# Electrical substation

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A **substation** is a part of an electrical generation, transmission, and distribution system. Substations transform voltage from high to low, or the reverse, or perform any of several other important functions. Between the generating station and consumer, electric power may flow through several substations at different voltage levels. A substation may include transformers to change voltage levels between high transmission voltages and lower distribution voltages, or at the interconnection of two different transmission voltages.

Substations may be owned and operated by an electrical utility, or may be owned by a large industrial or commercial customer. Generally substations are unattended, relying on SCADA for remote supervision and control.

The word *substation* comes from the days before the distribution system became a grid. As central generation stations became larger, smaller generating plants were converted to distribution stations, receiving their energy supply from a larger plant instead of using their own generators. The first substations were connected to only one power station, where the generators were housed, and were subsidiaries of that power station.

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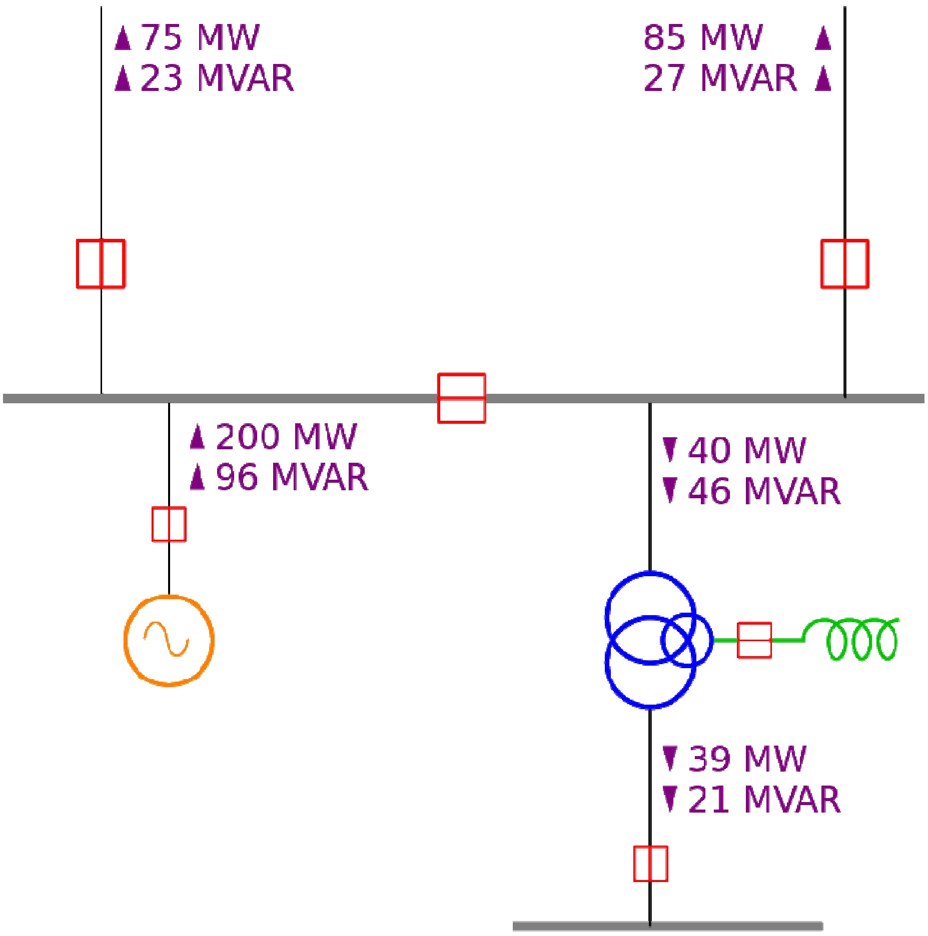
## Single-line diagram

In power engineering, a **single-line diagram** (**SLD**), also sometimes called **one-line diagram**, is a simplest symbolic representation of an electric power system.[1][2] A single line in the diagram typically corresponds to more than one physical conductor: in a direct current system the line includes the supply and return paths, in a three-phase system the line represents all three phases (the conductors are both supply and return due to the nature of the alternating current circuits).[1]

The one-line diagram has its largest application in power flow studies. Electrical elements such as circuit breakers, transformers, capacitors, bus bars, and conductors are shown by standardized schematic symbols.[2] Instead of representing each of three phases with a separate line or terminal, only one conductor is represented.

It is a form of block diagram graphically depicting the paths for power flow between entities of the system. Elements on the diagram do not represent the physical size or location of the electrical equipment, but it is a common convention to organize the diagram with the same left-to-right, top-to-bottom sequence as the switchgear or other apparatus represented. A one-line diagram can also be used to show a high level view of conduit runs for a PLC control system.


