بۆ یەکێتی ئەندازیارانی کوردستان

KURDISTAN ENGINEERS UNION

REPORT FOR

OPERATION OF DOUBLE BUSBAR POWER SUBSTATION

ئەندازیار

امیر علی محمد

پلە ڕپێدراو

Abstract

A substation receives electrical power from generating station via incoming transmission line and delivers electrical power through feeders and this is used for controlling the power on different routes . Substation are integral part of power system and form important part of transmission and distribution network of electrical power system . Their main functions are to receive energy transmitted at high voltage from the generating stations , reduce the voltage to a value appropriate for local distribution and provide facilities for switching , some sub-station are simply switching stations different connections between various transmission lines are made , others are converting sub-stations which either convert AC into DC or vice-versa or convert frequency from higher to lower or vice-versa .The various circuits are joined together through these components to a bus-bar at station . Basically , sub-station consist of power transformer ,circuit breakers ,relays ,isolators , earthing switches ,current transformer , voltage transformer, synchronous condensers/ capacitor banks etc. This project cover substations and it is types and component, and operation And we choose double busbar as the main subject of our research because of its important and uses in all substation.

Aim

The main objective of this project is to studying of double busbar substation which is one of the most common types of power substation that used in national and regional power station in terms of operation ,maintenance and control , these substation are preferred for easing control of where the maintenance when there is a problem in a particular place or when connecting feeders and the other components such as (transformer , bank capacitor …etc).

Table of Contents

List of figures:

List of tables:

Chapter One

CHAPTER ONE
SUBSTATION

1.1 Introduction

Electricity is one of the most important inventions that have been reached since ancient times and have continued to be needed until this time. They are the most abundant sources of energy that have become involved in many fields of life, such as scientific, practical and economic aspects. Between the ancient and modern times, and it must be noted that it is obtained from two sources, one renewable such as the sun and wind, and the other is not renewed, such as oil, and despite the many benefits that facilitated the lives of people, but is considered a double-edged sword, Material And humanity. After the studies and experiments, it was necessary to benefit from electricity and sensing through the so-called generation of electricity, ie access to electricity, it was the chemical reactions and electromagnetic induction, through a tool that revolves a winding in a magnetic field, this is called electric generator or dynamo, and this What Faraday did in 1831 when he founded the first technique of electric motor, which is a small model is managed by hand. Large generators are driven by mechanical means, and the electrical stations that operate on nuclear energy, coal or oil generators are rotated in Turbine Which are connected directly to generators, and also appeared in the so-called generation of electricity through water turbines that rely on the power of natural waterfalls or artificial dams, and the electricity is transmitted through electrical transformers, which controls the long-distance electric current, which runs through large electric wires, Less heavy to be distributed to homes and various industrial and service facilities, after we generate the power we distribute it by distribution Substations which is one of the main components of any electrical system. The electrical system is a simple electrical circuit consisting of a source of energy, transmission lines and distribution. The transformer stations provide the regional electrical connection of transport networks between the neighboring countries, which increases the reliability of the electrical systems in terms of production and exchange of electric power between the neighboring countries.

The functions of is to find the common points of connection of the generation stations by connecting them to the system of the common electrical system by raising the voltage of generators in the power stations to the voltage of the unified system network and thus enable the transfer of electricity generated to consumption, To reduce the values of high and medium voltages at consumption within the limits and requirements appropriate to the consumer, Regulating the voltage of the electrical network by means of switching switches at high and medium capacity switching stations, Protection of the electrical circuits associated with the electrical system such as transformers and circuit circuits through the protection systems that ensure that the parts of the affected by the faults without affecting the other parts, and thus continuity in the transmission and distribution of electric power, Separation of electrical circuits such as circuits and transformer circuits when required maintenance procedures and programmed tests. The main part that we talk about is double bus bar substation This type is required two bus bar and it’s very important because This type of arrangement provides the maximum reliability and flexibility in the supply. Because the fault and maintenance would not disturb their continuity. The continuity of the supply remains same because the load is transferrable from one bus to another on the occurrence of the fault.

1.2 Definition Substation:-

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.

1.3 CLASSIFICATION OF SUB-STATIONS:-

1.3.1 According to service requirement:-

a) Transformer substations

b) switching substations

c) Power factor substations

d) Frequency substations

e) Converting substations

f) Industrial substations

a) Transformer Substations: an electric substation that steps up or steps down the voltage of an AC power system, and also distributes electric power. Step-up substations, which are usually built at electric power plants, transform the voltage produced by the generators into a higher voltage (of one or more values) that is necessary for the transmission of electric power over power lines. Step-down substations transform the primary voltage of electric power systems to a lower secondary voltage. Step-down substations may be of the regional, principal, or local (plant) type, depending on their purpose and the values of the primary and secondary voltages. Regional substations take electric power directly from the high-voltage power lines and transmit it to the main step-down substations, from which—after reduction to 6, 10, or 35 kilovolts (kV)—it is fed to local and shop substations, where the last stage of transformation is accomplished (with step-downs to 690, 400, or 230 V) and the electric power is distributed to consumers. The site of a transformer substation depends on the station's purpose and the nature of the loads. Substations having secondary voltages of 6,10, 35, and 110 kV are usually centrally located with respect to the consumers they serve, thereby reducing power losses in transmission, as well as the consumption of construction materials for the distribution system. Among the factors considered in the siting of plant substations are the layout of the production areas, the arrangement of equipment, the environmental conditions, and fire safety requirements. The substation equipment may be outdoors or in an enclosure, such as a separate building.

b) Switching substation: A switching station is a substation without transformers and operating only at a single voltage level. Switching stations are sometimes used as collector and distribution stations. A switching station may also be known as a switch yard , The function of the switching station is to isolate the faulted portion of the system in the shortest possible time. Remote control of substations and switching stations has been and still is a priority in the most of distribution companies. Substation is the node point and the most important element of distribution grid, so eventual failure has a major impact on a large part of distribution network in specific location. That's why it is very important to not only disconnect existing fault and protect affected part of the line from destruction, but also identify the affected line

Fig 1.1

and the exact location of the fault as quickly as possible, that the service team can eliminate the fault in the shortest possible time.

Fig 1.2

c)Power Factor Substations: they improve the power factor of the system by using synchronous condensers, Power-factor correction increases the power factor of a load, improving efficiency for the distribution system to which it is attached. Linear loads with low power factor (such as induction motors) can be corrected with a passive network of capacitors or inductors. Non-linear loads, such as rectifiers, distort the current drawn from the system. In such cases, active or passive power factor correction may be used to counteract the distortion and raise the power factor. The devices for correction of the power factor may be at a central substation, spread out over a distribution system, or built into power-consuming equipment.

***Methods of Power Factor Improvement**:-

i) Capacitors: Improving power factor means reducing the phase difference between voltage and current. Since majority of loads are of inductive nature, they require some amount of reactive power for them to function. This reactive power is provided by the capacitor or bank of capacitors installed parallel to the load. They act as a source of local reactive power and thus less reactive power flows through the line. Basically they reduces the phase difference between the voltage and current.

Synchronous Condenser: They are 3 phase synchronous motor with no load attached to its shaft. The synchronous motor has the characteristics of operating under any power factor leading, lagging or unity depending upon the excitation. For inductive loads, synchronous condenser is connected towards load side and is overexcited. This makes it behave like a capacitor. It draws the lagging current from the supply or supplies the reactive power.

ii) Phase Advancer: This is an ac exciter mainly used to improve pf of induction motor. They are mounted on shaft of the motor and is connected in the rotor circuit of the motor. It improves the power factor by providing the exciting ampere turns to produce required flux at slip frequency. Further if ampere turns are increased, it can be made to operate at leading power factor.

Fig 1.3

d) Frequency Substations: those sub stations which change supply frequency , A frequency changer is a motor-generator set that changes power of an alternating current system from one frequency to one or more different frequencies, with or without a change in the number of phases, or in voltage. Sometimes a converter is used to accomplish this.

e) Converting Substations : A converter station converts electricity between Alternating Current (AC) and Direct Current (DC). AC is used in each country's transmission systems, while DC is used for sending electricity along the subsea cable. Converter substations may be associated with HVDC converter plants, traction current, or interconnected non-synchronous networks. These stations contain power electronic devices to change the frequency of current, or else convert from alternating to direct current or the reverse. Formerly rotary converters changed frequency to interconnect two systems; such substations today are rare.

Fig 1.4

1.3.2 According to Constructional Features:-

A) Indoor substation : the substation are constructed under roof is called indoor type substation ,generally 11KV and sometime 33KV substation are of this type . these types of substation occupy to outdoor substation these types of substation serves peak load sometimes, The indoor substation is subdivided into several compartments like control compartment, indicating and metering instruments and protective device compartment main bus-bar compartment, current transformer and cable sealing box compartment as shown in the figure below. indoor-substations The switch gear on the supply or primary side will consist of oil circuit breaker only. The high voltage supply is given to the primary of the transformer through a circuit breaker. From the bus bar, various feeders emerge out. The panel on each feeder consists of an isolator switch and a circuit breaker. In addition to isolator and circuit breaker, the panel also provided the measuring instrument .For the protection of feeders usually, reverse power relay is used. For the protection of oil filled transformer Buchholz relay is used. The accessories of the indoors type substations are a storage battery, fire fighting equipment such as water, buckets, and fire extinguisher, etc., The battery is used for the operation of protective gear and switching operating solenoids and emergency lighting in substations in the case of failure of supply .Indoor substations and transformer substation, as well as, high voltage switchboards consist of a series of open and enclosed chamber or compartments. The main equipment for this installation is arranged in these compartments. The chamber space within which the equipment of the main bus-bar is connected is called a compartment or a cubical cell .Substations of the Integrity Built Type In such type of substation, the device is equipped on site. In such substation, the cell structure is constructed of concrete or bricks .Substations of the Composite Built-Up Type In such type of substations factory or workshop are built but are assembled on site within a substation switch gear room. The compartments of such substations take the form of metal cabinets or enclosures, each of which contains the equipment of one main connection cell. In such cabinets, an oil circuit breaker, a load interrupter switch, and one or more voltage transformers may be mounted .Unit Type Factory Fabricated Substations and Metal Clad Switchboards These are built in electrical workshops and are carried to the site of installations fully pre-assembled. After installations of substations and switchboards only connection to the incoming and outgoing power circuits are required to be made.

Fig 1.5

B)Outdoor substation: A substation which is used for all voltage levels between 55 KV to 765 KV is called outdoor substation. Such type of substation requires less time for construction but uses more space. The outdoor substations are mainly classified into two types, namely pole-mounted substation and foundation-mounted substations.

Pole Mounted Substation

Such substations are used for supporting distribution transformers having the capacity up to 250 KVA. Such types of transformers are the cheapest, simplest, and smallest of distributions. All the equipment is the outdoor type and mounted on the supporting structures of high tension distribution line. Triple pole mechanically operated switch used for switching on and off the high tension transmission line.HT fuse is used for protection of the high tension transmission line. For controlling the low tension lines, low tension switches along with fuses is equipped. Lightning arresters are equipped over the high tension line for the protection of the transformers from the surges. Pole-Mounted substations are earthed at two or more places. pole-mounted-substations (Pole-Mounted Outdoor Substation) The transformers having a capacity up to 125 KVA are mounted on the double pole structure and for the transformer having a capacity between 125 to 250 KVA 4-pole structure with the suitable platform is used. Such types of the substation are placed in very thickly populated location. Their maintenance cost is low, and by using a large number of the substation in a town, it is desirable to lay the distributors at a lower cost. But when the number of transformers is increasing, total KVA is increased, no load losses in increases and the cost per KVA increases.

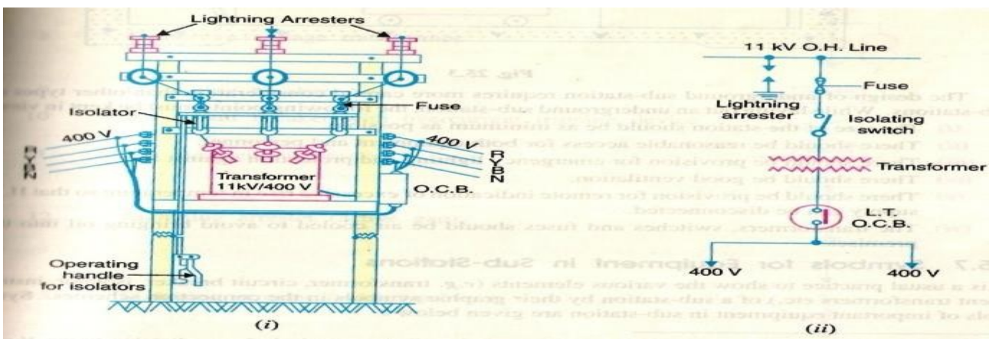


Fig 1.6

- Foundation Mounted Substation

In foundation mounted substation all the equipment area assembled and the substations are embedded by the fence for safety purpose. The equipment required for such type of substations are heavy, and hence the site selected for such type of substation must have a good path for heavy transport.

c) underground substation: The substation are situated at underground is called underground substation ,in congested places where can go for underground sub-station scheme.

While designing a underground sub station the following points are to be followed:

the size of substation should be minimum

There should be reasonable access for both equipment

There should be provision for emergency lights and protection against fire

There should be good ventilation

the transformers,switches,fuses should be air cooled to avoid bringing oil into premises

CHAPTER TWO

CHAPTER TWO

EQUIPMENT of SUBSTATION

2.1 Transformer: A transformer is an electrical device by which electricity can be transferred from one circuit to another at the same frequency

With the lifting or lowering of the voltage followed by lowering or raising the current successively.

The principle of conversion : The basis of the transformer's work depends on the mutual induction feature between two winding linked together in a field

Magnetic joint.

