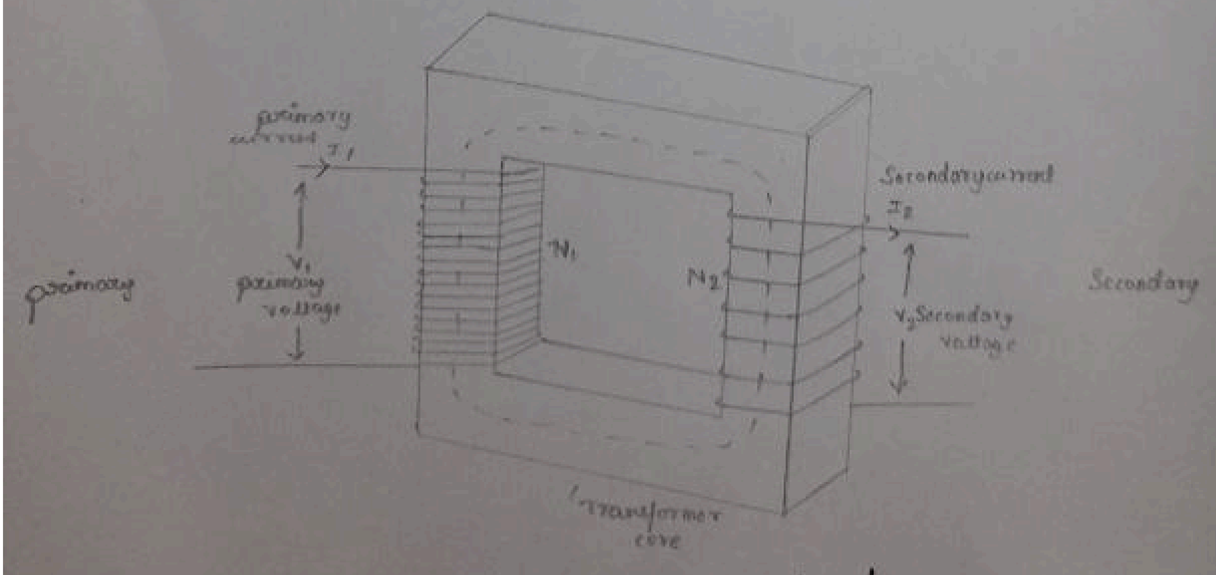
Transformers and Induction Machine

3ϕ Transformer

Introduction:

Transformer, device that transfers electric energy from one alternating-circuit to one or more other circuits, either increasing (stepping up) or reducing (stepping down) the voltage. Transformers are employed for widely varying purposes; from small voltage operation application to raise the voltage from electric generators so that electric power can be transmitted over long distances.

Transformer is an electrostatic device; that is it doesn't contain any rotating part. The power transmission is mainly due to the mutual induction of two electric circuits without any change in frequency. Transformers change voltage through electromagnetic induction, as the magnetic lines of flux (force) build up and collapse with the change in current passing through the primary coil, current is induced in another coil, called the secondary. The secondary voltage is calculated by multiplying the primary voltage by the ratio of the number of turns in the secondary coil to the number of turns in the primary coil, a quantity called turns ratio.



Single phase-Core-type ideal transformer

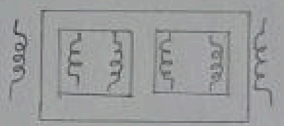
The transformers which are manufactured at "power System Controls" are mainly threephase stepdown transformers (core type transformers). Construction of transformer is based on the end user, that is wether the End user wants the transformer to be placed outside or inside the building or structure.

Three-phase Transformer

A three-phase transformer is made of three sets of primary and Secondary windings, each set wound around one leg of an iron core assembly. Essentially it looks like three-single-phase transformers sharing a joined core. Those sets of primary and Secondary windings will be connected in either delta(Δ) or star (Y) configurations to form a complete unit. The three-phase network in primary and Secondary of transformer can be connected in many forms and they can be connected as,

primary - Secondary

- Y - Y
- Y - Δ
- Δ - Y
- Δ - Δ



The reasons for choosing a Y or Δ configuration for transformer winding connections are the same as for any other three-phase application. Star (Y) connections provide the opportunity for multiple voltages, while Delta (Δ) connections have a higher level of reliability (if one winding fails open, the other two can still maintain full line voltages to the load).

In Construction site (power System controls), they manufacture a three phase Delta-Star Connection Stepdown transformers of mainly the rating of 11KV to 440V of rating.

- Delta-Star connection: The application of this type is distribution Systems.
  Since the Secondary side has a neutral, it can also serve as a single-phase power supply aside from supplying the full three-phase.