75 MW
23 MVAR
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27 MVAR
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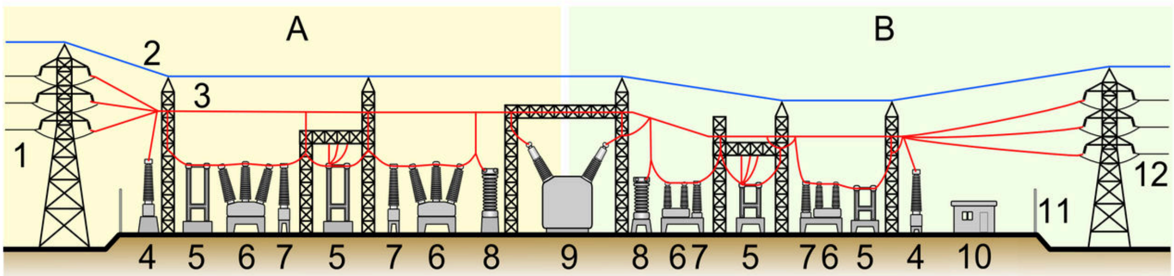
21 MVAR

# Elements of a substation




A. Primary power lines' side
B. Secondary power lines' side

1. Primary power lines
2. Ground wire
3. Overhead lines
4. Transformer for measurement of electric voltage
5. Disconnect switch
6. Circuit breaker
7. Current transformer
8. Lightning arrester
9. Main transformer
10. Control building
11. Security fence
12. Secondary power lines

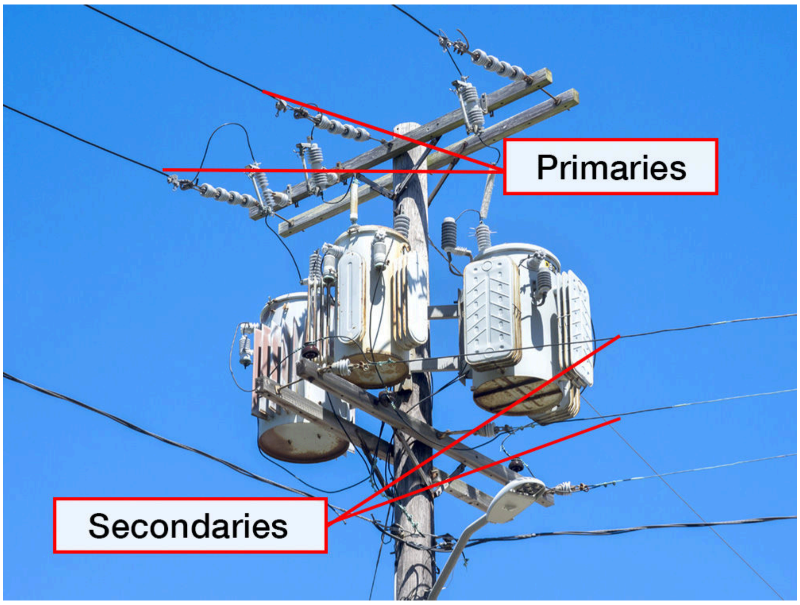
## Elements of a substation

Substations generally have switching, protection and control equipment, and transformers. In a large substation, circuit breakers are used to interrupt any short circuits or overload currents that may occur on the network. Smaller distribution stations may use recloser circuit breakers or fuses for protection of distribution circuits. Substations themselves do not usually have generators, although a power plant may have a substation nearby. Other devices such as capacitors, voltage regulators, and reactors may also be located at a substation.

Substations may be on the surface in fenced enclosures, underground, or located in special-purpose buildings. High-rise buildings may have several indoor substations. Indoor substations are usually found in urban areas to reduce the noise from the transformers, for reasons of appearance, or to protect switchgear from extreme climate or pollution conditions.

A grounding (earthing) system must be designed. The total ground potential rise, and the gradients in potential during a fault (called *touch* and *step* potentials),[6] must be calculated to protect passers-by during a short circuit in the transmission system. Earth faults at a substation can cause a ground potential rise. Currents flowing in the Earth's surface during a fault can cause metal objects to have a significantly different voltage than the ground under a person's feet; this touch potential presents a hazard of electrocution. Where a substation has a metallic fence, it must be properly grounded to protect people from this hazard.

