.”

Let’s break up this definition and further define key parts:

- “Control devices” check and/or regulate the flow of power.
- “Switching and interrupting devices” are used to turn power on or off.
- “Metering devices” are used to measure the flow of electric power.
- “Protective devices” are used to protect power service from interruption, and to prevent or limit damage to equipment.

As you can see, switchgear brings a number of very important functions together in one package.

Now, let’s get more specific, and look at a medium voltage switchgear assembly (Figures 2 and 3).

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**FIGURE 2. TYPICAL MEDIUM VOLTAGE SWITCHGEAR ASSEMBLY, COMPRISED OF 5 VERTICAL STRUCTURES**

**FIGURE 3. TYPICAL 3 VERTICAL STRUCTURE ASSEMBLY WITH UPPER COMPARTMENT VACUUM CIRCUIT BREAKER REMOVED FROM ITS COMPARTMENT ON EXTENSION RAILS**
For the purpose of this module, we will define a medium voltage switchgear assembly as: **an integrated assembly of compartmentalized, removable circuit breakers with an insulated main bus, associated control devices, and auxiliary equipment designed to provide medium voltage circuit protection.**

Medium voltage switchgear assemblies generally fall into one of three voltage categories. These are:

- 5 and 15 kV
- 27 kV
- 38 kV

Their *continuous current* ratings (in an ANSI market) are normally 1200, 2000 or 3000 amperes. (Higher ratings are available when fans are used to force-cool the equipment.) However, all voltage levels do not offer all the same continuous current ratings. **Generally, the assembly ratings are determined by the system requirements and the circuit breakers selected to provide the protection.**

A typical medium voltage switchgear assembly has:

- Removable medium voltage circuit breakers
- Separate compartments for *main bus*
- Separate compartments for incoming/outgoing line connections
- Separate compartments for circuit breakers, control equipment and other auxiliary equipment
- Insulated main bus and connections
- Metal barriers separating each *vertical structure* and each compartment within each structure.

**Metal-Clad vs. Metal-Enclosed**

You will frequently hear the expression “medium voltage *metal-clad* switchgear.” This means that the structures (and compartments within each structure) are physically separated from each other by grounded metal barriers. The phrase “metal-clad” might not be said every time when talking about medium voltage switchgear assemblies, but it is assumed.

This feature separates medium voltage switchgear assembly from other types of assemblies, such as a *metal enclosed* assembly. A metal enclosed assembly (often associated with low voltage equipment) encloses the equipment in separate metal vertical structures. However, compartments are not separated from one another with metal barriers.

**Insulated Main Bus and Connections**

All main bus and connections are insulated in a medium voltage metal-clad switchgear assembly. This is not necessarily the case with other types of assemblies. This is another differentiating feature.
Medium voltage switchgear assemblies provide centralized control of and protection for medium voltage power equipment and circuits. Typical, they are used in industrial, commercial and electric utility installations.

A typical application could involve generators, motors, transformers, feeder circuits, and transmission or distribution lines.

Let's take a look at a typical application. Look at Figure 4 on the next page.

This is part of a typical electrical system. (Each component in the illustration has been covered in a training module in this series.)

The substation transformer, $\text{ subst }$, steps the voltage down from 35 kV to 15 kV. It feeds a 15 kV medium voltage circuit breaker, $\text{ A }$. This is the main circuit breaker of a medium voltage switchgear assembly, $\text{ B }$.

Three other medium voltage circuit breakers in this assembly, $\text{ B, C, and D }$, are performing various functions. For this example, we will only consider breaker C.

Circuit breaker C feeds another transformer, $\text{ transformer }$, which steps the voltage down from 15 kV to 5 kV. This circuit breaker is referred to as a feeder circuit breaker.

From this point, a medium voltage switch, $\text{ switch }$, and a medium voltage motor starter, $\text{ motor }$, become part of the system.

The final piece of this system is a motor, $\text{ motor }$. This motor might be associated with a pumping operation in a water treatment plant, an assembly process in an automotive plant, or a manufacturing process in a textile plant. The possibilities are almost endless. The important point is that part of the medium voltage switchgear assembly plays a critical protective role for this motor.
Application Example (continued)

FIGURE 4. APPLICATION EXAMPLE
Look at this portion of a simple electric utility system, and the voltages indicated along the system. You can see that medium voltage switchgear assemblies can play many roles all along the system.