The transformer is enclosed in the simplest form of two non-electrically connected winding with a magnetic circle

If a coil is connected to an alternating electrical source, a magnetic flow is required

The same source frequency arises during the magnetic circuit, breaking the second coil and generating a momentum

When the second circuit is closed, an electrical current passes through it, transferring the electrical energy from the first coil

Primary) to the second winding is called the first winding connected to the source primary winding

(Secondary Winding) while the second winding is called the secondary winding (Winding

2.1.2 Type of transformer : (Iron Core) and the iron (Windings) The transformation consists of the basic elements are the coils

In terms of the position of the coils for the iron pipe there are two types:

i) Core-Type: Iron pulp The coil around the iron core is damaged.

ii) Shell type :The structural type of shell-type, where the iron core surrounds the winding, is a shield. The steel pulp is generally made of steel laminate, which is isolated from each other and assembled together so that the air gaps are as low as possible .There is a high proportion of silicon in the plate industry where thermal treatment is treated for high permeability Hysteresis Loss The purpose of plate use is to reduce energy lost due to eddy currents, where these currents increase as plate thickness increases. The ease of isolating the low-voltage coil from the iron core compared to the high-voltage coil is that the first is always placed close to the pulp in the pulp-type transformer (type I). In the second type (Shell-Type), the final parts are always low-voltage winding. The space left between the winding facilitates the cooling process as well as being neutral.

It remains to be known that high voltage and low voltage power winding exist between the low voltage and the iron block. These insulators are made of special paper known as bakelite paper. Connectors can be made of paper or cotton.

2.1.3 Cooling transformers : The process of cooling in the transformers is important in maintaining the insulators from the deterioration where the methods used in the cooling can be summarized as follows:

i) Natural Cooling (AN) This method is cooled by air circulation without the need for special cooling equipment, where the pulp and winding are directly exposed to the surrounding air . The method is used with small transformers (Few Kilo Volt Ampere) When efforts are low.

ii) Air Forced (AF) or Air Blast (AB) This method improves cooling by pushing the antenna through a fan and wave with appropriate guides.

iii)Oil Immersed with Natural Cooling (ON) The vast majority of transformers cooled naturally by immersing them in oil where the oil in the cooling ducts and the contact with the winding and the pulp and the heat by thermal conductivity Which leads to the rise to the top to replace cold oil in the bottom of the container and transfer heat from hot oil to the surface of the vessel where the radiation to the air surrounding the container and oil cooled down to the bottom and so on.

To increase the rate of heat dissipation from the surface of the oil pot, follow industrial means to increase the area of the section without increasing the size, including:

a) Fins are vertically welded on the sides of the vessel, b) corrugations in the vessel walls, and c) round tubes around the container.

iv) Oil Forced (OF):In high voltage transformers and due to high temperature and to increase the efficiency of their work, the oil is used through a pump from the top of the container to the cooling unit and then cool back to the bottom of the vessel is done Use water here in the cooling process.

2.1.4 Efficiency of transformer: The efficiency of the conversion depends mainly on the pregnancy burden. It may occur that a highly efficient conversion at full pregnancy is not efficient enough at half the load. If the transducer is likely to use long hours at half the load and a few hours at full load, its efficiency may appear low during the day. There is therefore no need to create a new term that is daily efficiency. Daily efficiency is defined as the ratio of energy out of converted to energy entering within 24 hours. As the loss of the pulp in a permanent and consistent and regardless of the loads that are exposed to lead to a difference between the incoming and outgoing energy and thus affect the efficiency of the transformer. In addition to the loss that occurs in the pulp there is loss in the winding and the factor factor also have a direct impact on the efficiency of the day of the transformer.

2.1.5 Three Phase Transformer: Connection Three-phase transformers have multiple uses in different joints of the electrical system, but the nature of connecting and connecting these phases varies depending on the nature of the load and the level of voltages used. Three similar phase mono converters can be operated as three-phase transformers. This transformer is called Transformer Bank or a three-phase transformer can be used in the iron or structural type.The two methods above each have advantages and disadvantages, which can be summed up as follows:

i) The use of the Bank of transformers reduces the cost of the backup unit as a single-phase transformer only.

ii) If the transformer is connected (Δ−Δ)and has a malfunction in a transformer, the faulty transformer can be separated to fix it while the load processing remains (58%) of the three transformer capacity, Less space, less weight and less cost

iii) The three phase transformer requires less space, which is less weight and less - expensive

iv) A three phase transformer has a slightly higher efficiency than the transformer bank (loss reduction).

2.1.6 Type of Transformer Connection: -

i) Delta-Delta is one of the most commonly used methods of communication in low-voltage efforts. In this way, an unbalanced load can be provided in addition to the elimination of harmonics, especially the third compatibility, which appears in star-Y-Y In this type of connection, currents and volts in primary winding are 180 ° (180 °) higher than their counterparts in secondary winding.

ii) Delta-star or star-delta binding where this type is used with high voltages, especially when switching between low and high voltages such as generator voltage (20 kV → 5.5) and voltages on the load side (33 or 11 kV), where the cost is lower than that of delta delta , in which there is always a difference in phase displacement between primary and secondary winding .In fact, all high voltages are higher than the low voltages at an angle of 30 (Minus the possible phase offset), as opposed to the negative sequence quantities (Ve-seq). This difference does not appear in the relay network (Zero Seq).

iii) Linking the star-star This connection works well in the case of balanced loads, where in this type it is possible to draw a break point If an unbalanced load is connected to the transformer, this means that the voltages are different on the phases, High on insulators The properties of this type of coupling have not been used except in the case of balanced loads, in addition to the disadvantages of this type the appearance of the third compatibility where the problem can be overcome by tying a tertiary winding is tethered Delta. In this way, the economy has the cost of condoms for its road counterparts Because the effort exerted on each winding is equivalent to (3) 1 of the total effort This feature uses triple winding to eliminate the disadvantages of this connection. The triple winding have other benefits: 1 - can be used to provide additional load. 2- To connect the voltage compensator . Because of a short circuit on the transformer, the value of the tertiary coil is high enough to determine the value of the current passing through the short circuit.

iv) Linking the Open Delta or Connecting the V If a winding is deleted in a delta-delta connection, the connection is called (VV) and is used in the following cases: a - If the load is small B) If one of the converter winding becomes invalid If the load is expected to increase, it is possible to connect the VV initially and then convert it to ($\Delta - \Delta$)when the load is increased.

Auto Transformers: The self-adapter is a single-coil transformer used for both inside and outside of the primary and secondary winding in the normal transformer. Thus, the source and voltage is not isolated from each other. The transformer is used to raise or lower the voltage when the conversion rate is not high as the benefit of using it lies in the savings in the amount of copper used in the winding.

2.2.1 Circuit Breaker : it is a tool of separation and connection of the circuit and located between the source and the source of the load loads loaded from this source, moving mechanical parts in it either manual or electrically electrical to act in turn to separate the power supply from the center of loads, whatever (feeder or line ... etc) The cutter can be operated manually, electrically or self-in different shapes and ways and may be equipped with electrical protection elements fuses or relays sufficient to protect the circuit used in either automatic separation is done by the cutter in the event of short-circuit short circuit or increase the current or low voltage received from different types of protection handlers. Where the main function of the cutter is to protect the electrical network and its equipment and can control the circuit in the case of opening or closing under normal operating conditions on, off or unusual operating conditions are summarized in the following cases

i) The case of exceeding the load, which, if it continues to exceed the maximum load of the temperature allowed for transformers, cables, lines and other devices.

ii) The occurrence of a breakdown in electrical insulation leads to a shortening between the conductor and the ground or between the conductor and the other.

iii) A large drop in voltage kv may cause the system to collapse.

- The size of the cutter and its specifications depends on the following:

a. Short circuit of interrupt of IS.C session.

b. The speed of separation of the circuit (separation time).

2.2.2 The circuit breakers can be classified according to the type of medium in which the electric spark is put down as follows:

i) Air Circuit Breakers

ii) Oil Breakers Oil Circuit Breakers

iii) Vacuum Circuit Breakers

iv) SF6 Circuit Breakers

i)Air breakers: It is one of the types of circuit breakers old and not used at present, the airway insulation where the fire is extinguished generated at the moment of opening and closing circuit breaker.

Fig 2.1

ii) Oil Breakers Oil Circuit Breakers: The oil breakers are divided into two parts:

a) Bulk oil breaker breaker

Consists of a large reservoir filled with oil where the function of oil insulation and extinguish the spark generated during the separation of the contacts circuit breaker but need continuous maintenance and a large amount of oil with periodic change and check its isolation by the oil testing device.

Fig 2.2

b) Low oil breakers

The cutter consists of two contacts, one fixed and the other moving. The moving contact consists of a hollow rod with an insulated cover. When the contact is separated, the electric arc occurs between them and the lower end is pulled into the lower chamber due to the insulation on the mobile. As mentioned previously, the arc is automatically switched off when the current passes by zero, but at the same time the ionization effects must be removed and the collapse voltage of the middle between the two contacts should be removed to ensure that the electric arc is not re-ignited due to the recovered transit voltage shown between the contacts. This is done by moving the oil in the area surrounding the contacts. The engine has two movements: a movement that does not depend on current strength and current movement.

When the hollow penis moves down during the opening process, the oil flows inward to the top and then exits from the openings at the top of the penis where the direct impact of the lower end of the arc is affected. This flow of oil is sufficient to ensure that the arc is completely extinguished in case of small currents.

In the case of cutting large short currents, the final arc of the electric arc is extinguished by an oil flow movement generated by the electric arc itself. Once the bottom end of the arc enters the lower chamber, a gas bubble is created that can not extend down to 27c. The oil is pushed through the two- Ionization of the arc path and raising the voltage of the electric breakdown of the gap between the two contacts. It should be noted that these cutters need periodic maintenance as the age of contacts estimated the number of times that open and close the cutter and depends on the number of the size of the cutting current

iii) Vacuum breakers: consists mainly of a vacuum chamber with a discharge rate of less than 100000000 cm Hg and contains two contacts, one fixed and the other moving and the provisions between the contact rod and the body of the room by a blower of stainless steel And when opening the contact extends the electric arc between them in a severe path Ionization is composed of metallic vapor. When passing a zero current and extinguishing the arc, this steam condenses on the metal parts in a time not exceeding a few microseconds. This leads to a very rapid rise to the durability of the electrical insulation of the gap between the contacts and then to not re-ignite the electric arc, In order to avoid exceeding the permitted heating limit for contacts when large currents are cut, contact objects may be formed with several slanted incisions that make the direction of the current running inward so that a magnetic force is generated on the electric arc that extends between the contacts to make it move on its surface. One of the advantages of this type is that it does not contain flammable liquids such as oil or on gases that may be difficult to deal with such as sulfur hexafluoride, light weight and quiet operation. Perhaps the most important advantage of the circuit breakers is the lack of need for any maintenance work and the recall life of the longest contacts.

iv) SF6 Circuit Breakers: Of sulfur hexafluoride gas is a colorless, odorless and non-toxic synthetic gas for chemical and non-flammable reaction. And its density at atmospheric pressure is 6.07 g / l at 20 ° C and represents five times the density of the air, which is one of the heaviest gases known, and the gas has excellent thermal properties and high susceptibility to negative ionization which attract free electrons negativity - electro, making it an ideal medium to depress the electric arc and height Its high temperature helps to quickly remove the heat generated from the arc, while high negative ionization helps to provide rapid maintenance of the insulation between

Contacts. It has also been found that the use of this gas as a medium to depress the electric arc makes the process of cutting the current is not sensitive to the value of the power factor, leading to high efficiency in performance when cutting the currents Induction and capacitance. It is worth mentioning that although sulfur hexafluoride itself is not chemically effective because its products under the influence of the electric arc are very sensitive, especially in the presence of moisture, which limits the types of materials that can be used inside the cutter. In all cases, the sf6 breakers are placed such as high-absorbent aluminum oxide Gases to remove these products

2.3.1 Insulator: An electrical insulator is a material whose internal electric charges do not flow freely; very little electric current will flow through it under the influence of an electric field. This contrasts with other materials, semiconductors and conductors, which conduct electric current more easily. The property that distinguishes an insulator is its resistivity; insulators have higher resistivity than semiconductors or conductors. A perfect insulator does not exist, because even insulators contain small numbers of mobile charges (charge carriers) which can carry current. In addition, all insulators become electrically conductive when a sufficiently large voltage is applied that the electric field tears electrons away from the atoms. This is known as the breakdown voltage of an insulator. Some materials such as glass, paper and Teflon, which have high resistivity, are very good electrical insulators. A much larger class of materials, even though they may have lower bulk resistivity, are still good enough to prevent significant current from flowing at normally used voltages, and thus are employed as insulation for electrical wiring and cables. Examples include rubber-like polymers and most plastics which can be thermoset or thermoplastic in nature . Insulators are used in electrical equipment to support and separate electrical conductors without allowing current through themselves. An insulating material used in bulk to wrap electrical cables or other equipment is called insulation. The term insulator is also used more specifically to refer to insulating supports used to attach electric power distribution or transmission lines to utility poles and transmission towers. They support the weight of the suspended wires without allowing the current to flow through the tower to ground.

2.3.2 Types of Insulators :-

i) Pin Insulator

ii) Suspension Insulator

iii) Strain Insulator

In addition to that there are other two types of electrical insulator available mainly for low voltage application, like Stay Insulator and Shackle Insulator:-

i) Pin Insulator : is earliest developed overhead insulator, but still popularly used in power network up to 33 KV system. Pin type insulator can be one part, two parts or three parts type, depending upon application voltage. In 11 KV system we generally use one part type insulator where whole pin insulator is one piece of properly shaped porcelain or glass.

As the leakage path of insulator is through its surface, it is desirable to increase the vertical length of the insulator surface area for lengthening leakage path. We provide one, two or more rain sheds or petticoats on the insulator body to obtain long leakage path. In addition to that rain shed or petticoats on an insulator serve another purpose. We design these rain sheds or petticoats in such a way that while raining the outer surface of the rain shed becomes wet but the inner surface remains dry and non-conductive. So there will be discontinuations of conducting path through the damp pin insulator surface. In higher voltage like 33KV and 66KV manufacturing of one part porcelain pin insulator becomes difficult. Because in higher voltage, the thickness of the insulator becomes more and a quite thick single piece porcelain insulator is not practical to manufacture. In this case, we use multiple part pin insulator, where some properly designed porcelain shells are fixed together by Portland cement to form one complete insulator unit. We generally use two parts pin insulators for 33KV, and three parts pin insulator for 66KV systems.