## Primary and Secondary Lines




***Primary lines*, or *primaries*,** are higher-voltage lines located at the top of utility poles, above transformers. Primary wires are typically copper, aluminum and aluminum with steel-reinforced conductors. Some are coated with a protective covering but should not be considered insulated. Typical primary voltages include 7,200 volts single phase and 12,500 volts three phase.

***Secondary lines*, or *secondaries*,** are located lower down on utility poles, usually below transformers. Typical secondary voltages are between 120 volts to 480 volts. Although the voltage is lower, these lines can still deliver a severe electric shock if contacted.

## 2. Ground wire

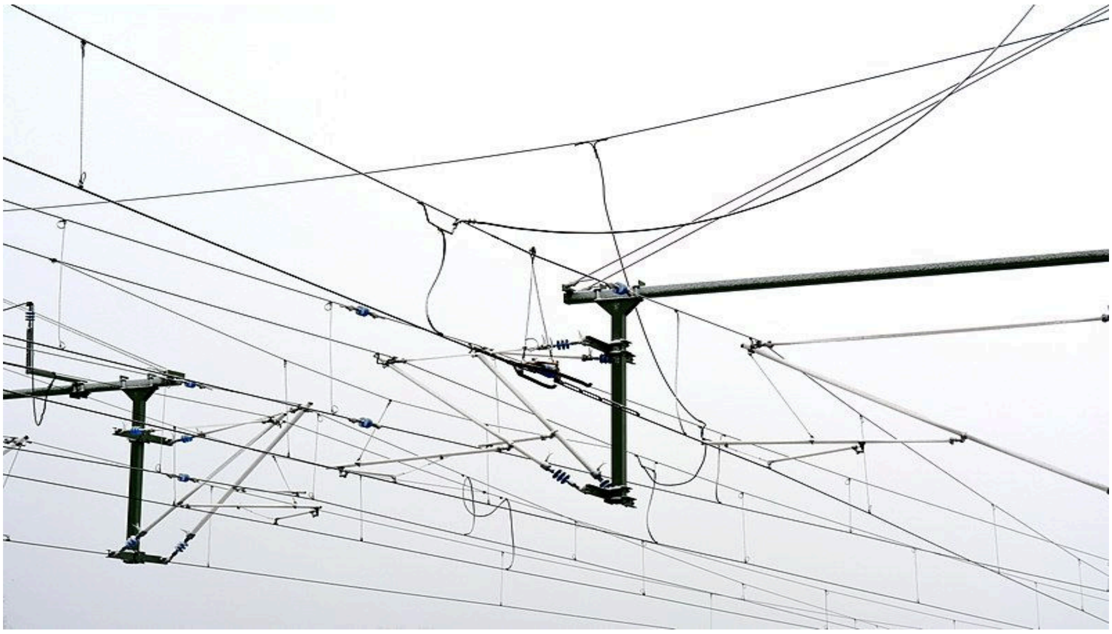
The grounding grid is placed underneath the entire electrical substation which has a dual purpose: operating grounding, carrying faulty currents into the earth without affecting the operation of any protective equipment, and safety for personnel in the vicinity assuring that they are not exposed to an electric shock

One of the fundamental parts of the electrical substation is a ground grid which provides proper grounding of all apparatus in substations (including transformers, circuit breakers, capacitor banks, steel tower structures, etc.). The grounding grid is placed underneath the entire electrical substation which has a dual purpose: operating grounding, carrying faulty currents into the earth without affecting the operation of any protective equipment, and safety for personnel in the vicinity assuring that they are not exposed to an electric shock which could result from the excessive step or touch potentials.

*The grounding grid is placed underneath the entire electrical substation*

## 3. Overhead line

*This article is about the transmission of electrical power to road and rail vehicles. For transmission of bulk electrical power to general consumers, see [Electric power transmission](). For powerlines mounted on pylons, see [Overhead power line](). For lines carrying information, see [Overhead cable]()*



- An **overhead line** or **overhead wire** is an electrical cable that is used to transmit electrical energy to electric locomotives.

## 4.Transformer for measurement of electric voltage

A transformer that is used to measure electrical quantities like current, voltage, power, frequency and power factor is known as an **instrument transformer**. These transformers are mainly used with relays to protect the power system.

## 5. Disconnect switch

Disconnect switches are **normally used to provide a point of visual isolation of the substation equipment for maintenance**. Typically a disconnect switch would be installed on each side of a piece of substation equipment to provide a visible confirmation that the power conductors have been opened for personnel safety.