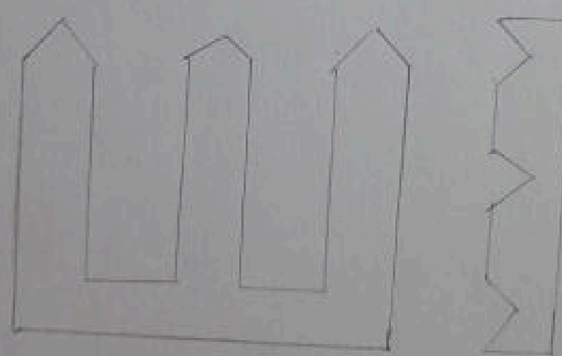
Three-phase transformer Construction:

1. Core: The Construction is done Step by step. First the Sketch is prepared based upon the requirements of the Customer (wether the windings should be of copper or Alluminium, the KVA ratings and many other parameters). All the transformers manufactured there was a core type transformer. That is windings surrounds the Core, the windings are evenly split and wound on the limbs of the core. The core consists of three limbs on the same plane.

Each of these limbs contains both the primary and Secondary windings. These windings may be better referred to as the high voltage (HV) and low voltage (LV) windings. The low voltage windings are wound closest to the core since it is easier to insulate. The high voltage coil is then wrapped around the low voltage winding with insulation between them. In this construction, the windings are magnetically coupled with each other where one winding uses the other two limbs as a return path for its magnetic flux.

The core laminations are cut into a thin sheet steel. The core is cut into sheets to reduce the eddy current loss. Eddy current loss is power loss in a transformer due to currents induced in the metal parts of the system from the changing magnetic field. Constructing the core from thin sheets of iron laminated together can minimize the eddy currents. Each sheet is coated with an insulating varnish that forces these currents to only flow within individual laminations. This reduces the overall eddy currents in the entire core. These thin sheets are manufactured from silicon-iron or nickel-iron alloys that can be magnetized more readily than pure iron. The use of alloys cores also improves the age resistance of the core. The sheets are often made from 29-guage alloy.

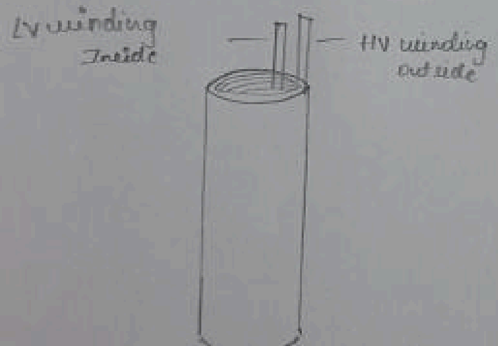
The core is madeup of Silicon steel in 'Power Control System'. The thickness of the core with the rating of the transformer. For a transformer the core thickness was around 0.23mm to 0.3mm. All the sheet steel were laminated.



The stamping was in E and I shape. The Edges were sharp due to avoid high reluctance at the joints. Commonly the core type transformers are used in high voltage and low-current applications. There are other type of thickness of core. Normally if the thickness of the core steel sheet is less than 0.23mm, then that type of core is known as Amourphous core. As the rating of the transformer changes, the diameter of the core also changes. Higher the rating, the Higher the Dia of Core.

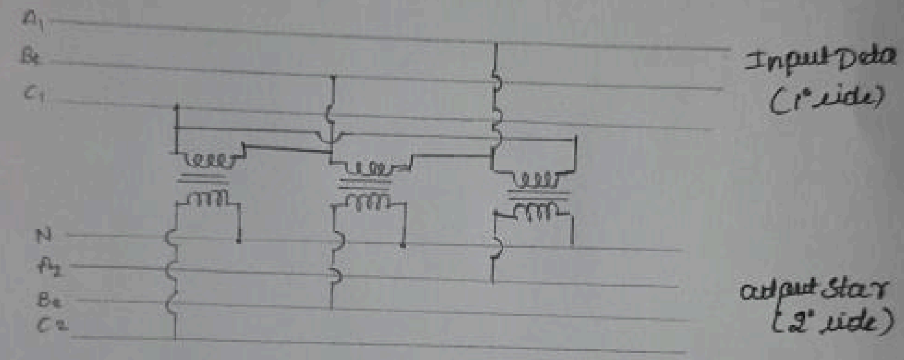
2. **Windings:** The transformers have two windings, they are primary and secondary windings. The primary winding is the coil that draws power from the source. The secondary winding is the coil that delivers the energy at the transformed or changed voltage to the load. Usually, these two coils are subdivided into several coil in order to reduce the creation of flux.

Transformer winding materials are alluminium and copper which are the most frequently used conductors in transformer windings. The mechanical strength and conductivity are high for copper whereas aluminum materials are less cost and lightweight as compared to copper. Generally, copper windings are used in large transformers whereas aluminum conductors are used for small size and medium size transformers. The transformer windings are available in different types. Core has two parts, one is limb and other one is yoke. The vertical section is known as limb and Horizontal section is known as yoke. The windings are wound the the limbs (in three phase transformer, there are three limbs and two yokes). The winding (Aluminum or copper depending upon the customer and usage) are wound on the limbs. Insulations are used between the high voltage (HV) and low voltage (LV) windings to prevent the short circuit. The Insulation material can be a wooden cardboard or a ducks or a insulating material for the electricity. The windings may be wound in cylindrical or sandwich types. For High voltage insulated sheets in between the windings are used.