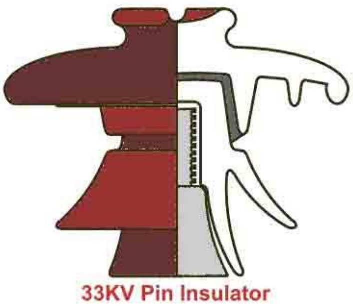


Fig 2.3

First : Designing Consideration of Electrical Insulator

The live conductor attached to the top of the pin insulator which is at the live potential. We fix the bottom of the insulator to supporting structure of earth potential. The insulator has to withstand the potential stresses between conductor and earth. The shortest distance between conductor and earth, surrounding the insulator body, along which electrical discharge may take place through the air, is known as flashover distance.

a) When the insulator is wet, its outer surface becomes almost conducting. Hence the flashover distance of insulator is decreased. The design of an electrical insulator should be such that the decrease of flashover distance is minimum when the insulator is wet. That is why the uppermost petticoat of a pin insulator has umbrella type designed so that it can protect, the rest lower part of the insulator from the rain. The upper surface of the topmost petticoat is inclined as less as possible to maintain maximum flashover voltage during raining.

b) The rain sheds are made in such a way that they should not disturb the voltage distribution. They are so designed that their subsurface at a right angle to the electromagnetic lines of force.

Second : Post Insulator

Fig 2.4

Post insulator is more or less similar to Pin insulator, but former is suitable for higher voltage application. Post insulator has higher numbers of petticoats and has greater height. We can mount this type of insulator on supporting structure horizontally as well as vertically. The insulator is made of one piece of porcelain and it has clamp arrangement are in both top and bottom end for fixing. The main differences between pin insulator and post insulator are,

SL	Pin Insulator	Post Insulator
1	It is generally used up to 33KV system	It is suitable for lower voltage and also for higher voltage
2	It is single stag	It can be single stag as well as multiple stags
3	Conductor is fixed on the top of the insulator by binding	Conductor is fixed on the top of the insulator with help of connector clamp
4	Two insulators cannot be fixed together for higher voltage application	Two or more insulators can be fixed together one above other for higher voltage application
4	Metallic fixing arrangement provided only on bottom end of the insulator	Metallic fixing arrangement provided on both top and bottom ends of the insulator

ii) Suspension Insulator

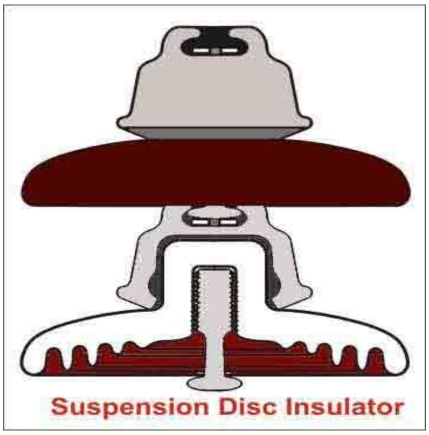


Fig 2.5

In higher voltage, beyond 33KV, it becomes uneconomical to use pin insulator because size, weight of the insulator become more. Handling and replacing bigger size single unit insulator are quite difficult task. For overcoming these difficulties, suspension insulator was developed. In suspension insulator numbers of insulators are connected in series to form a string and the line conductor is carried by the bottom most insulator. Each insulator of a suspension string is called disc insulator because of their disc like shape.

First : Advantages of Suspension Insulator:

a) Each suspension disc is designed for normal voltage rating 11KV (Higher voltage rating 15KV), so by using different numbers of discs, a suspension string can be made suitable for any voltage level.

b) If any one of the disc insulators in a suspension string is damaged, it can be replaced much easily.

c) Mechanical stresses on the suspension insulator is less since the line hanged on a flexible suspension string .

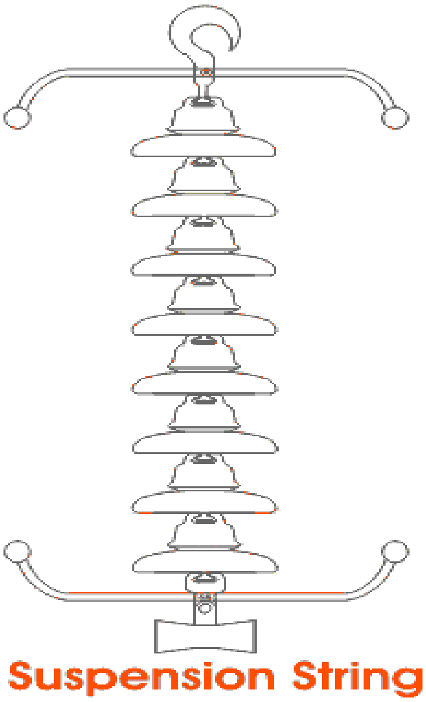


Fig 2.6

d) As the current carrying conductors are suspended from supporting structure by suspension string, the height of the conductor position is always less than the total height of the supporting structure. Therefore, the conductors may be safe from lightening.

Second : Disadvantages of Suspension Insulator:

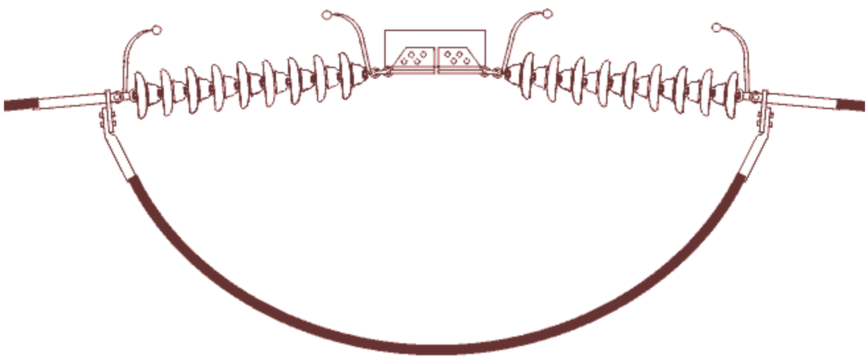
a) Suspension insulator string costlier than pin and post type insulator.

b) Suspension string requires more height of supporting structure than that for pin or post insulator to maintain same ground clearance of current conductor.

c) The amplitude of free swing of conductors is larger in suspension insulator system, hence, more spacing between conductors should be provided.

iii) Strain Insulator:

When suspension string is used to sustain extraordinary tensile load of conductor it is referred as string insulator. When there is a dead end or there is a sharp corner in transmission line, the line has to sustain a great tensile load of conductor or strain. A strain insulator must have considerable mechanical strength as well as the necessary electrical insulating properties.



STRAIN INSULATOR

Fig 2.7

Rated System Voltage	Number of disc insulator used in strain type tension insulator string	Number of disc insulator used in suspension insulator string
33KV	3	3
66KV	5	4
132KV	9	8
220KV	15	14

a) Stay Insulator:

For low voltage lines, the stays are to be insulated from ground at a height. The insulator used in the stay wire is called as the stay insulator and is usually of porcelain and is so designed that in case of breakage of the insulator the guy-wire will not fall to the ground.

Fig 2.8

b) Shackle Insulator or Spool Insulator :

The shackle insulator or spool insulator is usually used in low voltage distribution network. It can be used both in horizontal and vertical position. The use of such insulator has decreased recently after increasing the using of underground cable for distribution purpose. The tapered hole of the spool insulator distributes the load more evenly and minimizes the possibility of breakage when heavily loaded. The conductor in the groove of shackle insulator is fixed with the help of soft binding wire.

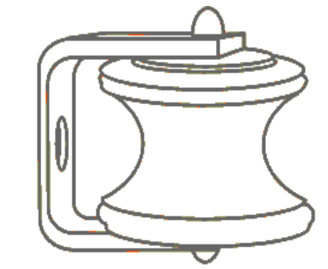


Fig 2.9

Electrical Insulator Testing | Cause of Insulator failure:

To ensure the desired performance of an electrical insulator, that is for avoiding unwanted insulator failure, each insulator has to undergo numbers of insulator test. Before going through testing of insulator we will try to understand different causes of insulator failure. Because insulator testing ensures the quality of electrical insulator and chances for failure of insulation depend upon the quality of insulator.

Causes of Insulator Failure

There are different causes due to which failure of insulation in electrical power system may occur. Let's have a look on them one by one-

c) Cracking of Insulator

The porcelain insulator mainly consists of three different materials. The main porcelain body, steel fitting arrangement and cement to fix the steel part with porcelain. Due to changing climate conditions, these different materials in the insulator expand and contract in different rate. These unequal expansion and contraction of porcelain, steel and cement are the chief cause of cracking of insulator.

- **Defective Insulation Material**

If the insulation material used for insulator is defective anywhere, the insulator may have a high chance of being puncher from that place.

- **Porosity in The Insulation Materials**

If the porcelain insulator is manufactured at low temperatures, it will make it porous, and due to this reason it will absorb moisture from air thus its insulation will decrease and leakage current will start to flow through the insulator which will lead to insulator failure

- **Improper Glazing on Insulator Surface**

If the surface of porcelain insulator is not properly glazed, moisture can stick over it. This moisture along with deposited dust on the insulator surface, produces a conducting path. As a result the flash over distance of the insulator is reduced. As the flash over distance is reduced, the chance of failure of insulator due to flash over becomes more.

- **Flash Over Across Insulator**

If flash over occurs, the insulator may be over heated which may ultimately results into shuttering of it.

Mechanical Stresses on Insulator

If an insulator has any weak portion due to manufacturing defect, it may break from that weak portion when mechanical stress is applied on it by its conductor. These are the main causes of insulator failure. Now we will discuss the different insulator test procedures to ensure minimum chance of failure of insulation.

- **Insulator Testing**

According to the British Standard, the electrical insulator must undergo the following tests

1. Flashover tests of insulator
2. Performance tests
3. Routine tests

Let's have a discussion one by one-

1.Flashover Test

There are mainly three types of flashover test performed on an insulator and these are-

Power Frequency Dry Flashover Test of Insulator

1. First the insulator to be tested is mounted in the manner in which it would be used practically.
2. Then terminals of variable power frequency voltage source are connected to the both electrodes of the insulator.
3. Now the power frequency voltage is applied and gradually increased up to the specified value. This specified value is below the minimum flash over voltage.
4. This voltage is maintained for one minute and observe that there should not be any flash-over or puncher occurred.

The insulator must be capable of sustaining the specified minimum voltage for one minute without flash over.

- **Power Frequency Wet Flashover Test or Rain Test of Insulator**

1. In this test also the insulator to be tested is mounted in the manner in which it would be used practically.
2. Then terminals of variable power frequency voltage source are connected to the both electrodes of the insulator.
3. After that the insulator is sprayed with water at an angle of 45^o in such a manner that its precipitation should not be more 5.08 mm per minute. The resistance of the water used for spraying must be between 9 kΩ 10 11 kΩ per cm^3 at normal atmospheric pressure and temperature. In this way we create artificial raining condition.

4. Now the power frequency voltage is applied and gradually increased up to the specified value.
5. This voltage is maintained for either one minute or 30 second as specified and observe that there should not be any flash-over or puncher occurred. The insulator must be capable of sustaining the specified minimum power frequency voltage for specified period without flash over in the said wet condition.

- **Power Frequency Flash over Voltage test of Insulator**

1. The insulator is kept in similar manner of previous test.
2. In this test the applied voltage is gradually increased in similar to that of previous tests.
3. But in that case the voltage when the surroundings air breaks down, is noted.

- **Impulse Frequency Flash over Voltage Test of Insulator**

The overhead outdoor insulator must be capable of sustaining high voltage surges caused by lightning etc. So this must be tested against the high voltage surges.

1. The insulator is kept in similar manner of previous test.
2. Then several hundred thousands Hz very high impulse voltage generator is connected to the insulator.
3. Such a voltage is applied to the insulator and the spark over voltage is noted.
4. The ratio of this noted voltage to the voltage reading collected from power frequency flash over voltage test is known as impulse ratio of insulator.

$$\therefore \text{Impulse Ratio} = \frac{\text{Impulse Frequency Flashover Voltage}}{\text{Power Frequency Flashover Voltage}}$$

This ratio should be approximately 1.4 for pin type insulator and 1.3 for suspension type insulators.

Performance Test of Insulator

Now we will discuss performance test of insulator one by one-

- **Temperature Cycle Test of Insulator**

1. The insulator is first heated in water at 70^{o}C for one hour.
2. Then this insulator immediately cooled in water at 7^{o}C for another one hour.
3. This cycle is repeated for three times.

4. After completion of these three temperature cycles, the insulator is dried and the glazing of insulator is thoroughly observed. After this test there should not be any damaged or deterioration in the glaze of the insulator surface.

Puncture Voltage Test of Insulator

1. The insulator is first suspended in an insulating oil.
2. Then voltage of 1.3 times of flash over voltage, is applied to the insulator.

A good insulator should not puncture under this condition.

Porosity Test of Insulator

1. The insulator is first broken into pieces.
2. Then These broken pieces of insulator are immersed in a 0.5 % alcohol solution of fuchsine dye under pressure of about 140.7 kg/cm^2 for 24 hours.
3. After that the sample are removed and examine.

The presence of a slight porosity in the material is indicated by a deep penetration of the dye into it.

Mechanical Strength Test of Insulator

The insulator is applied by 2½ times the maximum working strength for about one minute. The insulator must be capable of sustaining this much mechanical stress for one minute without any damage in it.

Routine Test of Insulator

Each of the insulator must undergo the following routine test before they are recommended for using at site.

Proof Load Test of Insulator

In proof load test of insulator, a load of 20% in excess of specified maximum working load is applied for about one minute to each of the insulator.