A disconnect switch is a mechanical device that conducts electrical current and provides an open point in a circuit for isolation of circuit breakers, circuit switchers, power transformers, capacitor banks, reactors or any other substation equipment. Disconnect switches are also known as isolators in some part of the world.

The three most important functions disconnect switches must perform are

- to open and close reliably when called to operate,
- to carry load currents continuously without overheating,
- and to remain in the closed operation position under fault current conditions.

Disconnect switches are normally used to provide a point of visual isolation of the substation equipment for maintenance.


## 6. Circuit breaker

A **circuit breaker** is an electrical safety device designed to protect an electrical circuit from damage caused by an overcurrent or short circuit. Its basic function is to interrupt current flow to protect equipment and to prevent the risk of fire. Unlike a fuse, which operates once and then must be replaced, a circuit breaker can be reset (either manually or automatically) to resume normal operation.

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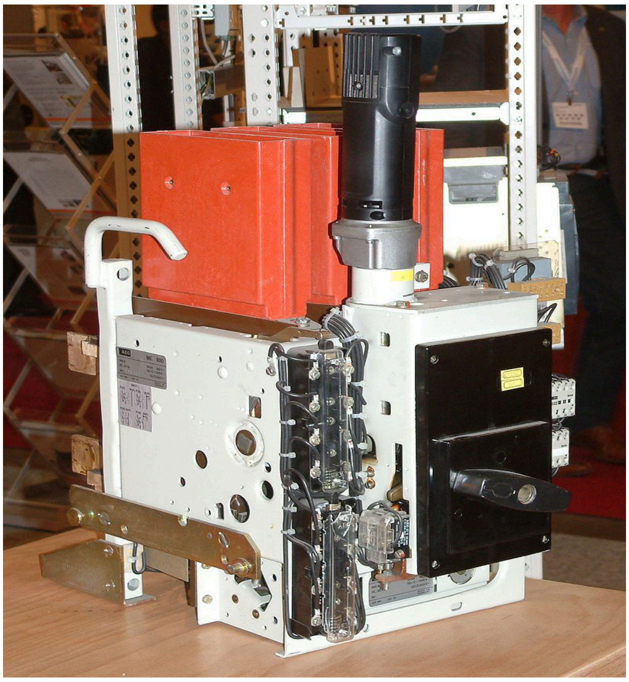

## Operation

All circuit breaker systems have common features in their operation, but details vary substantially depending on the voltage class, current rating and type of the circuit breaker.

The circuit breaker must first detect a fault condition. In small mains and low voltage circuit breakers, this is usually done within the device itself. Typically, the heating or magnetic effects of electric current are employed. Circuit breakers for large currents or high voltages are usually arranged with protective relay pilot devices to sense a fault condition and to operate the opening mechanism. These typically require a separate power source, such as a battery, although some high-voltage circuit breakers are self-contained with current transformers, protective relays, and an internal control power source.

Once a fault is detected, the circuit breaker contacts must open to interrupt the circuit; this is commonly done using mechanically stored energy contained within the breaker, such as a spring or compressed air to separate the contacts. Circuit breakers may also use the higher current caused by the fault to separate the contacts, such as thermal expansion or a magnetic field. Small circuit breakers typically have a manual control lever to switch off the load or reset a tripped breaker, while larger units use solenoids to

## Types

Many classifications of circuit breakers can be made, based on their features such as voltage class, construction type, interrupting type, and structural features:

## Low-voltage Circuit breaker

Low-voltage (less than 1,000 $V_{AC}$) types are common in domestic, commercial and industrial application, and include:

- Miniature circuit breaker (MCB)—rated current up to 125 A. Trip characteristics normally not adjustable. Thermal or thermal-magnetic operation. Breakers illustrated above are in this category.
- Molded Case Circuit Breaker (MCCB)—rated current up to 1,600 A. Thermal or thermal-magnetic operation. Trip current may be adjustable in larger ratings.
- Low-voltage power circuit breakers can be mounted in multi-tiers in low-voltage switchboards or switchgear cabinets.

The characteristics of low-voltage circuit breakers are given by international standards such as IEC 947. These circuit breakers are often installed in draw-out enclosures that allow removal and interchange without dismantling the switchgear.

Large low-voltage molded case and power circuit breakers may have electric motor operators so they can open and close under remote control. These may form part of an automatic transfer switch system for standby power.