Generating Station
(11,000 to 25,000 Volts)

Station Switchyard

Transmission Substation
(Stepped up to 69,000 – 765,000 Volts)

Subtransmission
(Stepped down to 22,000 – 69,000 Volts)

Distribution Substation
(Stepped down to 4160 – 34,000 Volts)

Industrial Load
(2400 – 15,000 Volts)

MEDIUM VOLTAGE SWITCHGEAR ASSEMBLIES AT WORK
IN A SIMPLE ELECTRIC UTILITY SYSTEM
Let's take a closer look at the basic parts that make up a medium voltage switchgear assembly.

Keep in mind that an assembly consists of as many vertical structures (sections) as it takes to meet an application’s needs. That could be one structure or many structures.

Vertical Structure

Vertical structures are usually 26, 36 or 42 inches wide, and 90 to 100 inches high. They are all bolted together to form one rigid, continuous assembly. The exact dimensions of the vertical structure are dictated by the voltage class and specification requirements for the application.

Normally, the front of each structure has hinged, metal doors. Access from the rear is provided through bolted, removable metal panels, or hinged doors. Rear access is usually dictated by the equipment specification requirements.
A medium voltage switchgear assembly is an integrated combination of a number of compartments. Compartment types include:

A. Circuit Breaker Compartment

B. Main Bus Compartment

C. Line Compartment

D. Control Compartment Area
   (doors available for device mounting)

E. Auxiliary Compartment
   (as required)

Keep in mind that the different compartments – as well as the individual vertical structures – are physically separated from one another by metal barriers.

We will look more closely at each compartment in the next two sections.
CIRCUIT BREAKER COMPARTMENT

The removable (drawout) circuit breaker is the heart of the switchgear. Each circuit breaker is provided with its own compartment, within which it performs its function.

Generally, the circuit breaker compartment provides:

- an enclosure for the circuit breaker
- means to move (lever) the circuit breaker into or out of the compartment
- a means for the circuit breaker to make primary and secondary electrical connections
- matching safety interlocks, to interact with circuit breaker interlocks
- extension rails to support the circuit breaker as it is pulled out of the compartment

Let's consider each of these provisions in turn.
The circuit breaker compartment includes a top, bottom, right and left sides, and rear portions of the compartment. When the circuit breaker is levered into its CONNECTED position, the faceplate of the circuit breaker itself acts as the front part of the compartment (Figure 8).

In this position, the operating and current-carrying parts of the circuit breaker are compartmentalized from the rest of the assembly structure (Figure 9).
Primary Electrical Connections

Circuit breakers have six primary electrical connections: three line and three load. The compartment provides six matching stationary primary connections.

When the circuit breaker’s primary connections mate with the compartment’s primary connections, the circuit breaker is electrically tied into the application system. This connection is automatically made as the circuit breaker is levered into the CONNECTED position within the circuit breaker compartment.

As the circuit breaker is levered out of its compartment, the primary connection is automatically disconnected.

Usually, the circuit breaker makes the primary connection using **finger clusters** (Figure 10). A finger cluster is a configuration of spring-loaded conductive fingers, often made of silver-plated copper.

![Diagram of circuit breaker with labels: 1 Vacuum Interrupter, 2 Primary Finger Cluster](image)

**FIGURE 10. REAR VIEW OF CIRCUIT BREAKER, SHOWING SIX PRIMARY FINGER CLUSTERS**

When the circuit breaker is levered into the CONNECTED position, its finger clusters engage the compartment’s stationary primary conductors. The compartment’s primary conductors are usually solid silver-plated copper bars or rods (Figure 11). The shape depends on the finger cluster design.

![Diagram of circuit breaker compartment showing bar-shaped primary connectors](image)

**FIGURE 11. INSIDE VIEW OF CIRCUIT BREAKER COMPARTMENT, SHOWING SIX BAR-SHAPED STATIONARY PRIMARY CONNECTIONS INSIDE INDIVIDUAL BOTTLE-SHAPED INSULATORS**
When the circuit breaker is levered out of the CONNECTED position, the compartment’s fixed primary conductors are automatically covered to prevent contact with live primary current-carrying parts. This safety feature can be observed when the circuit breaker is removed from its compartment. The device used by the compartment to cover the primary parts is generally called an automatic shutter system.

The shutters are mechanically closed as the circuit breaker leaves the CONNECTED position, and mechanically opened as it enters the CONNECTED position.

Figure 11 shows the inside of the compartment with the shutters removed to clearly show the primary connections. In reality, the inside of the compartment would look like Figure 12 when the circuit breaker removed. The protective shutters are closed, and the stationary primary connections are not visible or accessible.