Corrosion Test of Insulator

In corrosion test of insulator,

1. The insulator with its galvanized or steel fittings is suspended into a copper sulfate solution for one minute.
2. Then the insulator is removed from the solution and wiped, cleaned.

3. Again it is suspended into the copper sulfate solution for one minute.
4. The process is repeated for four times.

2.4.1 Isolating switches: an electrical device for the reliable disconnection of certain sections of a high-voltage electrical network when there is no current in them. The use of isolating switches (either alone or in combination with high-speed short-circuiting devices) makes it possible to simplify the arrangement of switching points and transformer substations and to eliminate expensive high-voltage circuit breakers. In the case of damage to certain sections of a network, the circuit breakers operate first, and then the isolating switches automatically disconnect the damaged section, after which the circuit breakers close again and restore electric power to the rest of the consumers on the network. Isolating switches are also used to disconnect and reconnect unloaded transformers and sections of power lines during operation. An isolating switch must provide a reliable connection in case of a random occurrence of a short circuit in the network. An important characteristic of an isolating switch is a short operate time, particularly the disconnect time, which must not exceed 0.1 sec. The most promising type of isolating switch is the elegaz (sulfur hexafluoride) switch, with contacts that are sealed inside a housing filled with SF_6. In some designs air circuit breakers in series with arc arresters connect the isolating switches. In such cases, in addition to performing their usual functions, the isolating switches disconnect the current flowing through resistors that shunt the arc arresters. Isolating switches are also used to isolate long unloaded lines.

2.4.2 Types of Electrical Isolators

There are different types of isolators available depending upon system requirement such as

i) Double Break Isolator
ii) Single Break Isolator
iii) Pantograph type Isolator.

Depending upon the position in the power system, the isolators can be categorized as:

a) Bus side isolator – the isolator is directly connected with main bus
b) Line side isolator – the isolator is situated at line side of any feeder
c) Transfer bus side isolator – the isolator is directly connected with transfer bus.

First : Constructional Features of Double Break Isolators

Let's discuss constructional features of Double Break Isolators. These have three stacks of post insulators as shown in the figure Double Break Isolators. The central post insulator carries a tubular or flat male contact which can be rotated horizontally with a rotation of central post insulator. This rod type contact is also called moving contact.

Fig 2.10

The female type contacts are fixed on the top of the other post insulators which fitted at both sides of the central post insulator. The female contacts are generally in the form of spring-loaded figure contacts. The rotational movement of male contact causes to come itself into female contacts and isolators becomes closed. The rotation of male contact in the opposite direction make to it out from female contacts and isolators becomes open.

Rotation of the central post insulator is done by a driving lever mechanism at the base of the post insulator, and it is connected to operating handle (in case of hand operation) or motor (in case of motorized operation) of the isolator through a mechanical tie rod.

Fig 2.11

Second : Constructional features of Single Break Isolators

The contact arm is divided into two parts one carries male contact and other carries female contact. The contact arm moves due to rotation of the post insulator upon which the contact arms are fitted. Rotation of both post insulators stacks in opposite to each other causes to close the isolator by closing the contact arm. Counter rotation of both post insulators stacks open the contact arm and isolator becomes in off condition. This motorized form of this type of isolators is generally used, but an emergency hand driven mechanism is also provided.

Third : Earthing switches : are mounted on the base of line side isolator. Earthing switches are usually vertically broken switches. Earthing arms (contact arm of earthing switch) usually are aligned horizontally at off condition during switching on the operation, these earthing arms rotate and move to vertical position and make contact with earth female contacts fitted at the top of the post insulator stack of the isolator at its outgoing side. The earthing arms are so interlocked with the main isolator moving contacts that it can be closed only when the primary contacts of the isolator are in open position. Similarly, the main isolator contacts can be closed only when the earthing arms are in open position.

Operation of Electrical Isolator

As no arc quenching technique is provided in isolator it must be operated when there is no chance current flowing through the circuit. No live circuit should be closed or open by isolator operation. A complete live closed circuit must not be opened by isolator operation, and also a live circuit must not be closed and completed by isolator operation to avoid huge arcing in between isolator contacts. That is why isolators must be open after circuit breaker is open, and these must be closed before circuit breaker is closed. The isolator can be operated by hand locally as well as by motorized mechanism from a remote position. Motorized operation arrangement costs more compared to hand operation; hence decision must be taken before choosing an isolator for the system whether hand operated or motor operated economically optimum for the system. For voltages up to 145 KV system hand operated isolators are used whereas for higher voltage systems like 245 KV or 420 KV and above motorized isolators are used.

2.5.1 BusBar : An electrical bus bar is defined as a conductor or a group of conductor used for collecting electric power from the incoming feeders and distributes them to the outgoing feeders. In other words, it is a type of electrical junction in which all the incoming and outgoing electrical current meets. Thus, the electrical bus bar collects the electric power at one location.

The bus bar system consists the isolator and the circuit breaker. On the occurrence of a fault, the circuit breaker is tripped off and the faulty section of the busbar is easily disconnected from the circuit. The electrical bus bar is available in rectangular, cross-sectional, round and many other shapes. The rectangular bus bar is mostly used in the power system. The copper and aluminium are used for the manufacturing of the electrical bus bar.

The most common of the bus-bars are **:**40×4mm (160 mm^2); 40×5 mm (200 mm^2) ; 50×6 mm (300mm^2) ; 60×8 mm (480 mm^2) ; 80×8 (640 mm^2) and 100×10 mm (1000 mm^2).

The small substation where continuity of the supply is not essential uses the single bus bar. But in a large substation, the additional busbar is used in the system so that the interruption does not occur in their supply. The different type of electrical busbar arrangement is shown below.

2.5.2Type of Electrical Busbar Arrangement:-

i) Single Bus-Bar Arrangement: The arrangement of such type of system is very simple and easy. The system has only one bus bar along with the switch. All the substation equipment like the transformer, generator, the feeder is connected to this bus bar only.

First : The advantages of single bus bar arrangements are:

- It has low initial cost.
- It requires less maintenance
- It is simple in operation

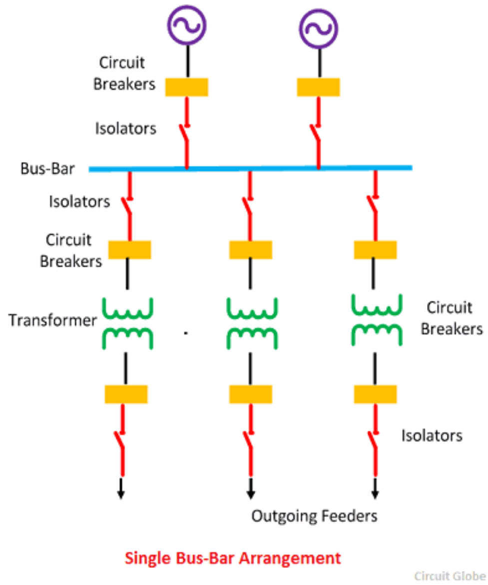


Fig 2.12

- The only disadvantage of such type of arrangement is that the complete supply is disturbed on the occurrence of the fault.
- The arrangement provides the less flexibility and hence used in the small substation where continuity of supply is not essential.

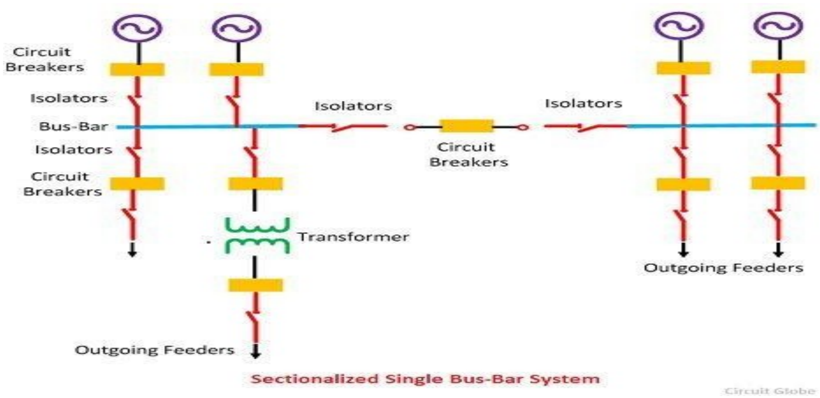


Fig 2.13

ii) Single Bus-Bar Arrangement With Bus Sectionalized

In this type of busbar arrangement, the circuit breaker and isolating switches are used. The isolator disconnects the faulty section of the busbar, hence protects the system from complete shutdown. This type of arrangement uses one addition circuit breaker which does not much increase the cost of the system.

Second : Advantage of single Bus-bar Arrangement with Bus Sectionalization

- The faulty section is removed without affecting the continuity of the supply.
- The maintenance of the individual section can be done without disturbing the system supply.
- The system has a current limiting reactor which decreases the occurrence of the fault.

Third : Main and Transfer Bus Arrangement

Such type of arrangement uses two type of busbar namely, main busbar and the auxiliary bus bar. The busbar arrangement uses bus coupler which connects the isolating switches and circuit breaker to the busbar. The bus coupler is also used for transferring the load from one bus to another in case of overloading. The following are the steps of transferring the load from one bus to another.

a) The potential of both the bus bar kept same by closing the bus coupler.
b) The bus bar on which the load is transferred is kept close.
c) Open the main bus bar.

Thus, the load is transferred from the main bus to reserve bus.

Fourth : Advantages of Main and Transfer Bus Arrangement

- The continuity of the supply remains same even in the fault. When the fault occurs on any of the buses the entire load is shifted to the another bus.
- The repair and maintenance can easily be done on the busbar without disturbing their continuity.
- The maintenance cost of the arrangement is less.
- The potential of the bus is used for the operation of the relay.
- The load can easily be shifted on any of the buses.

Fifth : Disadvantages of Main and Transfer Bus Arrangement

- In such type of arrangements, two bus bars are used which increases the cost of the system.
- The fault on any of the bus would cause the complete shutdown on the whole substation.

ii) Double Busbar: In double bus bar system two identical bus bars are used in such a way that any outgoing or incoming feeder can be taken from any of the bus.

A single-line diagram of an electric power substation using the double bus, single breaker scheme is shown in Figure. The double bus, single breaker scheme includes all components in the single bus scheme (circuitry shown in black in Figure) plus a second bus, disconnecting switches linking the second bus to each line circuit breaker, and a bus coupler circuit breaker with disconnecting switches (circuitry shown in green in Figure).

Each power line in the double bus, single breaker scheme can be connected to either of the two buses by closing one of the two disconnecting switches that connect the corresponding line circuit breaker to the buses. This provides some operating flexibility that allows the power lines to be connected to the buses in any combination required. For instance, the power lines can be grouped onto separate buses or they can all be connected to the same bus. Furthermore, the bus coupler circuit breaker allows any power line to be transferred from one bus to the other, without interruption in the supply of power to loads, by operating the two disconnecting switches that connect the corresponding line circuit breaker to the buses. Such an operation is commonly referred to as on-load transfer or on load bus selection. The procedure to be followed when performing an on-load transfer is described in the next section of the discussion.

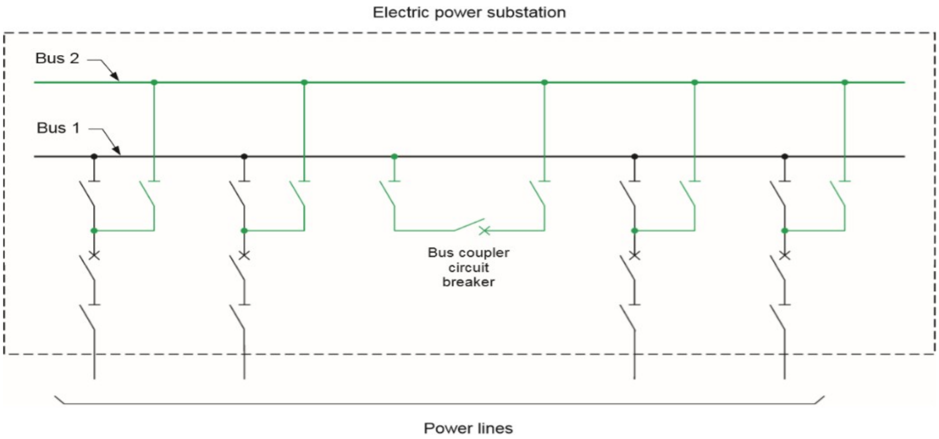


Fig 2.14

- **On-load transfer procedure**

An on-load transfer is accomplished by making sure that the disconnecting switches of the bus coupler circuit breaker are closed, making sure that the bus coupler circuit breaker is closed, closing the disconnecting switch that connects to the bus where the power line is to be transferred, and opening the disconnecting switch that connects to the bus from where the power line is transferred. Most importantly, the above operations must be performed in the order they are enumerated to avoid damage to the contacts of the two disconnecting switches during the on-load transfer. In fact, proceeding this way ensures that the contacts of the two disconnecting switches are short-circuited throughout the on-load transfer. Consequently, this maintains the voltage across the contacts of the two disconnecting switches close to zero which, in turn, avoids electric arcs and possible damage to the contacts.

Once an on-load transfer is completed, the bus coupler circuit breaker and the bus coupler disconnecting switches are normally left closed. This allows subsequent on-load transfers to be performed by simply operating the two disconnecting switches that connect a power line to the buses (following the order mentioned in the procedure above). Note that when the bus coupler circuit breaker is initially open and the two buses in the substation are fed by two different ac power sources, synchronism between the voltage at bus 1 and the voltage at bus 2 must be checked before allowing closure of the bus coupler circuit breaker.

- **Reliability of substations using the double bus, single breaker scheme :**

This section of the discussion deals with the reliability of an electric power substation using the double bus, single breaker scheme. The section starts with a series of subsections, each one describing how a fault at a particular location in the electric power substation affects the supply of power to loads. The section then concludes on the reliability of electric power substations using the double bus, single breaker scheme.