## Medium-voltage Circuit breaker

Medium-voltage circuit breakers rated between 1 and 72 kV may be assembled into metal-enclosed switchgear line ups for indoor use, or may be individual components installed outdoors in a substation. Air-break circuit breakers replaced oil-filled units for indoor applications, but are now themselves being replaced by vacuum circuit breakers (up to about 40.5 kV). Like the high voltage circuit breakers described below, these are also operated by current sensing protective relays operated through current transformers. The characteristics of MV breakers are given by international standards such as IEC 62271. Medium-voltage circuit breakers nearly always use separate current sensors and protective relays, instead of relying on built-in thermal or magnetic overcurrent sensors.

Medium-voltage circuit breakers can be classified by the medium used to extinguish the arc:

- ## Vacuum circuit breakers

With rated current up to 6,300 A, and higher for generator circuit breakers application (up to 16,000 A & 140 kA). These breakers interrupt the current by creating and extinguishing the arc in a vacuum container - aka "bottle". Long life bellows are designed to travel the 6–10 mm the contacts must part. These are generally applied for voltages up to about 40,500 V,[10] which corresponds roughly to the medium-voltage range of power systems. Vacuum circuit breakers have longer life expectancy between overhaul than do other circuit breakers. In addition their global warming potential is by far lower than $SF_6$ circuit breaker.

- ## $SF_6$ circuit breakers

extinguish the arc in a chamber filled with sulfur hexafluoride gas.

Medium-voltage circuit breakers may be connected into the circuit by bolted connections to bus bars or wires, especially in outdoor switchyards. Medium-voltage circuit breakers in switchgear line-ups are often built with draw-out construction, allowing breaker removal without disturbing power circuit connections, using a motor-operated or hand-cranked mechanism to separate the breaker from its enclosure.

## High-voltage Circuit breaker

Electrical power transmission networks are protected and controlled by high-voltage breakers. The definition of *high voltage* varies but in power transmission work is usually thought to be 72.5 kV or higher, according to a recent definition by the International Electrotechnical Commission (IEC). High-voltage breakers are nearly always solenoid-operated, with current sensing protective relays operated through current transformers. In substations the protective relay scheme can be complex, protecting equipment and buses from various types of overload or ground/earth fault.

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**General**

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## 7. Current Transformer

A Current Transformer (CT) is used to measure the current of another circuit. CTs are used worldwide to monitor high-voltage lines across national power grids. A CT is designed to produce an alternating current in its secondary winding that is proportional to the current that it is measuring in its primary. In doing so, the current transformer reduces a high current to a lower value and therefore provides a safe way of monitoring electrical current flowing in an AC transmission line

### 8. Lightning arrester

The circuit which is protected from the strokes of lightning with the help of a protection device is known as lightning arrester. Here the lightning strokes are nothing but surges with high transient voltage, arcs of isolation, spark, and surge currents because of lightning, etc. These devices are used to defend the power systems by forwarding the high voltage surges in the direction of the ground. And these power systems and over headlines can also be protected by using ground wire or the earthing from the direct strikes of lightning. The **lightning arrester diagram** is shown below.

## Advantages

The **advantages of lightning arrestor** are

- Property damage can be reduced from strokes of lighting.
- Outdoor equipment of the substation can be protected
- Avoid damage in lines
- Outlet surges can be avoided
- Electromagnetic interference
- Simple to use

## Disadvantages

The **disadvantages of lightning arrestor** are

- It occupies more space
- The installation cost is high.

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## 9. Main Transformer

A transformer substation is a part of the electrical installation that includes the terminations of the transmission or distribution lines and switchgear. It contains one or more transformers as the central part. The substation also typically includes all the necessary devices for control and protection of electricity and itself.
Transformer substations transform voltage from high to low, or the reverse, or perform any of several other important functions. Before being used, electric power may flow through several transformer substations at different voltage levels. A transformer substation includes transformers to change voltage levels between high transmission voltages and lower distribution voltages, or at the interconnection of two different transmission voltage

Power Transformer is the Most Important and costliest electrical device in the transmission substation and in the Power Grid.

The function of Power Transformer in Substation is to transform the Voltage level.