FIGURE 12. INSIDE VIEW OF CIRCUIT BREAKER COMPARTMENT, WITH PROTECTIVE SHUTTERS CLOSED OVER STATIONARY PRIMARY CONNECTIONS
A switchgear, and many of the devices that make up a switchgear, require secondary control power to operate. For example, the circuit breaker’s charging motor needs a source of control power to operate.

When the circuit breaker is levered into the CONNECTED position, a secondary contact plug automatically engages a compatible secondary plug mounted in the circuit breaker compartment. Control power is provided to the charging motor and other devices, depending upon how the wiring is done.

When the circuit breaker is levered out of the CONNECTED position, the secondary contacts automatically disengage.

The secondary contact plugs can be manually engaged when the circuit breaker is in the TEST position within its compartment (Figure 13). This means that the circuit breaker can be safely tested electrically without concern about primary connections being made.

The secondary plug is often mounted on the underside of the circuit breaker, with the compartment’s secondary plug mounted on the compartment floor (Figure 14).
Safety Interlocks

Safety interlocks in the compartment interact with matching circuit breaker interlocks. This series of interlocks help ensure safe and proper interfacing between the circuit breaker and its compartment. **Safety interlocks are required by governing standards, and must be supplied by all manufacturers.**

Several different interlock designs are in common use. Two examples of such interlock functions are:

- Prevents insertion of a circuit breaker into a compartment with a higher power rating
- Trips the breaker automatically if the breaker’s main contacts are closed when it is levered from TEST position to CONNECTED position
Extension Rails

Since the introduction of medium voltage vacuum circuit breakers, which permitted two circuit breakers to be stacked vertically in one structure, compartment extension rails have come to be expected.

Extension rails permit circuit breakers – and other auxiliary devices such as large removable transformers – to be withdrawn from the compartment for inspection and maintenance (Figures 15 and 16). The need to always lift and/or move the device to another area has been significantly reduced.

FIGURE 15. VACUUM CIRCUIT BREAKER WITHDRAWN FROM COMPARTMENT ON EXTENSION RAILS

FIGURE 16. VOLTAGE TRANSFORMERS WITHDRAWN FROM AUXILIARY COMPARTMENT ON EXTENSION RAILS
1. “Medium voltage” refers to a voltage range from _________ to _________.

2. In your own words, define the generic term “switchgear.”

   _______________________________________________________________
   _______________________________________________________________
   _______________________________________________________________

3. A medium voltage switchgear assembly can be composed of as many as five different types of compartments. The circuit breaker compartment is one of them. Name three others.
   • _____________________________________________________________
   • _____________________________________________________________
   • _____________________________________________________________

4. The exact dimensions of the vertical structure are dictated by the _________ and _________ for the application.

5. The circuit breaker compartment accommodates the circuit breaker with a number of provisions. Name three of them.
   • _____________________________________________________________
   • _____________________________________________________________
   • _____________________________________________________________
The circuit breaker compartment is the most complex compartment in a switchgear assembly. The other compartments are less complex, but still very important.

Let’s take some time to consider the function of each one.

A *main bus compartment* is identified as item “B” in Figure 7.

The main bus itself is a set of electrical conductors, usually three per set. These individually insulated conductors provide for multiple connections into the electrical system. In medium voltage switchgear assemblies, the main bus usually takes the form of solid copper bars.

Connections to the main bus within a vertical structure for circuit breakers (and other devices) are called *bus joints* (Figure 18). Bus joints must also be insulated.

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**FIGURE 17. TWO-HIGH MEDIUM VOLTAGE VACUUM VERTICAL STRUCTURE (SIDE VIEW)**

**FIGURE 18. THREE MAIN BUS BARS EXTENDING THROUGH INSULATED OPENINGS IN THE SIDE OF VERTICAL STRUCTURE (ADJACENT VERTICAL STRUCTURE REMOVED FOR CLARITY)**
The main bus extends the length of the assembly from one vertical structure to another through insulated openings in the sides of the vertical structures. Depending upon the length of the assembly, main bus bars are not usually one continuous piece, but standard lengths bolted together.

The bus system must be supported and braced to withstand the stresses created by fault currents that could be experienced.

Isolating barriers are used within each vertical structure to compartmentalize the main bus from other compartments and equipment. Access to the main bus is provided by removing specific barriers (Figure 19).