- **Outgoing line fault :**

The effect of an outgoing line fault is the same as in a substation using the single bus scheme, i.e., opening the corresponding line circuit breaker isolates the faulty outgoing line, thereby interrupting the fault current, and causes an interruption in the supply of power to the loads fed by this line. On the other hand, power is maintained in the rest of the substation. The interruption in the supply of power lasts until the faulty outgoing line is repaired. For instance, when outgoing line fault F1 occurs in Figure below, opening line circuit breaker CB1 isolates the faulty outgoing line (outgoing line A) and power is lost at load 1.

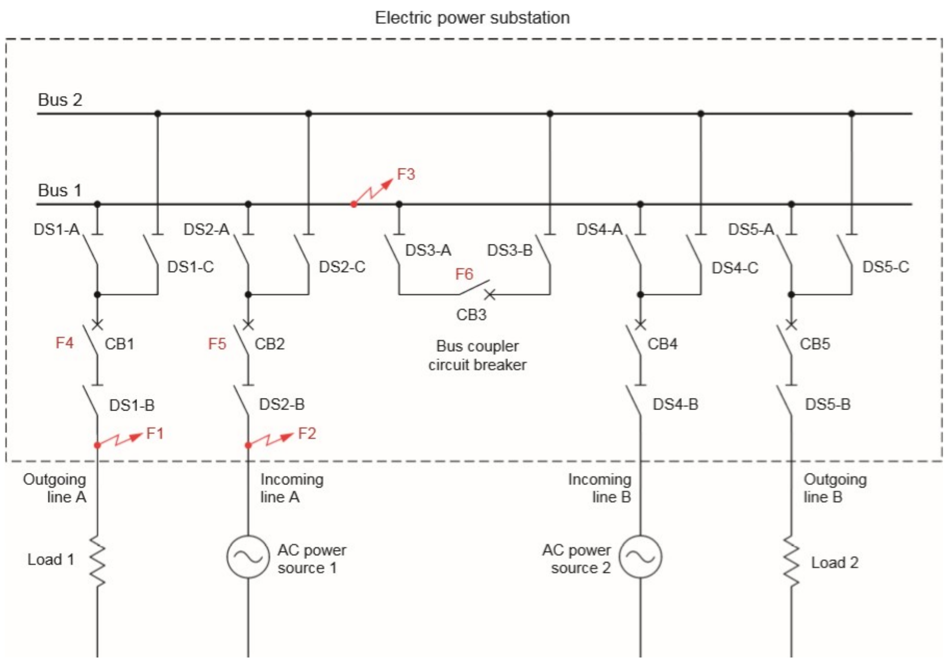


Fig 2.15

2.6 BUS COUPLER : a bus coupler is another breaker that connects two buses together such that total power transfer take place from these two bus but in case of any fault in feeder of any bus and its required to trip the whole bus supplying its feeder fault then the bus coupler operates and disconnect the faulty bus system such that a healthy is still available to supply at least 50% of power to loads.

in the end to summarise the concept it would be like that a bus coupler remain normally open while healthy operation of ps without fault suppling maximum power and in case of any fault the bus coupler remains normaly open to isolate the faulty part and supply healthy part of system after all its just a circuit breaker but connected between two buses.

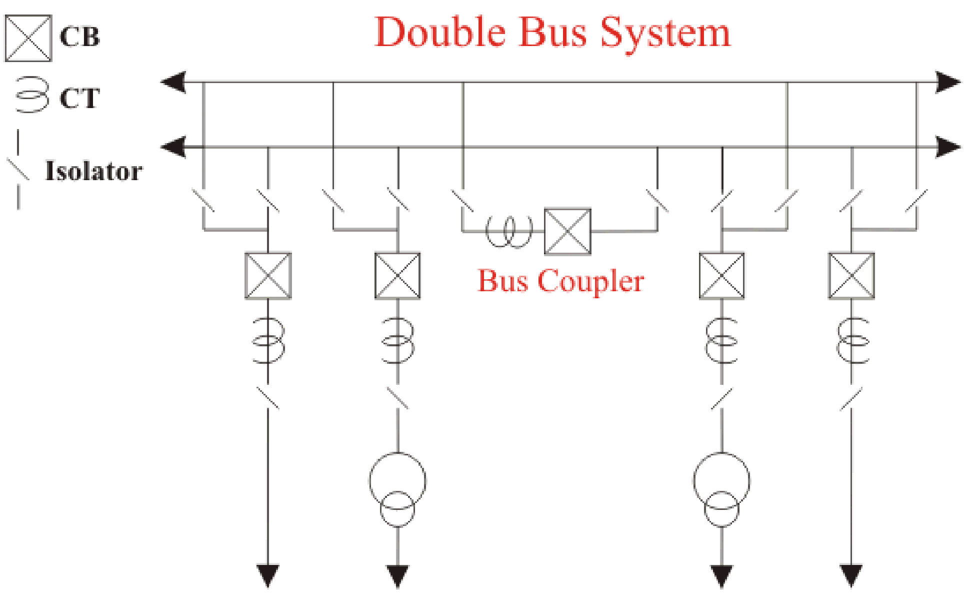


Fig 2.16

CHAPTER THREE

CHAPTER THREE

Measuring and Protection

3.1.1 Measuring : is the assignment of a number to a characteristic of an object or event, which can be compared with other objects or events.

3.1.2 Measuring Equipments:

A) Current Transformer (C.T)

B) Voltage Transformer (V.T)

C) Measuring Device

A) Current Transformer (C.T):

Current Transformers produce an output in proportion to the current flowing through the primary winding as a result of a constant potential on the primary

The **Current Transformer** (C.T.), is a type of “instrument transformer” that is designed to produce an alternating current in its secondary winding which is proportional to the current being measured in its primary. *Current transformers* reduce high voltage currents to a much lower value and provide a convenient way of safely monitoring the actual electrical current flowing in an AC transmission line using a standard ammeter. The principal of operation of a basic current transformer is slightly different from that of an ordinary voltage transformer.

Fig 3.1

Typical Current Transformer

Unlike the voltage or power transformer looked at previously, the current transformer consists of only one or very few turns as its primary winding. This primary winding can be of either a single flat turn, a coil of heavy duty wire wrapped around the core or just a conductor or bus bar placed through a central hole as shown.

Due to this type of arrangement, the current transformer is often referred too as a "series transformer" as the primary winding, which never has more than a very few turns, is in series with the current carrying conductor supplying a load.

The secondary winding however, may have a large number of coil turns wound on a laminated core of low-loss magnetic material. This core has a large cross-sectional area so that the magnetic flux density created is low using much smaller cross-sectional area wire, depending upon how much the current must be stepped down as it tries to output a constant current, independent of the connected load.

The secondary winding will supply a current into either a short circuit, in the form of an ammeter, or into a resistive load until the voltage induced in the secondary is big enough to saturate the core or cause failure from excessive voltage breakdown.

Unlike a voltage transformer, the primary current of a current transformer is not dependent of the secondary load current but instead is controlled by an external load. The secondary current is usually rated at a standard 1 Ampere or 5 Amperes for larger primary current ratings.

There are three basic types of current transformers: wound, toroidal and bar.

- Wound Current Transformer – The transformers primary winding is physically connected in series with the conductor that carries the measured current flowing in the circuit. The magnitude of the secondary current is dependent on the turns ratio of the transformer.
- Toroidal Current Transformer – These do not contain a primary winding. Instead, the line that carries the current flowing in the network is threaded through a window or hole in the toroidal transformer. Some current

transformers have a “split core” which allows it to be opened, installed, and closed, without disconnecting the circuit to which they are attached.

- Bar-type Current Transformer – This type of current transformer uses the actual cable or bus-bar of the main circuit as the primary winding, which is equivalent to a single turn. They are fully insulated from the high operating voltage of the system and are usually bolted to the current carrying device.

Current transformers can reduce or “step-down” current levels from thousands of amperes down to a standard output of a known ratio to either 5 Amps or 1 Amp for normal operation. Thus, small and accurate instruments and control devices can be used with CT’s because they are insulated away from any high-voltage power lines. There are a variety of metering applications and uses for current transformers such as with Wattmeter’s, power factor meters, watt-hour meters, protective relays, or as trip coils in magnetic circuit breakers, or MCB’s.

Current Transformer

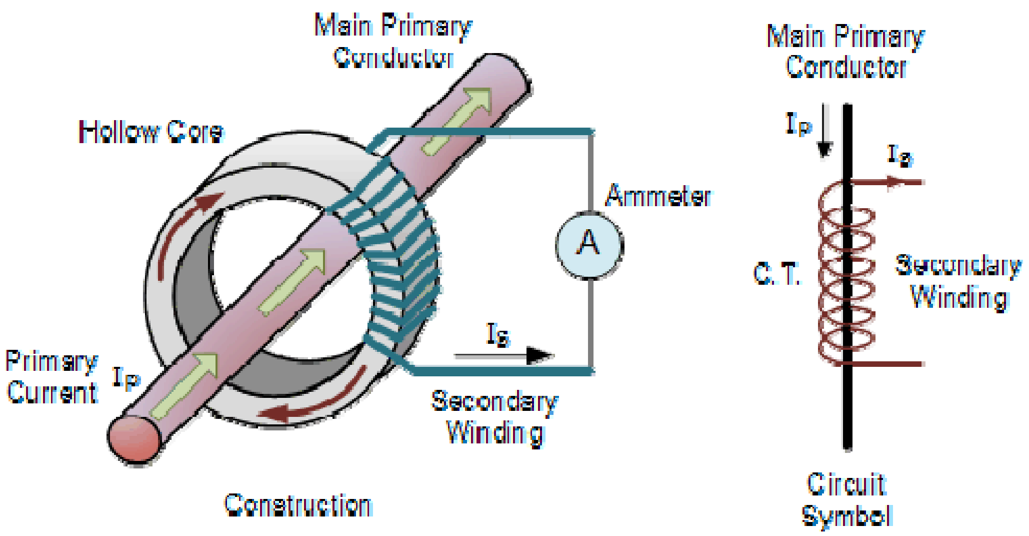


Fig 3.2

Generally current transformers and ammeters are used together as a matched pair in which the design of the current transformer is such as to provide a maximum secondary current corresponding to a full-scale deflection on the ammeter. In most current transformers an approximate inverse turns ratio exists between the two currents in the primary and secondary windings. This is why calibration of the CT is generally for a specific type of ammeter.

Most current transformers have a the standard secondary rating of 5 amps with the primary and secondary currents being expressed as a ratio such as 100/5. This means that the primary current is 20 times greater than the secondary current so when 100 amps is flowing in the primary conductor it will result in 5 amps flowing in the secondary winding. A current transformer of say 500/5, will produce 5 amps in the secondary for 500 amps in the primary conductor, 100 times greater.

By increasing the number of secondary windings, Ns, the secondary current can be made much smaller than the current in the primary circuit being measured because as Ns increases, Is goes down by a proportional amount. In other words, the number of turns and the current in the primary and secondary windings are related by an inverse proportion.

A current transformer, like any other transformer, must satisfy the amp-turn equation and we know from our tutorial on double wound voltage transformers that this turns ratio is equal to:

$$T.R. = n = \frac{N_P}{N_S} = \frac{I_S}{I_P}$$

from which we get:

$$\text{secondary current, } I_S = I_P\left(\frac{N_P}{N_S}\right)$$

The current ratio will sets the turns ratio and as the primary usually consists of one or two turns whilst the secondary can have several hundred turns, the ratio between the primary and secondary can be quite large. For example, assume that the current rating of the primary winding is 100A. The secondary winding has the standard rating of 5A. Then the ratio between the primary and the secondary currents is 100A-to-5A, or 20:1. In other words, the primary current is 20 times greater than the secondary current.

It should be noted however, that a current transformer rated as 100/5 is not the same as one rated as 20/1 or subdivisions of 100/5. This is because the ratio of 100/5 expresses the “input/output current rating” and not the actual ratio of the primary to the secondary currents. Also note that the number of turns and the current in the primary and secondary windings are related by an inverse proportion.

But relatively large changes in a current transformers turns ratio can be achieved by modifying the primary turns through the CT’s window where one primary turn is equal to one pass and more than one pass through the window results in the electrical ratio being modified.

So for example, a current transformer with a relationship of say, 300/5A can be converted to another of 150/5A or even 100/5A by passing the main primary conductor through its interior window two or three times as shown. This allows a higher value current transformer to provide the maximum output current for the ammeter when used on smaller primary current lines.

Current Transformer Primary Turns Ratio

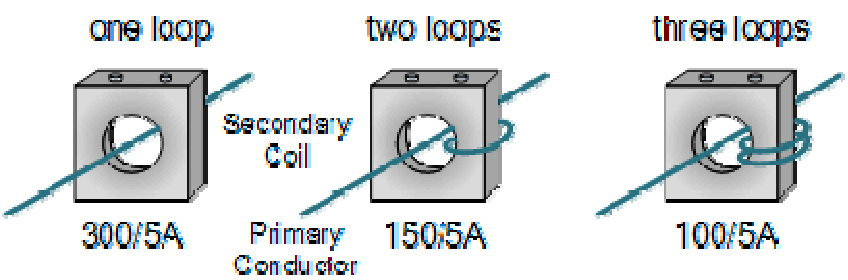


Fig 3.3

Current Transformer Example No1

A bar-type current transformer which has 1 turn on its primary and 160 turns on its secondary is to be used with a standard range of ammeters that have an internal resistance of 0.2Ω. The ammeter is required to give a full scale deflection when the primary current is 800 Amps. Calculate the maximum secondary current and secondary voltage across the ammeter.

Secondary Current:

$$I_S = I_P\left(\frac{N_P}{N_S}\right) = 800\left(\frac{1}{160}\right) = 5A$$

Voltage across Ammeter:

$$V_S = I_S \times R_A = 5 \times 0.2 = 1.0\,\text{Volts}$$

We can see above that since the secondary of the current transformer is connected across the ammeter, which has a very small resistance, the voltage drop across the secondary winding is only 1.0 volts at full primary current.