## *Applications of Power Transformers:*

1. Generator Transformers
2. Unit auxiliary Transformers/ station Transformers
3. Transmission Transformers
4. Auto Transformers

## *Type of transformer used in substation*

Based on Voltage Level:

High Voltage Transformer

Low Voltage Transformer

### Based on design:

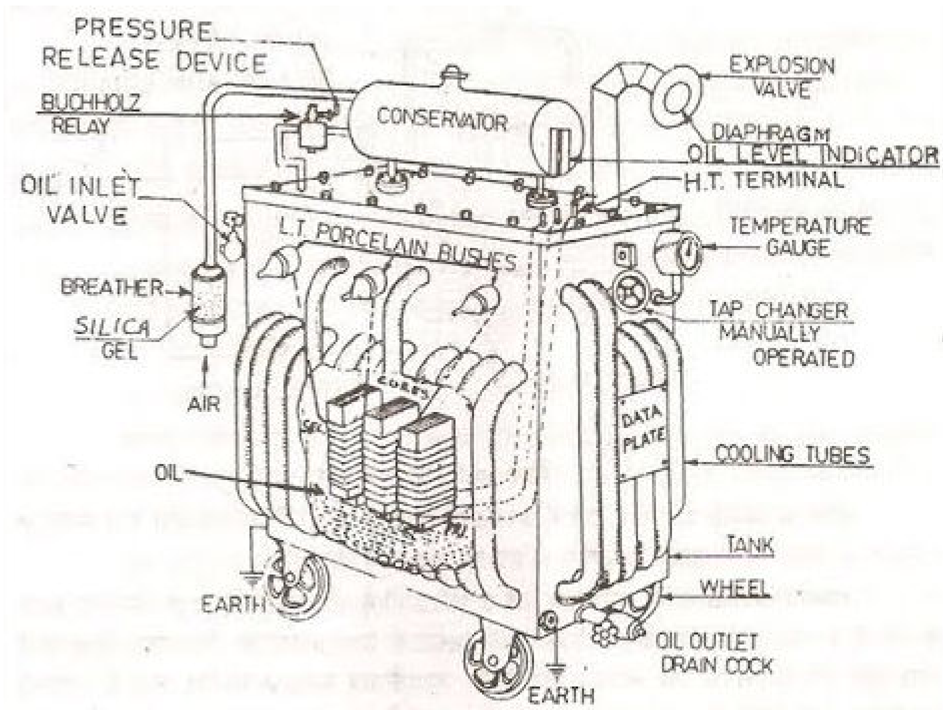
- Shell type transformer
- Core type transformer

### Base upon cooling:

1. ONAN (all natural air natural): cooling is done by using radiators
2. ONAF (Oil Natural Air Forced): cooling is done using Radiator and Fan

3. OFAF (Oil Forced Air Forced): Colling is done using Radiator, Fan and Pump
4. OFW (Oil forced water): Cooling is done using Heat Exchangers.

# Parts of transformer and their functions




## Following are the various parts of transformer:

1. Laminated core
2. Windings
3. Insulating material
4. Tank
5. Terminals and bushings
6. Transformer oil
7. Tap changer
8. Buchholz relay
9. Oil conservator
10. Explosion vent
11. Breather

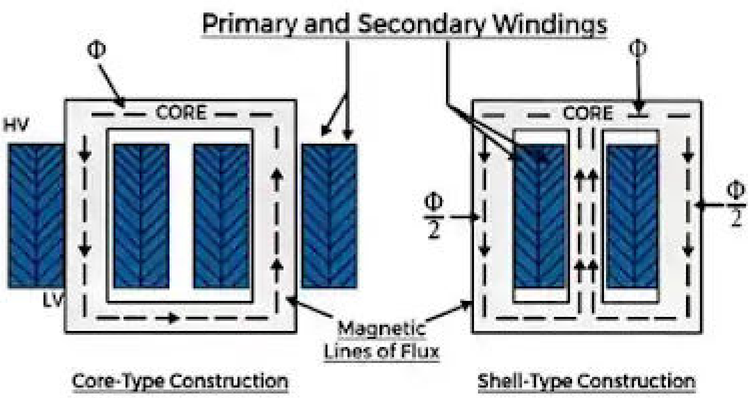
12. Radiator and fans
13. Insulating Transformer Oil
14. Cooling Tubes
15. Insulating Materials
16. Earth connector
17. Wheel

## *Laminated core*

Laminated core is the most important parts of transformer, used to support the windings of transformer. It is made up of laminated soft iron material to reduce eddy current loss and hysteresis loss. Nowadays in the core of transformer laminated sheets are used to minimize eddy current losses and CRGO steel material is used to minimize hysteresis losses. The composition of core material depends on the voltage, current, and frequency of supply to the transformer.

## *Windings*

In a transformer always two sets of windings are placed on laminated core and these are insulated from each other. Winding consists of several no of turns of copper conductors that is bundled together and connected in series.




*windings of transformer*

The main function of windings is to carry current and produce working magnetic flux and induce mutual EMF for transformer action.

Windings are classified in two ways:

- Based on the input and output of supply
- Based on the voltage level of supply

Based on the input and output of the supply, windings are further classified as:

1. **Primary winding**:- the winding at which the input supply is connected is known as the primary winding.