Main bus conductors are sized to handle the current, while maintaining the rated temperature requirements established by standards. In medium voltage switchgear assemblies, the rated continuous current of the main bus is usually 1200, 2000 or 3000 amperes, although higher ratings are possible.
The rearmost compartment is the line compartment. It is accessed through removable rear panels or rear doors. Space is provided in the compartment for line terminations (such as cable connectors) or other special devices.

Assembly designs usually permit entry and/or exit of cable or bus from the top or bottom of the compartment. Other devices, such as surge arresters and large control power transformers, can also be mounted in the line compartment.

Refer back to Figure 17. In this drawing, there are two individual line compartments in a two-high circuit breaker vertical structure. When there is only one circuit breaker in a vertical structure, the line compartment usually runs from bottom to top, providing a significant amount of space (Figure 20).

FIGURE 20. TWO VERTICAL STRUCTURES OF ONE-HIGH CIRCUIT BREAKER SWITCHGEAR, REAR PANELS REMOVED (REAR VIEW)
When two circuit breakers are stacked in the same vertical structure, two individual line compartments are necessary (Figure 21).

An uninsulated *ground bus* runs the length of the assembly, and is normally located in the lower part of the line compartment. **For safety reasons, the ground bus is capable of carrying the rated short circuit current of the installed circuit breakers for a certain amount of time.**
Control Compartment

The control compartment is considered to be the space between the front of the circuit breaker and the front doors of the assembly. This is where instruments, meters, relays and other control equipment are usually mounted.

The front doors are used heavily for control equipment mounting, with the front of the device viewable when the door is closed. The rear portion of door-mounted devices protrudes into the space between the door and the front of the circuit breaker (Figure 22).

Refer back to Figure 1 to see a typical switchgear assembly with a large number of front door-mounted devices.

Control devices are not restricted to the area shown. This is just the preferred location. **If there is a large volume of control equipment, it could be located in a dedicated compartment.** This is called an auxiliary compartment, and will be discussed next.
Auxiliary Compartment

When used, an auxiliary compartment is usually located above or below a circuit breaker compartment.

An auxiliary compartment could be an entire full-height vertical structure (with no circuit breakers in that compartment). This approach is used when there is a significant volume of auxiliary equipment, such as sizable transformers, required in the assembly.

Auxiliary compartments are frequently used to mount drawout voltage transformers and control power transformers (Figure 23).

**FIGURE 23. AUXILIARY COMPARTMENT TRANSFORMER MOUNTING**

Figure 24 illustrates how an entire vertical structure might be used for a large number of devices.

**FIGURE 24. ENTIRE VERTICAL STRUCTURE DEDICATED TO AUXILIARY EQUIPMENT**
INSTALLATION

Medium voltage switchgear assemblies are installed in a wide variety of locations under a wide range of conditions. Since the introduction of two-high vacuum switchgear, the number of construction possibilities has significantly increased.

This provides customers with more and better solutions to difficult installation problems. Installation locations are not always ideal, and electrical system requirements have become more demanding. Smaller and more capable circuit breakers and control devices have helped dramatically in these areas.

The two main installation types are:

- Indoor
- Outdoor
Thus far, we have looked only at medium voltage switchgear assemblies for indoor installation. Actually, all medium voltage switchgear assemblies start out as indoor assemblies. If the equipment is to be installed outdoors and/or in adverse ambient conditions, modifications are made to meet the need.

For the moment, let's assume the equipment is for indoor installation. The conditions, such as temperature, humidity and cleanliness, are acceptable. What possible assembly configurations exist to help use the smallest amount of floor space, or deal with a difficult installation location?

Let's look at typical configurations used with medium voltage switchgear assemblies. Keep in mind that some configurations may not necessarily be possible for all system voltages. In addition, all manufacturers do not necessarily offer the same configurations.

The question is: What size circuit breakers and/or auxiliary equipment can be stacked into one vertical structure, while maintaining temperature requirements? For the answer, look at Figure 25.

![FIGURE 25. TYPICAL TWO-HIGH CONFIGURATIONS](image-url)

\(1\) This space can have one or two drawout auxiliary drawers for devices like potential (voltage) transformers.
Outdoor Installation

Suppose a medium voltage switchgear assembly must be installed in a location where a convenient indoor location does not exist, and it does not make good economic sense to construct a building.

The solution is to supply equipment that can be used outdoors. This is typically accomplished by manufacturing an indoor-type switchgear assembly and constructing some type of outdoor enclosure around it.