However, if the ammeter was removed, the secondary winding effectively becomes open-circuited, and thus the transformer acts as a step-up transformer. This due in part to the very large increase in magnetising flux in the secondary core as the the secondary leakage reactance influences the secondary induced voltage because there is no opposing current in the secondary winding to prevent this.

The results is a very high voltage induced in the secondary winding equal to the ratio of: Vp(Ns/Np) being developed across the secondary winding. So for example, assume our current transformer from above is used on a 480 volt to earth three-phase power line. Therefore:

$$T.R. = n = \frac{V_P}{V_S} = \frac{N_P}{N_S}$$

$$\therefore\ V_S = V_P\left(\frac{N_S}{N_P}\right) = 480\left(\frac{160}{1}\right) = 76{,}800V \text{ or } 76.8kV$$

This high voltage is because the volts per turns ratio is almost constant in the primary and secondary windings and as Vs = Ns*Vp the values of Ns and Vp are high values, so Vs is extremely high.

For this reason a current transformer should never be left open-circuited or operated with no-load attached when the main primary current is flowing through it just as a voltage transformer should never operate into a short circuit. If the ammeter (or load) is to be removed, a short-circuit should be placed across the secondary terminals first to eliminate the risk of shock.

This high voltage is because when the secondary is open-circuited the iron core of the transformer operates at a high degree of saturation and with nothing to stop it, it produces an abnormally large secondary voltage, and in our simple example above, this was calculated at 76.8kV!. This high secondary voltage could damage the insulation or cause electric shock if the CT's terminals are accidentally touched.

B) Voltage Transformer (V.T):

Transformer Basics: Transformers are electrical devices consisting of two or more coils of wire used to transfer electrical energy by means of a changing magnetic field

One of the main reasons that we use alternating AC voltages and currents in our homes and workplace's is that AC supplies can be easily generated at a convenient voltage, transformed (hence the name transformer) into much higher voltages and then distributed around the country using a national grid of pylons and cables over very long distances.

The reason for transforming the voltage to a much higher level is that higher distribution voltages implies lower currents for the same power and therefore lower I^2*R losses along the networked grid of cables. These higher AC transmission voltages and currents can then be reduced to a much lower, safer and usable voltage level where it can be used to supply electrical equipment in our homes and workplaces, and all this is possible thanks to the basic Voltage Transformer.

Fig 3.3

A Typical Voltage Transformer

The Voltage Transformer can be thought of as an electrical component rather than an electronic component. A transformer basically is very simple static (or stationary) electro-magnetic passive electrical device that works on the principle of Faraday's law of induction by converting electrical energy from one value to another.

The transformer does this by linking together two or more electrical circuits using a common oscillating magnetic circuit which is produced by the transformer itself. A transformer operates on the principals of "electromagnetic induction", in the form of Mutual Induction.

Mutual induction is the process by which a coil of wire magnetically induces a voltage into another coil located in close proximity to it. Then we can say that transformers work in the "magnetic domain", and transformers get their name from the fact that they "transform" one voltage or current level into another.

Transformers are capable of either increasing or decreasing the voltage and current levels of their supply, without modifying its frequency, or the amount of electrical power being transferred from one winding to another via the magnetic circuit.

A single phase voltage transformer basically consists of two electrical coils of wire, one called the "Primary Winding" and another called the "Secondary Winding". For this tutorial we will define the "primary" side of the transformer as the side that usually takes power, and the "secondary" as the side that usually delivers power. In a single-phase voltage transformer the primary is usually the side with the higher voltage.

These two coils are not in electrical contact with each other but are instead wrapped together around a common closed magnetic iron circuit called the “core”. This soft iron core is not solid but made up of individual laminations connected together to help reduce the core’s losses.

The two coil windings are electrically isolated from each other but are magnetically linked through the common core allowing electrical power to be transferred from one coil to the other. When an electric current passed through the primary winding, a magnetic field is developed which induces a voltage into the secondary winding as shown.

- **Single Phase Voltage Transformer**

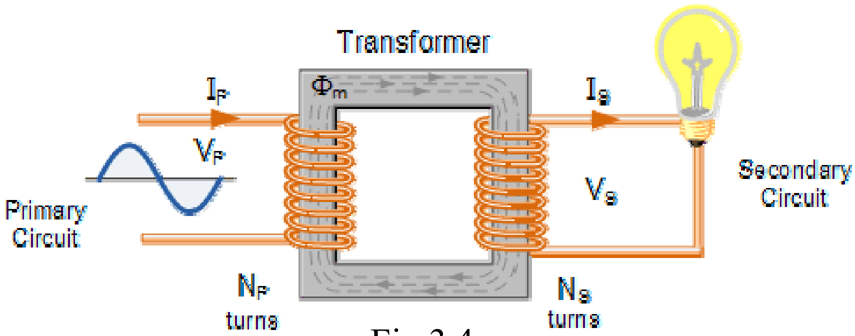


Fig 3.4

In other words, for a transformer there is no direct electrical connection between the two coil windings, thereby giving it the name also of an Isolation Transformer. Generally, the primary winding of a transformer is connected to the input voltage supply and converts or transforms the electrical power into a magnetic field. While the job of the secondary winding is to convert this alternating magnetic field into electrical power producing the required output voltage as shown.

- **Transformer Construction (single-phase)**

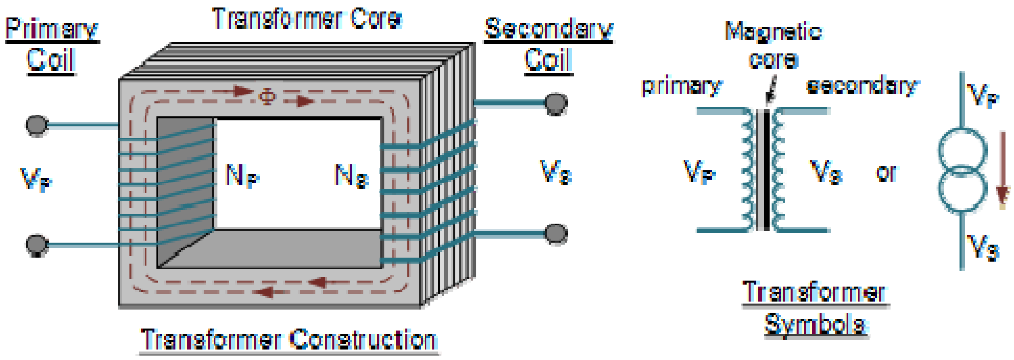


Fig 3.5

- Where:
- V_P - is the Primary Voltage
- V_S - is the Secondary Voltage
- N_P - is the Number of Primary Windings
- N_S - is the Number of Secondary Windings
- Φ (phi) - is the Flux Linkage

Notice that the two coil windings are not electrically connected but are only linked magnetically. A single-phase transformer can operate to either increase or decrease the voltage applied to the primary winding. When a transformer is used to "increase" the voltage on its secondary winding with respect to the primary, it is called a Step-up transformer. When it is used to "decrease" the voltage on the secondary winding with respect to the primary it is called a Step-down transformer.

However, a third condition exists in which a transformer produces the same voltage on its secondary as is applied to its primary winding. In other words, its output is identical with respect to voltage, current and power transferred. This type of transformer is called an "Impedance Transformer" and is mainly used for impedance matching or the isolation of adjoining electrical circuits.

The difference in voltage between the primary and the secondary windings is achieved by changing the number of coil turns in the primary winding (N_P) compared to the number of coil turns on the secondary winding (N_S).

As the transformer is basically a linear device, a ratio now exists between the number of turns of the primary coil divided by the number of turns of the secondary coil. This ratio, called the ratio of transformation, more commonly known as a transformers "turns ratio", (TR). This turns ratio value dictates the operation of the transformer and the corresponding voltage available on the secondary winding.

It is necessary to know the ratio of the number of turns of wire on the primary winding compared to the secondary winding. The turns ratio, which has no units, compares the two windings in order and is written with a colon, such as 3:1 (3-to-1). This means in this example, that if there are 3 volts on the primary winding there will be 1 volt on the secondary winding, 3 volts-to-1 volt. Then we can see that if the ratio between the number of turns changes the resulting voltages must also change by the same ratio, and this is true.

Transformers are all about "ratios". The ratio of the primary to the secondary, the ratio of the input to the output, and the turns ratio of any given transformer will be the same as its voltage ratio. In other words for a transformer: "turns ratio = voltage ratio". The actual number of turns of wire on any winding is generally not important.

C) Measuring Devices:

- Ampere Meter
- Volt Meter
- Watt Meter
- VAR Meter
- VA Meter
- Frequency meter
- Power Factor Meter

i) **Ampere Meter**:

Ammeters are used to measure the current in electricity in amperes, also called amps. Named after French scientist Andre-Marie Ampere, amperes are a unit of measurement for determining the amount of electricity moving through a circuit. Ampere's Law basically states that the magnetic field within a closed loop, or circuit, is proportional to the electric current in that loop. Ammeters used to measure smaller currents have different names. Those that measure milliamperes are called milliammeters. Those that measure currents in the microampere range are called microammeters.

- **How Ammeters Work:**

Ammeters are used to measure electrical current by having the current move through a set of coils. In moving-coil ammeters, this movement results from the fixed magnets that are set opposite to the current. The movement then turns a centrally located armature that is attached to an indicator dial. This dial is set above a graduated scale that lets the operator know how much current is moving through a closed circuit.

- **Uses for Ammeters:**

Ammeters have various applications where they can be used to read alternating current, or AC, as well as direct current, or DC. Ammeters can be found in cars, where they measure DC electricity.

Fig 3.6

ii) Volt Meter :

A voltmeter, also known as a voltage meter, is an instrument used for measuring the potential difference, or voltage, between two points in an electrical or electronic circuit. Some voltmeters are intended for use in direct current (DC) circuits; others are designed for alternating current (AC) circuits. Specialized voltmeters can measure radio frequency (RF) voltage.

- **How It Works:**

An analog voltmeter works by passing a current through a coil that is suspended between two permanent magnets. This coil of wire is known as a moving coil since it moves in relation to the permanent magnets when a voltage is applied. When a voltage is applied and the voltage scale is chosen, a resistor of known value is placed in series with the measurement leads. This way Ohm's Law can be applied. The applied voltage through the coil creates a magnetic field which acts against the permanent magnets that the pointer pivot is placed between. This magnetic field causes a corresponding deflection of the pointer. This pointer deflection will be in direct proportion to the amount of voltage being applied to the moving coil wrapping the pointer pivot. Once pointer oscillation has stopped, accurate readings can be taken.

Fig 3.7

iii) Watt Meter :

The wattmeter is an instrument for measuring the electric power (or the supply rate of electrical energy) in watts of any given circuit. Electromagnetic wattmeters are used for measurement of utility frequency and audio frequency power; other types are required for radio frequency measurements. The three main types are electrodynamic, electronic and digital.

- **Electrodynamic Watt meter:**

Electrodynamic wattmeters are a design that goes back to the early 20th century. They work by using three coils: two fixed in series with the electrical load, and a moving coil in parallel with it. The series coils measure current flowing through the circuit, the parallel coil measures voltage. A series resistor limits the current through the moving coil. It's situated between the two fixed coils and is attached to an indicator needle. The magnetic fields in all three coils influence the needle

- **Digital Watt meter :**

Digital wattmeters measure current and voltage electronically thousands of times a second, multiplying the results in a computer chip to determine watts. The computer can also perform statistics such as peak, average, low watts and kilowatt-hours consumed. They can monitor the power line for voltage surges and outages. In 2009, a variety of inexpensive digital wattmeters are available to consumers. With the falling price and improved capabilities of digital electronics, they have become popular for conveniently measuring power consumption in household appliances with an eye toward saving energy and money.

Fig 3.8

iv) VAR Meter :

The instruments which measure the reactive power of the circuit

Fig 3.9

v) VA Meter:

The instruments which measure the apparent power of the circuit

Fig 3.10

vi) Frequency meter :

Frequency meter, device for measuring the repetitions per unit of time (customarily, a second) of a complete electromagnetic waveform. Various types of frequency meters are used. Many are instruments of the deflection type, ordinarily used for measuring low frequencies but capable of being used for frequencies as high as 900 Hz. These operate by balancing two opposing forces. Changes in the frequency to be measured cause a change in this balance that can be measured by the deflection of a pointer on a scale. Deflection-type meters are of two types, electrically resonant circuits and ratiometers.

An example of a simple electrically resonant circuit is a moving-coil meter. In one version, this device possesses two coils tuned to different frequencies and connected at right angles to one another in such a way that the whole element, with attached pointer, can move. Frequencies in the middle of the meter's range cause the currents in the two coils to be approximately equal and the pointer to indicate the midpoint of a scale. Changes in frequency cause an imbalance in the currents in the two coils, causing them and, in turn, the pointer to move.

Another type of frequency meter, not of the deflection type, is the resonant-reed type, ordinarily used in ranges from 10 to 1,000 Hz, although special designs can operate at lower or higher frequencies. These work by means of specially tuned steel reeds that vibrate under the effect of electric current; only those reeds that are in resonance vibrate visibly

Fig 3.11

vii) Power Factor meter :

Definition: The power factor meter measures the power factor of a transmission system. The power factor is the cosine of the angle between the voltage and current. The power factor meter determines the types of load using on the line, and it also calculates the losses occur on it.

The power factor of the transmission line is measured by dividing the product of voltage and current with the power. And the value of voltage current and power is easily determined by the voltmeter, ammeter and wattmeter respectively. This method gives high accuracy, but it takes time.

The power factor of the transmission line is continuously changed with time. Hence it is essential to take the quick reading. The power factor meter takes a direct reading, but it is less accurate. The reading obtained from the power factor meter is sufficient for many purposes to expect precision testing.

The power factor meter has the moving system called pointer which is in equilibrium with the two opposing forces. Thus, the pointer of the power factor meter remains at the same position which is occupied by it at the time of disconnection.

Fig 3.12

3.2 Protection

Ability and self-sufficiency to ensure prevention and peace or minimize damage to persons, equipment or facilities after exposure to a state of danger in a timely manner and with the required speed and reliability by neutralizing that risk and isolating it or at least minimizing it.