2. **Secondary winding**:- the winding from which output is taken to the load is known as the secondary winding.

## *Insulating material*

Since insulation failure can cause the most severe damages to the transformer. So insulation and insulating material should be high grade and it is the most important part of transformer. Insulation is required between each turn of windings, between windings, winding and core, and all current-carrying parts and tank of transformer.

The main function of insulating material is to protect transformer against short circuits by providing insulation to windings so that it does not come in contact with the core and any other conducting material.

## *Main Tank*

Main tank is the robust part of transformer that serves mainly two purposes:

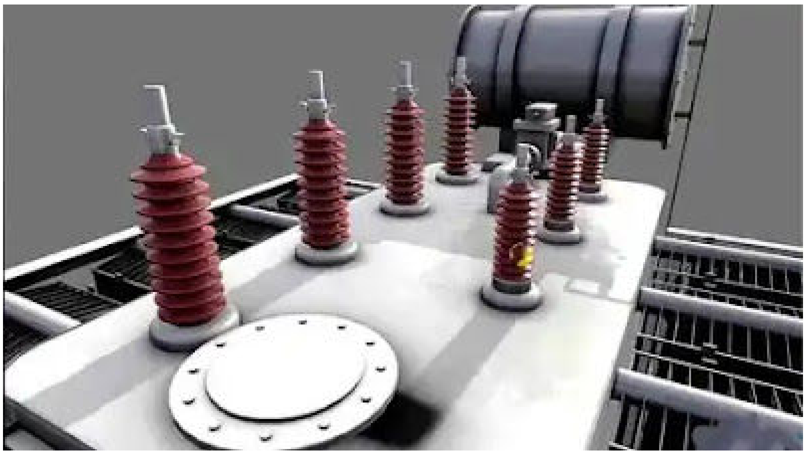
1. It protects core and windings from the external environment and provide housing for them.

2. It is used as a container for transformer oil and provides support for all other external accessories of the transformer.

*The main tank of the transformer*

## *Terminals and bushings*

Terminals and bushings are also important parts of the transformer that are used to connecting incoming and outgoing cables of supply and load. These are connected with the ends of the windings conductor.



***bushings of transformer***

Bushings are mainly an insulators made up of porcelain or epoxy resins. They are mounted over the tank and forms a barrier between terminals and tank. They provide safe passage for the conductor connecting terminals to the windings.

As windings are of two types and so bushings are also of two types as named below:

1. High-voltage bushing
2. Low-voltage bushing

## *Transformer oil*

The function of transformer oil is to provide insulation between windings as well as cooling due to its chemical properties and very good dielectric

It dissipates the heat generated by the core and windings of a transformer to the external environment. When the windings of transformer gets heated due to flow of current and losses, the oil cools down the windings by circulating inside the transformer and transfer heat to the external environment through its cooling tubes.

## *Tap changer*

**The main function of the tap changer is to regulate the output voltage of** transformer by changing its turns ratio. There are two types of tap changers.

1. **On-load tap changer**:- in an on-load tap changer, tapping can be changed without isolating the transformer from the supply. Hence it is capable to operate without interrupting the power supply.

2. **Off-load tap changer**:- in off-load tap changer, the transformer needs to isolate from supply to change its tapping (turns ratio).

An automatic tap changer is also available.

## *Buchholz relay*

Buchholz relay is the most important part of a power transformer rated more than 500kVA. It is a gas-actuated relay mounted on the pipe connecting the main tank and conservator tank.

The function of the Buchholz relay is to protect the transformer from all internal faults such as short circuit fault, inter-turn fault, etc

When short circuit occurred in winding then it generates enough heat to decompose transformer oil into gases ( hydrogen, carbon monoxide, methane, etc). These gases move towards the conservator tank through a connecting pipe, then due to these gases, Buchholz relay gets activated. It sends signal to trip and alarm circuits and activate it. Then circuit breaker disconnects the transformer from the supply.

## *Oil conservator*

The function of the oil conservator tank is to provide adequate space for expansion and contraction of transformer oil according to the variation in the ambient temperature of transformer oil inside the main tank.

It is a cylindrical drum-type structure installed on the top of the main tank of the transformer. It is connected to the main tank through a pipe and a Buchholz relay mounted on the pipe. A level indicator is also installed on the oil conservator to indicate the quantity of oil inside the conservator tank. It is normally half-filled with transformer oil.

## Breather

Breather is a cylindrical container filled with silica gel and directly connected with the conservator tank of the transformer.