There are three primary approaches used to accomplish this task:

- **Outdoor Aisle-Less Switchgear**
  
  Outdoor aisle-less switchgear is basically the assembly of a weatherproof enclosure around an indoor switchgear assembly (Figure 26). Usually, weatherproof doors are located on the front to allow for the drawout and removal of the circuit breakers. Removable weatherproof panels or doors are usually provided for rear access. Another provision is additional ventilation, coupled with small space heaters to minimize condensation of moisture.

![Diagram of Outdoor Aisle-Less Construction](image)
**Outdoor Installation (continued)**

- **Sheltered Aisle Switchgear**
  
  *Sheltered aisle switchgear* uses an approach similar to that for aisle-less switchgear. An outdoor enclosure is constructed around an indoor switchgear assembly. The primary difference is that an *aisle* is constructed as part of the enclosure at the front of the assembly. This provides for sheltered operation and maintenance (Figure 27). Weatherproof access doors are normally supplied at both ends of the aisle.

![FIGURE 27. TYPICAL OUTDOOR SHELTERED AISLE CONSTRUCTION (SIDE VIEW)](image)

When the assembly is very large, it could be broken up and installed on both sides of the aisle. The aisle doors and aisle are common to both sides of the switchgear assembly. This construction approach is called *common aisle switchgear* (Figure 28).

![FIGURE 28. TYPICAL OUTDOOR COMMON AISLE CONSTRUCTION (SIDE VIEW)](image)
Outdoor Installation (continued)

- **Outdoor Control Room**
  Some installations require installation of a variety of equipment at a location that does not have a building. (Components such as: switchgear, motor starters and motor control centers, to mention a few.) The *outdoor control room* approach can be used to enclose all the equipment in one confined area. Basically, this approach uses indoor versions of all the equipment and encloses it in one weatherproof house. Normally, the construction takes place at the manufacturer's location and then moved to the installation site.
A medium voltage switchgear assembly is designed, built and tested in accordance with a specific set or sets of standards. To participate on a global basis, the equipment must meet all applicable ANSI, IEEE, NEMA and IEC standards, depending upon the region where the equipment is applied.

Unlike an individual component, which also must meet certain specific standards, the manufacturer must know – and be able to prove by testing – that each and every component functions properly when installed in the assembly. This is quite a task, considering the vast number of different devices and pieces that can comprise an assembly.

In addition to regional standards, an assembly may frequently be required to meet specific local standards. Very specific tests could even be required for the equipment before it can be permitted for use in certain areas or applications.

Two such applications are seismically-qualified and arc-resistant equipment. The design of arc-resistant equipment is dedicated to the safe control and release of arc-related overpressures.

Finally, an assembly often must meet very specific customer requirements, such as the type of wire used, or the type of finish applied to the metal housing.
## Testing is Very Extensive

The design and proof testing and the production testing of a medium voltage switchgear assembly varies, depending upon whether it is compliant with ANSI or IEC standards.

**No matter which set of standards is dominant, the testing programs are very extensive.** We will not attempt to cover the individual aspects of assembly testing here. But, to provide an idea of the testing’s involvement, look below at just some of the ANSI requirements.

## Design and Proof Testing

The design and proof testing of the assembly to show compliance with applicable ANSI standards includes, but is not limited to:

- Short circuit testing
- BIL testing
- Dielectric testing
- Continuous current testing
- Mechanical life testing
- Thermal testing
- Environmental testing
Production testing of an assembly is performed in compliance with specific ANSI standards for the circuit breaker and the assembled housing individually. These production tests are also referred to as “routine tests.”

Circuit breaker testing includes, but is not limited to:

- Verification of nameplate ratings
- Control wiring check
- Control wiring insulation test
- Charging motor insulation test
- Operation of switches, control devices, latches and interlocks
- Breaker operation at minimum, maximum, and rated control voltages
- Vacuum interrupter operation and withstand tests
- Breaker contact resistance
- Closing and opening timing tests
- Dielectric tests

The assembled housing’s testing includes, but is not limited to:

- Component nameplate verification for compatible application
- Dielectric tests
- Mechanical testing of all operational parts and devices
- Control wiring continuity verification
- Operation of all relays, instruments, meters and other devices
- Control wiring insulation tests
- Instrument transformer polarity verification tests
- Sequence of operation tests, if applicable
Coming up with a final bill of materials for a complete medium voltage switchgear assembly is an involved task. It takes a qualified individual to analyze the requirements of a system, and review customer specifications and line diagrams of the system.