3.2.1 Characteristic and requirements of the electrical protection system

There are several factors that are classified as influential criteria on the performance and effectiveness of the protection system.

1- Selectivity 2- speed 3-sensitivity 4-reliability 5-discrimination

6-simplicity 7-adequateness and economy 8- backup

3.2.2 Cases that require the protection

A-Transformer : that have electrical and mechanical protection

First-Electrical Protection:-

i -Over current relay : is a type of the protection relay, which operates when the current increases beyond the operating value of the relay. Over Current conditions are the one where there is short circuit occurs in the system or the faults which causes the current in the conductor to increase exponentially

ii -Earth fault relay : Earth-fault relay is used to protect feeder against faults involving ground. Typically, earth faults are single line to ground and double line to ground faults. For the purpose of setting and coordination, only single line to ground faults are considered.

iii -Diffrential protection relay : This handling is considered an electrical handling and is often used for transformers with large capacities. The most important of these handling is to know the nature of its work as it is based on the differentiation of any comparison between the current in the primary winding and the second of the transfer iv -Main trip relay : is a contact multiplication or an Auxillary relay, which operates on the command from Multiple protection relays and gives a Single Commmand to the Breaker Trip Coil. Remarks

v - Lightning arrester: is a device used on electrical power systems and telecommunications systems to protect the insulation and conductors of the system from the damaging effects of lightning. The typical lightning arrester has a high-voltage terminal and a ground terminal

Second- Mechanical :-

i- Buchholz relay: is a safety device mounted on some oil-filled power transformers and reactors, equipped with an external overhead oil reservoir called a "conservator".

ii- Explosion vent: The explosion vent is used to expel boiling oil in the transformer during heavy internal faults in order to avoid the explosion of the transformer

iii- Sudden pressure relay : The relay is designed to detect a sudden pressure increase caused by arcing. It is set to operate before the pressure relief device. The control circuit should de-energize the transformer and provide an alarm. The relay will ignore normal pressure changes such as oil-pump surges, temperature changes.

iv-Gas receiver relay : is a protective device installed on the top of oil-filled transformers. It performs two functions. It detects the slow accumulation of gases, providing an alarm after a given amount of gas has been collected.

v-Oil level gauge : is a rod that shows the **oil level** in an engine **oil** pan or transmission.

vi-Thermometer gauge : is an instrument designed to measure and indicate the temperature of a specific application or condition. A Dial Thermometer (filled system thermometer) can either be read at the point of measurement or from a remote location using a desired length of capillary tubing.

vii- Off local tap changer tripping .

B-Transmition line : -

A-for (132 Kv)

1-Distan Relay

2-Auto Reclose relay

3-Inter –tripping relay

4-Over current relay

5-Pilot-wire relay for (cable)

6-Directional E/F

B – for (33Kv)

1-O/C Relay

2-Directional over current relay

3-Pilot wire

C-Busbar :

Differential protection for busbars

Differential protection operation directly uses the Kirchhoff's Current Law where it is required that the currents going into a node are equal to current leaving the node. When the sum of the currents is not equal to zero by comparing their magnitude or phase the difference is referred as a fault current as shown in Figure

When the busbar has a fault also known as internal fault, the total currents entering it is not equal to zero. Fault current If is the sum of the all currents.

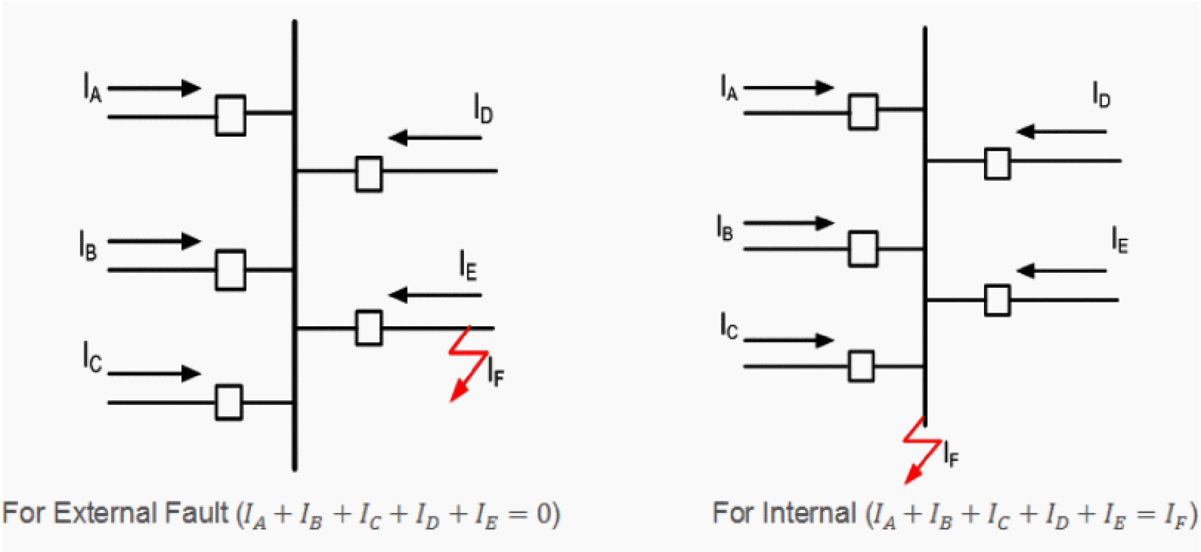


Fig 3.13

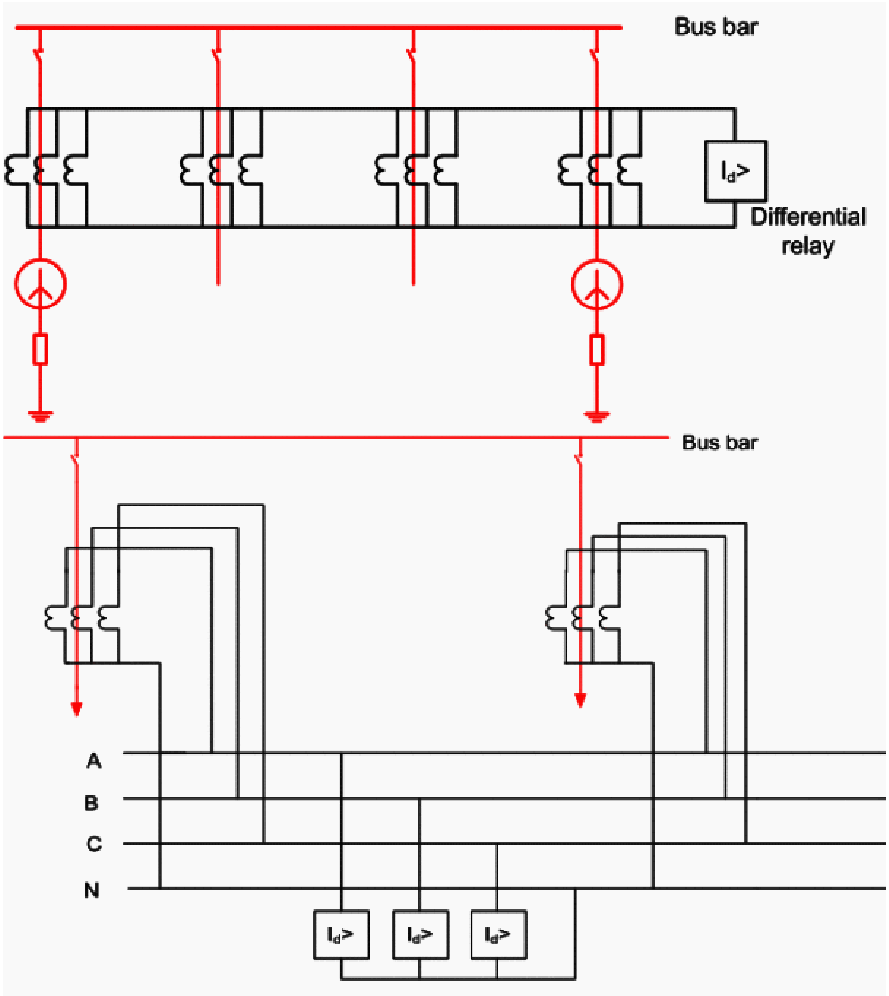


Fig 3.14

3.3 DC Supply

Benefits of DC supply in substation is

1. Separation and connection from within control
2. Protections
3. Signals
4. For forced lighting

3.3.1 DC power can be obtained from two sources

a. charger: In the case of alternating current

b. Batteries : When there is no AC power

i charger

The charger is fed 380 volts of the transformer where it is considered the most important device fed by the transformer and it is not possible to change the link (RST) to any switch in any two stages because this is because it does not work for every phase in the circuit. Thyristor gives trigger at the beginning of each wave in case of any difference In two feeding stages we do not get 110 volts or we get an irregular voltage

ii Batteries

Batteries are the main source of constant current and are fed from the charger at 132 kV and contain one or two sets of batteries. On two charger, the base batteries has liquid its density equals to 1.18 ,volt of one pattery ranging from 1.2_1.4 volts

*Battery Room

The batteries are placed in an isolated room even from the charger and the ventilated room is more air-conditioned because the gas from the batteries helps to burn

*Maintenance of Battery

Batteries must be continuously maintained by adding distilled water to the batteries by washing them, cleaning their heads, lubricating them, taking the solution density and replacing it if it fails the test and sometimes testing the solution to indicate the percentage of carbon in it

3.4 Auxillary system

Usually the AC-power distribution at a substation utilizes the same voltage levels and principles as the normal household electrification of that country. Depending on the practice and the legislation in the target country, the AC distribution system can either be 4-wire or 5- wire .

First-These loads would typically include the following:

A. Substation building(s) climate control and lighting
B. Outdoor equipment and indoor panels desiccation heaters
C. Power transformer cooling fans
D. Driving motor for on-load tap changer of a power transformer
E. Station battery (DC system) charger(s)
F. Normal wall socket outlets

Second-Elements of AC Auxiliary System

The main components of AC auxiliary supply system are:
A.Station auxiliary transformer(s)
B.AC main distribution switchgear
C.AC sub-distribution board(s) and
D. The cable network

3.5 Remote Terminal Unit (RTU)

An electronic device that monitors and gives reports at terminals, usually called master and slave, by the control center. The remote control unit is located in the various electrical stations. It transmits the exchange signals with the load distribution center to a language understood by the electrical station components (switch_ gear) This unit also collects information from (alarms, conditions, measurements, etc.) from the stations and transfers them to the distribution center of the porter in digital form and then in the center is received and analyzed and take the appropriate pups separately

3.5.1 Uses of RTU

1-To monitor and control the electrical system

2-Industrial plants

3-Transport and communication

4-water supply

5-Gas and oil supply

3.5.2 The data, information and decals handled by RTU are

i-Double indication:-It is used to transfer the parameters of the circuit breaker and Commands which are the command information that is issued from the distribution center to the loads of the stations of open, lock and others

ii-Single indication Include

A) Alarms:-Are the various warnings issued by the electrical stations, which are several types of them

i.station alarms

ii.feeder alarms

iii.Transformer alarms

B) Status:-Which means to clarify the situation on the various components of the station in terms of being open or packaged or in a special case known as Disturb

C) Measurements:- It is information that carries readings and measurements from different parts of the station and includes this information(V, A, MW, MVAR, F, Tempreture, etc)

3.5.3 RTU system consist of:-

A- General electronic unit

B-Power supply unit

C-Input/output unit

D-monitor unit

E-Store Data&programes unit

F-Real Time unit

G-CPU

3.5.4 Type of Data:-

There are three types of information transfer cards and each card has a specific property for transferring information, which is all the following

1-Al carts:-Used to transfer this information

a. Frequency

b. MW

C. MVAR

d. Current

e. KV

2-DI carts:-Used to transfer this information

a. DPI (double period indication)

b. SPI(single period indication)

c. Alarms

d. Protection

e. ITI

3- DO Carts: Used to transfer the information of circuit breaker

CHAPTER FOUR

CHAPTER FOUR

OPERATION AND MAINTENANCE

4.1 OPERATION

4.1.1 Parallel operation of transformer

The conditions of connected transformer in parallel:-

1- Same phase displacement (same vector group)

2-Same phase sequence

3-Same percentage impedance

4-Same frequency and voltage

5-Same turn ratio

6-Same MVA

4.1.2 Energizing of busbars

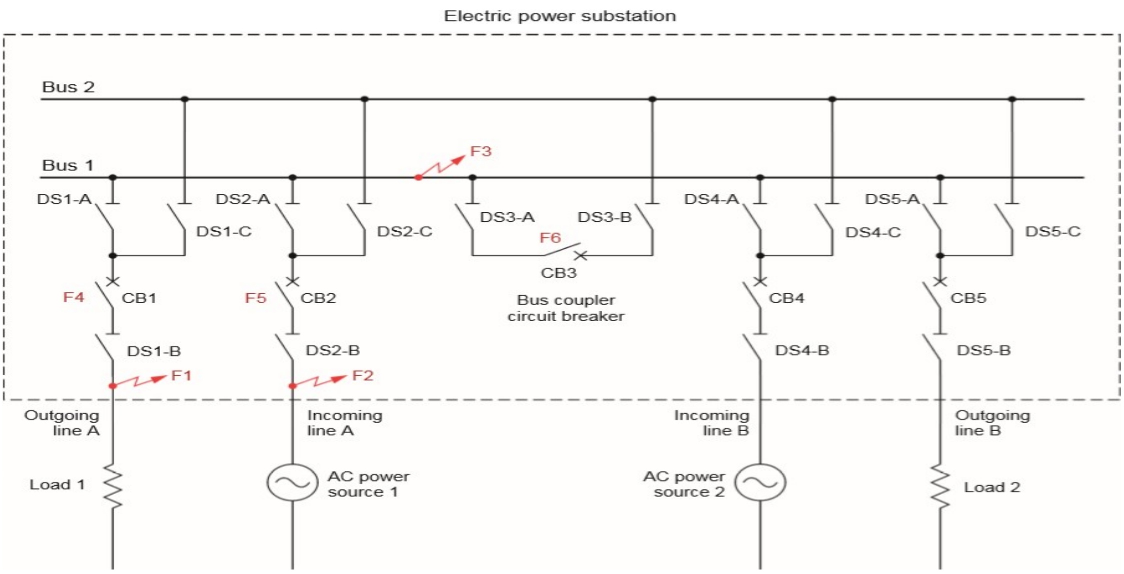


Fig 4.1

If we have a problem in **DS1-A** and we need to work in this place and we have two busbars [**BUS1** is active and **BUS2** is unactive] so we need to use **BUS2.**