The main function of the breather is to supply moisture-free fresh air to the conservator tank during the expansion and contraction of transformer oil. This is because the transformer oil when reacting with moisture can affect the insulation and cause an internal fault in a transformer. That's why the air entering in conservator tank should be moisture free for better life of transformer oil.

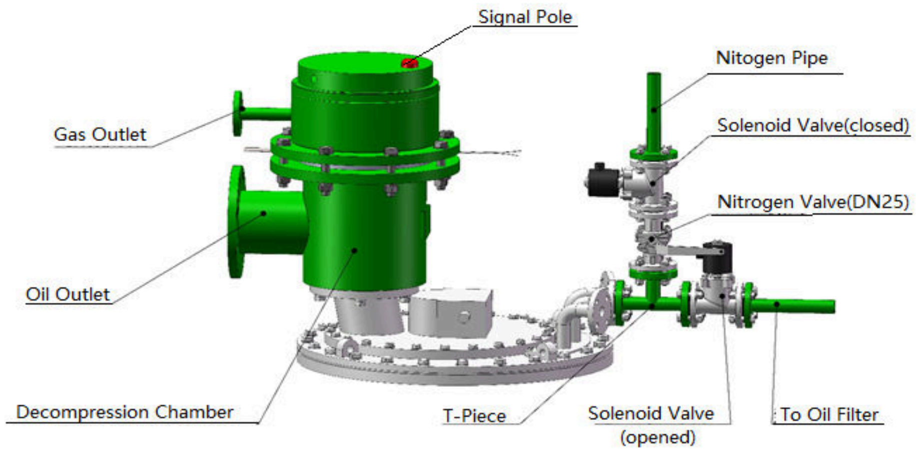
In a breather, when air passes through silica gel then moisture present in the air is absorbed by silica gel crystal and hence a moisture-free dry air is supplied to the conservator tank. Thus we can also say that breather is acting as an air filter for the transformer.

## Explosion vent

Explosion vent is a metallic pipe with a diaphragm at one end and installed on the main tank slightly above than conservator tank. It is available only in high rated power transformer.

The main function of the explosion vent is to protect power transformer against explosion during excessive pressure build up in the main tank due to severe internal faults. It acts as an emergency exit for oil and hot air gases inside the main tank of the transformer.

The explosion vent works on the same principle as the safety valve works in the pressure cooker. Hence In other words we can also called the explosion vent as safety valve of the transformer.




## Insulating Transformer Oil

Insulator transformer oil works a lot. It helps keep the transformer cool. Protects the device from major accidents by controlling the sparks from winding. Reduces current loss of the transformer. It needs to be replaced when the oil is lost as a result of regular use. The transformer has to maintain certain values in this oil.

## *Radiator and fans*

Since power losses in the transformer are dissipated in the form of heat. So a cooling arrangement is required for the power transformer. Dry-type transformers are generally natural air-cooled. But when we talk about oil-immersed transformers then several cooling methods are used depending upon kVA rating, power losses, and level of cooling required.

Hence to provide proper cooling, radiators and fans are installed on the main tank of the power transformer. Radiators are also called cooling tubes.

The main function of cooling tubes or radiators is to transfer heat generated by core and windings to the environment by circulating heated oil throughout the cooling tubes.

In a large power transformer, forced cooling is achieved with the help of cooling fans fitted on the radiator.

## Insulating Materials

Insulators are used to increase the efficiency of transformer work. It is also used to avoid the connection between two wires. It protects the transformer from various accidents—a heated element of a transformer such as heated crepe paper, transformer oil, etc.

## Earth connector

When an electric current is complete, electrons flow from negative to positive. And the electric current flows from positive to negative. If for some reason suddenly the amount of positive charge in the transformer increases, it has to be reduced, otherwise there is a possibility of an accident.

So, the ground connection is given to the transformer to eliminate this positive charge because this extra charge will go to the ground and protect the transformer from accidents.

## Wheel

The transformer is a very heavy device, so it cannot be transferred very easily. But sometimes, it needs to be relocated. Therefore, the wheel is provided as required with its lower structure for easy transfer.

## 10.Control building

All substation control and protection systems, including system splitting devices, steady-state overvoltage control system, and other safe controls, are subjected to comprehensive check and immunity test, the results of which show that the system and auxiliary equipment are operating normally.
ans The necessity for supplemental equipment such as protection relays, controls, batteries, communications equipment, and LV distribution equipment also increases. And all that equipment must be placed somewhere in the field. That’s why the substation needs a control house In short.

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