Fortunately, a significant part of the work has been completed when a manufacturer states that the equipment complies with a certain set of applicable standards. This says a great deal about the equipment.

Also, customers normally provide exact specifications and line diagrams that describe the equipment in detail. System considerations are made and ratings are determined. This task also requires a very knowledgeable individual.

But, a medium voltage switchgear assembly is not a piece of equipment that can be selected from a table. It is a built-to-order product with many details to be considered and many selections to be made. Selecting each component and device to will do the job, be acceptable to the customer, and comply with all regional and local standards is quite an undertaking. Every detail, from the electrical and mechanical requirements, down to the finish and composition of the structure must be considered.

The more knowledgeable you are about ANSI and IEC standards, the more valuable you will be to your customer. Become comfortable with reading diagrams that describe a system. They supply a wealth of information about the electrical equipment required, its functioning, and its ratings.
Being aware of certain basic information about an assembly that is always required will help to avoid additional questions and lost time. For this reason, a mini-specification guide, covering medium voltage switchgear assemblies is presented for your review. Use it as a simple guideline when discussing an assembly possibility with your customer.

**General Considerations**
- What general standards are applicable to the equipment (i.e. ANSI, IEC)?
- Do any special local standards apply?

**Ratings**
- The switchgear operates on a ____ kV, three-phase, ____ wire, ____ Hz system
- What are the medium voltage circuit breaker ratings?

**Main Bus**
- The main bus will be of what material and how should it be insulated?
- The main bus will have a continuous current rating of ______ amperes.
- Bus supports should be made from what insulating material?

**Circuit Breaker**
- What type of interrupting means is the circuit breaker required to use?
- The control voltage for circuit breaker operation will be ______ volts AC (DC).
- What will be the source of control power?

**Tripping Means**
- What type of protective relaying is required? Single unit microprocessor-based type, or electromagnetic relay types?

**Wiring and Terminations**
- What is the size and type of the secondary wiring?
- How is secondary wiring to be terminated within the switchgear assembly?
- How will incoming cables be terminated within the switchgear assembly?
Auxiliary Devices
• What are the ratings of required potential (voltage) and/or control power transformers and how are they to be mounted (fixed or drawout)?

Accessory Devices
• Other than standard accessory devices supplied with the switchgear assembly as standard, are any special accessories required, such as:
  • Portable circuit breaker lifting device
  • Ramp for rolling circuit breaker into lower compartment
  • Test cabinet for testing circuit breakers outside the assembly
  • Dolly for moving circuit breakers about when outside the assembly
  • Electrical levering-in device

Enclosure
• Is the assembly to be indoor or outdoor construction?
• If outdoor construction, what type of construction?
  • Outdoor Aisle-less
  • Outdoor Sheltered Aisle (or Common Aisle)
  • Outdoor Control Room

Finish
• Are there any special finishes, colors or processes required?

Testing
• Is there any special test required during production or after installation?

Environment
• Is there anything special or unusual about the location or the environment where the equipment will be installed? A few to consider are:
  • Altitude
  • Humidity and temperature
  • Cleanliness
  • Available space and ability to support equipment weight, especially at indoor locations

Being aware of questions and issues like these just presented will go a long way to increasing your knowledge of medium voltage switchgear assemblies. In doing so, you will be able to help your customers with their equipment decisions.
1. Main bus conductors are sized to handle the __________, while maintaining the rated ______________ _______________ established by standards.

2. In your own words, describe where controls are generally found in a switchgear assembly.

____________________________________________________________

____________________________________________________________

____________________________________________________________

____________________________________________________________

3. There are three primary approaches to outdoor switchgear assembly installations. Name two of them.

• _______________________________________________________________________

• _______________________________________________________________________

4. ANSI design and proof testing for switchgear assembly includes many types of tests. Seven types were mentioned. Name four.

• _______________________________________________________________________

• _______________________________________________________________________

• _______________________________________________________________________

• _______________________________________________________________________

5. In an area where ______ compliance is required, hydraulic magnetic and current limiting supplementary protectors are used.

6. There are four main pieces of information that are needed from a customer when attempting to match a product to an application. Name three of them.