- **Permanently case**

To change the busbar we should follow this steps

1-Close [**DS3-A ,DS3-B]**and put bus coupler in **ON** state

2-Close [**DS1-C, DS2-C, DS4-C, DS5-C]**

3-switch **off** bus coupler

4-Open [**DS1-A, DS2-A, DS4-A, DS5-A]**

Finally we put all components on the busbar2

- **Temporary case**

To change the busbar we should follow this steps

1-Close [**DS3-A ,DS3-B]**and put bus coupler in **ON** state

2-Close [**DS1-C]**

3-Open [**DS1-A]**

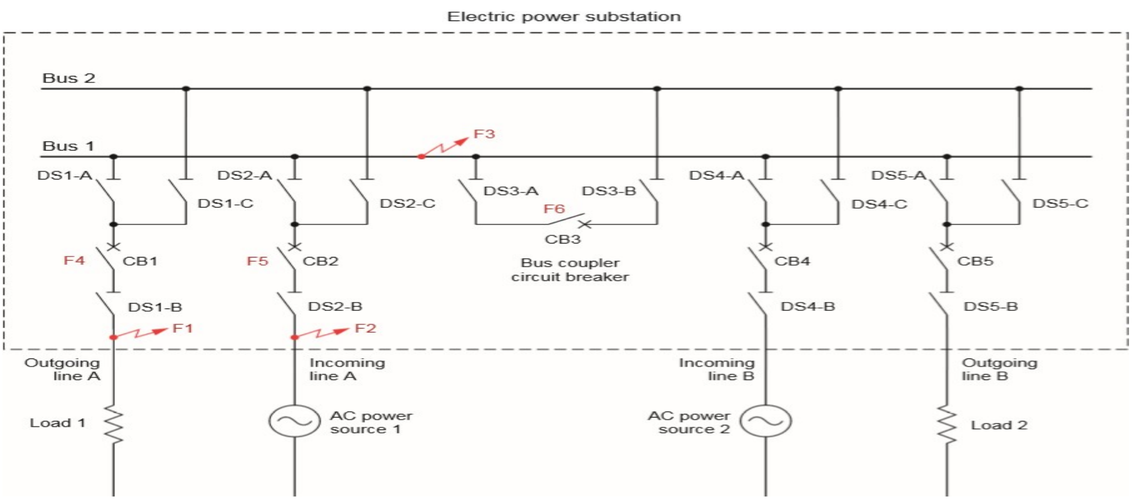


Fig 4.2

4.1.3 Switching off lines for maintenance

If we need to switch off line of **load 2** we follow this steps:-

1-Switching off **C.B** in both side

2-Open bus isolator [**DS5-A,DS5-C]** in both side

3-Open line isolator[**DS5-B**] in both side

4-Earthing both side of line by portable or by earthing switch

4.1.4 Operation of bank capacitors

1- Before the capacitors are switched on, the MVA is pressed on the section to be operated on.

2- The capacitors are not operated only by order of control and documented it in the operating notebook

3- Before turning on the capacitors, we noted the value of voltages that applied to the section where the capacitor is to be operated.

4- If the voltages are 33 KV, the tap changer is converted to manual operation and the voltages are reduced to 31 KV or 30 KV, then the capacitors are switched on and then the tap changer is returned to the auto mode

(In case we turning the transformer on or off, the capacitors on the transformer Must be switched off)

4.1.5 Regulating voltage by tap changer

4.1.5.1 Off load tap changer

1-we use it in 33KV transformerThe tap is changed from (1_5). This is done when the transformers are turned off. This process (ie, change from one tap to another) is manually done by a rod mechanical device located on the upper surface of the transformer and always on tap 3

2-The purpose of the medium winding is to coordinate and control the voltages of the winding. This type of tap changer is composed of an additional winding with points. The number of these points (five points), the third tap dont change the voltage, (1,2) tap reduce the voltage and (4,5) tap increase the voltage

3- The winding of this tap in main tank of transformer

4- The transformer must be switched off completely when changing from one tap to another for fear of high spark when switching one step to another because this type is not separate exists with the main windings of the transformer

4.1.5.2 On load tap changer

1- The voltage is attenuated by voltage 11 in the power transformer. The tap is changed (1-17) or (1-23) manually or electrically is changed by a 3PH engine. This process uses an electrically charged circuit as well as automatic voltage regulation. Primary to install the transformer voltages are also changed from tab to another manually by the lever intended is that the purpose

2- Designing (tap-changer) based on transformers current load and equals to (1.1) of the stream (rated current)

3- Connect tap changer on (132)KV side because of the current few so as not to affect the oil through the spark as a result of the conversion tab to another through the relationship [N2/N1=V2/V1] Fit voltages inversely proportional to the number of laps (turn ratio)

4- (on-load tap changer) Putted in main reservoir tanks transferred completely insulated tank is transferred and placed in oil for cooling and insulation so they don't pollute the converted oil, because the oil in the tank (on load tap changer) is often exposed to rapid pollution as a result of the change in tap where a spark is generated when moving from one tap to another

5- The idea was raised or decreased voltages in this type is done on the basis of making the current passes in the winding of (tap changer)in the same direction of the current in the main winding in the cases of increasing voltage either in the case of reducing the voltage must be made current of tap changer passes in the opposites direction of the current passing through the main winding of the transformer

4.1.6 Synchronization

- The conditions of synchronization is

i- The difference between voltage should not exceeding 10%

ii- The difference between frequency should not exceeding 0.00125

iii- There should be no difference in sequence

4.2 Maintenance

The continuity of electric supply is an important requirement in modern societies. Electric utilities are thus required to develop and maintain sound power networks. The maintenance of the electrical equipment in substations plays a major role in this requirement. Failures of equipment may precipitate outages for large service areas and can cost millions of dollars in lost revenues, and damages.

4.2.1 Objective of Maintenance

- Primary objective of maintenance is to ensure a long lasting equipment life cycle without abnormal failures and outages.
- Maintenance shall ensure that the system is kept in proper operational condition at all time.
- Maintenance shall secure the height degree of energy availability and reliability.
- Trouble shooting and fault recovery in the shortest possible time.

4.2.2 Category of maintenance

1-Preventive Maintenance : Preventive maintenance is carried out at predetermined interval

a) Routine maintenance
   Routine/scheduled maintenance is carried out at a fixed interval (time ,operations).

b) Condition based maintenance

Condition based maintenance is initiated as a result of knowledge of the condition of an item from monitoring e.g. visual inspection, thermos vision and diagnostic tests.

2-Corrective maintenance : Corrective maintenance is carried out after failure or unacceptable condition has occurred .

a) Breakdown maintenance

Emergency/Breakdown maintenance is carried out immediately to prevent danger to personnel, equipment,or system performance e.g. equipment requires repair under tripping situation.

b) Deferred maintenance

Deferred maintenance is maintenance work that may be programmed for later action e.g. defect found during inspection and the repair is plan in the next available outage.

4.2.3 **Important Maintenance of some equipments**

1-Transformer Testing

- Power Factor
- Ratio
- Insulation
- Winding Resistance
- SFRA (Sweep Frequency Response Analysis)
- DGA and Oil Quality

Transformer Maintenance

- Verify oil level in main tank & LTC (Monthly)
- Verify oil level in bushing (Monthly)
- Verify insulator integrity (Monthly)

• Verify tank integrity and free of oil leak (Monthly)

• Inspect surge arrestors (Monthly)

• Verify paint is in good condition (Monthly)

• Record winding/liquid temperatures (current & max) (Monthly)

• Record LTC position indicator & operation counter (current & max raise/lower) (Monthly)

• Verify correct operation of fans and free of bird nests (Monthly)

• Verify correct operation pumps (if applicable) (Monthly)

• Verify nitrogen pressure (if applicable) (Monthly)

• Verify transformer and pad are level (Monthly)

• Verify control cabinet is free of moisture (Monthly)

• Verify cabinet heater operation (Monthly)

•Thermographic Imaging (Infrared) (Annual)

• Transformer oil analysis (DGA) (Annual)

• Power factor (Every 5 years)

• Winding resistance test (Every 5 years)

• Transformer turns ratio test (Every 5 years)

• Insulation test (Every 5 years)

• Calibrate temperature gauge (Every 5 years)

• Verify alarms points (Every 5 years)

• Verify Bucholtz relay operation (Every 5 years)

• Verify rapid pressure rise relay operation (Every 5 years)

• SFRA (sweep frequency response analysis) (New install & after fault operation)

• Vibration & acoustic testing (Dependent on criticality of equipment)

2- Circuit Breakers Testing

• Power Factor

• Speed

• Micro-ohm

• Ratio Bushing Current Transformer

• SF6 Gas

• Installation Testing (e.g. Air Mag)

Circuit Breaker Maintenance

• Verify breaker is level (Monthly)

• Verify paint is in good condition (Monthly)

• Verify insulator integrity (Monthly)

• Verify SF6 gas pressure (check oil level in oil breaker) (Monthly)

• Record operation counter number (Monthly)

• Verify control cabinet is free of moisture and cabinet is working (Monthly)

• Check control voltages & operation of breaker (Annual)

• Thermographic Imaging (Infrared) (Annual)

• Verify tank heaters (if applicable) (Annual)

• Motion testing (speed test) (Every 5 years)

• Micro-Ohm (ductor) contacts (Every 5 years)

• Test SF6 gas for moisture, purity & SO2 content (Every 5 years)

• Check alarm points in control house (Every 5 years)

3-Voltage Regulator Testing

- Maintenance usually based on manufacturers recommended operations and load.
- DGA Oil Analysis
  - Frequency - Annual or Biannual

Conclusion

double busbar substation is on of the most important type of substation in our country because it is easy to control in the maintenance and during the fault accurance

its very important for the engineer to know the type of substation ,the equipment of substation and most important of all the operation of distribution of substation in general double busbar in practical.

Refrences:-

1. https://en.wikipedia.org/wiki/Electrical_substation:

* *Baker, Joseph W,. "Eliminating Hurricane Induced Storm Surge Damage To Electric Utilities Via In-place Elevation Of Substation Structures And Equipment" (PDF). DIS-TRAN Packaged Substations. Crest Industries. Archived from the original (PDF) on 5 February 2016. Retrieved 4 February 2016.*

2. Training of operators of electricity switching stations. Directorate General of Electricity Transmission / Central Region Directorate of Wasit Network. Expert Engineer Mohamed Hussein Mohsen Salem 2013

3. https://www.electrical4u.com/electrical-isolator-or-electrical-isolation-switch/:

*Electrical Isolator or Electrical Isolation Switch
Published on 15/3/2013 & updated on 19/8/2018

4. https://www.quora.com/What-type-of-isolators-are-used-in-electrical-substations:

*Krishan Kumar, Project Engineer - Embedded at Cyan Technology (2016-present)

5. https://www.collinsdictionary.com/dictionary/english/switching-station:

*Definition of switching station from the Collins English Dictionary

6. https://en.wikipedia.org/wiki/Disconnector:

* *Edvard Csanyi (2014-06-20). "Differences between disconnectors, load switches, switch disconnectors and circuit breakers". Electrical Engineering Portal. Retrieved 21 January 2016.*

*"Applications of Disconnecting Circuit Breakers, Michael Faxå, p. 1-2" (PDF). Archived from the original (PDF) on 16 May 2013. Retrieved 11 July 2013.

7. https://en.wikipedia.org/wiki/Current_transformer:

*"IEC 60050 - International Electrotechnical Vocabulary - Details for IEV number 321-02-34: "knee point voltage"". *www.electropedia.org*. Retrieved 2018-07-12.

* *Protective Relays Application Guide*, (The General Electric Company Limited of England, 1975) pages 78-87

8. https://en.wikipedia.org/wiki/Busbar:

* *"Copper for Busbars : Guidance for Design and Installation" (PDF). Copperalliance.org.uk. Retrieved 30 October 2017.*

9. https://en.wikipedia.org/wiki/Transformer:

* *Mack, James E.; Shoemaker, Thomas (2006). "Chapter 15 - Distribution Transformers"(PDF). The Lineman's and Cableman's Handbook (11th ed.). New York: McGraw-Hill. pp. 15–1 to 15–22. ISBN 0-07-146789-0.*

*L. Dalessandro, F. d. S. Cavalcante, and J. W. Kolar, "Self-Capacitance of High-Voltage Transformers," IEEE Transactions on Power Electronics, vol. 22, no. 5, pp. 2081-2092, 2007

10. https://en.wikipedia.org/wiki/Circuit_breaker:

* Robert Friedel and Paul Israel, *Edison's Electric Light: Biography of an Invention*, Rutgers University Press, New Brunswick New Jersey USA,1986 ISBN 0-8135-1118-6 pp.65-66

* Hwaiyu Geng, *Data Center Handbook*, John Wiley & Sons,2014 page 542

11. http://pages.mtu.edu/~avsergue/EET3390/Lectures/CHAPTER6.pdf:

*"Electrical Power Distribution and Transmission", L.M Faulkenberry and W. Coffer

12. The main protections in power systems. M. Majid Rahim Kalhour / Northern Control Center

13.(UGLYS'S) Electrical Refrences by GEORGE V.HART and SMMIE HART WILLIAM C.BUCHANAN editor … copyright 1978 by GEORGE V.HART copyright 2005 by RON BURILSON printed in USA