• _______________________________________________________________________

• _______________________________________________________________________

• _______________________________________________________________________
## GLOSSARY

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aisle</td>
<td>Part of a sheltered aisle switchgear installation. Connected accessway for multiple vertical enclosures in an outdoor installation. Weatherproof access doors are normally supplied at both ends of the aisle.</td>
</tr>
<tr>
<td>ANSI</td>
<td>American National Standards Institute. It was organized to simplify and standardize production and construction.</td>
</tr>
<tr>
<td>Arc-Resistant</td>
<td>A special certification that equipment must have for use in certain circumstances. The design of arc-resistant equipment is dedicated to the safe control and release of arc-related overpressures.</td>
</tr>
<tr>
<td>Automatic Shutter</td>
<td>Circuit breaker compartment safety feature. When the circuit breaker is removed from its compartment, the compartment’s fixed primary conductors are automatically covered to prevent contact with live primary current-carrying parts.</td>
</tr>
<tr>
<td>Auxiliary Compartment</td>
<td>An optional compartment in a medium voltage switchgear assembly, usually located above or below a circuit breaker compartment. Used when there is a significant volume of auxiliary and/or control equipment required in the assembly.</td>
</tr>
<tr>
<td>Bus Joint</td>
<td>The connection between the main bus and a circuit breaker (or other devices). Bus joints must be insulated.</td>
</tr>
<tr>
<td>Circuit Breaker</td>
<td>A reusable overcurrent protection device. After tripping to break the circuit, it can be reset to protect the circuit again.</td>
</tr>
<tr>
<td>Circuit Breaker Compartment</td>
<td>A compartment in a medium voltage switchgear assembly that contains and electrically connects one or more circuit breakers.</td>
</tr>
<tr>
<td>Common Aisle Switchgear</td>
<td>An outdoor installation solution for very large assemblies. A variation on sheltered aisle switchgear, in which vertical structures are on both sides of the aisle.</td>
</tr>
<tr>
<td>Continuous Current</td>
<td>The amount of current the breaker can carry continuously at 60 cycles without exceeding the temperature rise limit, according to ANSI charts.</td>
</tr>
</tbody>
</table>
### MEDIUM VOLTAGE SWITCHGEAR ASSEMBLY

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
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<tbody>
<tr>
<td>Control Compartment</td>
<td>The space between the front of the circuit breaker and the front doors of the assembly. This is where instruments, meters, relays and other control equipment are usually mounted.</td>
</tr>
<tr>
<td>Control Power Transformer</td>
<td>A transformer that provides a safe, reasonable low voltage source for relays, contactors and other devices.</td>
</tr>
<tr>
<td>Extension Rails</td>
<td>A common feature of the circuit breaker itself. Allow the circuit breaker slide out of its compartment easily for inspection.</td>
</tr>
<tr>
<td>Feeder Circuit Breaker</td>
<td>A reusable overcurrent protection device designed to protect a panel downstream from a medium voltage switchgear assembly.</td>
</tr>
<tr>
<td>Finger Cluster</td>
<td>A configuration of spring-loaded conductive fingers mounted on the circuit breaker, often made of silver-plated copper. When the circuit breaker is levered into the CONNECTED position, its finger clusters engage the circuit breaker compartment’s stationary primary conductors to make electrical connection.</td>
</tr>
<tr>
<td>Ground Bus</td>
<td>A grounded bus that runs the length of the assembly, and is normally located in the lower part of the line compartment. For safety reasons, the ground bus is capable of carrying the rated short circuit current of the installed circuit breakers for a certain amount of time.</td>
</tr>
<tr>
<td>IEC</td>
<td>Abbreviation for International Electro-technical Commission. This organization is associated with equipment used internationally.</td>
</tr>
<tr>
<td>IEEE</td>
<td>Institute of Electrical and Electronic Engineers. A professional organization of scientists and engineers whose purpose is the advancement of engineering.</td>
</tr>
<tr>
<td>Lever</td>
<td>A term to describe the act of moving a circuit breaker from one position to another.</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
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</tr>
<tr>
<td>Line Compartment</td>
<td>Space is provided in this compartment for line terminations or other special devices. Assembly designs usually permit entry and/or exit of cable or bus from the top or bottom of the compartment.</td>
</tr>
<tr>
<td>Main Bus</td>
<td>A set of electrical conductors, usually three per set. These individually insulated conductors provide for multiple connections into the electrical system. In medium voltage switchgear assemblies, the main bus usually takes the form of solid copper bars.</td>
</tr>
<tr>
<td>Main Bus Compartment</td>
<td>A compartment in a medium voltage switchgear assembly through which the main bus runs.</td>
</tr>
<tr>
<td>Main Circuit Breaker</td>
<td>Also “Main Breaker.” A reusable overcurrent protection device designed to protect an entire medium voltage switchgear assembly.</td>
</tr>
<tr>
<td>Medium Voltage Switchgear Assembly</td>
<td>An integrated assembly of compartmentalized, removable circuit breakers with an insulated main bus, associated control devices, and auxiliary equipment designed to provide medium voltage circuit protection.</td>
</tr>
<tr>
<td>Metal-Clad</td>
<td>Equipment in the assembly is enclosed, and separated by metal barriers into individual compartments. Typically associated with medium voltage equipment.</td>
</tr>
<tr>
<td>Metal-Enclosed</td>
<td>Equipment in the assembly is enclosed, but not necessarily separated by barriers. Typically associated with low voltage equipment.</td>
</tr>
<tr>
<td>Outdoor Aisle-less Switchgear</td>
<td>An outdoor installation solution. Basically, the assembly of a weatherproof enclosure around an indoor switchgear assembly.</td>
</tr>
<tr>
<td>Outdoor Control Room</td>
<td>An outdoor installation solution. Encloses all the equipment in one weatherproof house. Normally, the construction takes place at the manufacturer’s location and then moved to the installation site</td>
</tr>
<tr>
<td>Term</td>
<td>Description</td>
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<tr>
<td>Safety Interlock</td>
<td>A feature of both the circuit breaker compartment and the circuit breaker itself. Helps ensure safe and proper interfacing between the circuit breaker and its compartment. Interlocks are required by governing standards, and must be supplied by all manufacturers.</td>
</tr>
<tr>
<td>Seismically-Qualified</td>
<td>A special certification that equipment must have for use in certain earthquake-prone zones.</td>
</tr>
<tr>
<td>SF₆</td>
<td>An arc extinguishing technology involving the use of sulfur hexafluoride gas.</td>
</tr>
<tr>
<td>Sheltered Aisle Switchgear</td>
<td>An outdoor installation solution. An outdoor enclosure is constructed around an indoor switchgear assembly with an aisle constructed as part of the enclosure at the front of the assembly.</td>
</tr>
<tr>
<td>Surge Arrester</td>
<td>A device that protects equipment from electrical surges.</td>
</tr>
<tr>
<td>Switchgear</td>
<td>An assembly of switching and interrupting devices, along with control, metering, protective and regulating equipment.</td>
</tr>
<tr>
<td>Vacuum Interrupter</td>
<td>An arc extinguishing technology. Features a pair of separable contacts enclosed in a vacuum-tight envelope. Since the environment inside the interrupter envelope is a vacuum, an arc cannot be sustained easily.</td>
</tr>
<tr>
<td>Vertical Structure</td>
<td>A metal enclosure for the other switchgear components. A switch gear assembly can consist of practically any number of adjacent vertical structures.</td>
</tr>
<tr>
<td>Voltage Transformer</td>
<td>Also “potential transformer.” A step-down transformer that steps down supplied voltage to a voltage usable by control components such as relays and meters.</td>
</tr>
</tbody>
</table>
MEDIUM VOLTAGE SWITCHGEAR ASSEMBLY

REVIEW 1
ANSWERS

1.  1000 volts, 38 kV

2.  Answer should basically say: “switching and interrupting devices, and assemblies of those devices and control, metering, protective and regulating equipment, with the associated interconnections and supporting structures.”

3.  Any three of the following:
   •  Main Bus Compartment
   •  Line Compartment
   •  Control Compartment Area
   •  Auxiliary Compartment

4.  voltage class, specification requirements

5.  Any three of the following:
   •  an enclosure for the circuit breaker
   •  means to move the circuit breaker into or out of the compartment
   •  a means to make primary and secondary electrical connections
   •  safety interlocks
   •  extension rails

REVIEW 2
ANSWERS

1.  current, temperature requirements

2.  Answer should basically say: “The space between the front of the circuit breaker and the front doors of the assembly is generally considered as the control compartment area. Door-mounted devices are viewable with the door closed. If there is a large volume of control equipment, it could be located in an auxiliary compartment.”

3.  Any two of the following:
   •  outdoor aisle-less switchgear
   •  sheltered aisle switchgear (or common aisle switchgear)
   •  outdoor control room

4.  Any four of the following:
   •  Short circuit
   •  BIL
   •  Dielectric
   •  Continuous current
   •  Mechanical life
   •  Thermal
   •  Environmental