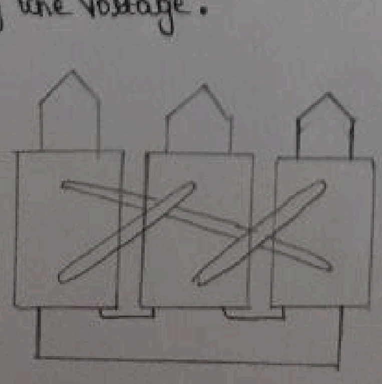
For wounding the wire in cylindrical shape, the workers use the machine called PCP (pre-compressed pressure board). First they prepare a solid cylinder madeup of wood or any other material. This is done because to create a hollow path for windings to fit it on the core. Then the windings are wound on this wooden sphere to primary and secondary. The LV - Low voltage windings have greater diameter due to low voltage and high current. whereas the HV - High voltage winding have lower diameter because of high voltage and less current. The type of transformer which is constructed is step down distribution transformer (In power system Controls), so the primary side has

HV- High voltage windings which are outside the core and the LV- Low voltage windings are Secondary which are closer to the core. The Thickness of wire (primary) is more and the Secondary is less. The thickness is around 0.25mm. Winding material is selected in such a way to suitable application and cost. The layers of primary and Secondary windings are wound due to high advantages like travel of magnetic flux in a core (magnetic path). In between the windings the Insulating material called Ducks are used. It is provided in between the core and tank to avoid the Earthing of the windings, and also lesser the thickness of ducks, lesser will be the Eddy current loss because the gap created in between the windings will be less. Similarly the Higher the thickness of Duck, more will be the Eddy current loss.



phase wiring for Δ-Y transformer.

As shown in the circuit, normally the transformer used there is stepdown transformer (11KV to 440V). The HV- High voltage winding is connected in Delta format and given to outlet bushing whereas the LV- Low voltage winding is connected in star expression. The output side we can get a single phase voltage by taking neutral wire and any one phase wire. The ratio of secondary to primary line voltage is $\sqrt{3}$ times the transformation ratio. There is 30° shift between the primary and secondary line voltage.



Tank and oil

Transformer tank also named transformer Body. It is used to hold, protect, cool the winding and core in one electrical distributor transformer. The tank body provides isolation of oil and the core from the outside environment. There are many types of tanks available. ex plain steel sheet tank, Tube tank, tank with separate coolers etc.

When the transformer is loaded, and the ambient temperature rises, the volume of oil inside the transformer increases. A tank of transformer provides adequate space to this expanded transformer oil. It also acts as a reservoir for transformer insulating oil. Commonly the transformer tank is madeup of materials like Steel, Alloy steel, MS material, SS material etc. The capability or strength of the tank is expressed in atmospheric pressure to withstand the expandage of oil. the tank or box protects all the windings & cores from the atmospheric effect. three phase winding is inserted into the tank.

Transformer oil or insulating oil is an oil that is stable at high temperatures and has excellent electrical insulating properties. It is used in oil-filled transformers (wet transformers). Transformer oil is most often bas based on mineral oil, but alternative formulations with different engineering or environmental properties are growing in popularity.

The oil which is used in a transformer should not have a flash point less than 160°c. That means it should be highly inflamable under standard temperatures. Also the freezing point should not be higher than 15°c and its viscosity should be 30°c and 15°c.

Transformer oils are subject to electrical and mechanical stresses while a transformer is in operation. In addition there is contamination caused by chemical interactions with windings and other solid insulation, catalyzed by high operating temperature. The original chemical properties of transformer oil change gradually, rendering it ineffective for its intended purpose after many years.

Conservator

The Conservator tank is simply a tank that is used to provide enough space for the oil in the transformer to spread after heating. It is placed on the roof of the transformer. The main function of the Conservator tank is that once the transformer is loaded, its temperature rises, and the oil in it starts spreading. That is why the Conservator tank is acts like pond for the Insulation of the transformer. To the conservator tank, the oil level indicator is used to indicate or measure the oil level in the tank. There are two types of transformer Conservator tank,

1. Atmoseal type conservator
2. Diaphragm sealed Conservator.

Construction of Conservator tank: This is a cylindrical shaped oil container closed from both ends. One large inspection cover is provided on either side of the container to facilitate maintanance and cleaning inside of the conservator. Conservator pipe, that is pipe comes from main transformer tank, is projected inside the conservator from bottom portion. Head of the Conservator pipe inside the conservator is provided with a cap. This pipe is projected as well as provided with a cap because this design prevent oil sludge and sediment to enter into the conservator from top. If it enters from bottom, it should be projected well above the level of oil inside the Conservator. This arrangement ensure that oil does not enter the silica gel breather even at highest operating level.

Working of Conservator tank: when volume of transformer insulating oil increases due to load and ambient temperature, the vacant space above the oil level inside the conservator is partially occupied by the expanded oil. Consequently, corresponding quantity of air of that space is pushed away through breather. On other hand, when load of transformer decreases, the transformer is switched off and when the ambient temperature decreases, the oil inside the transformer contracts. This causes outside air to enter in the Conservator tank of transformer through silica gel breather.

Silica gel Breather of transformer

whenever an electrical power transformer is loaded, the temperature of the transformer insulating oil increases, consequently the volume of the oil is increased. As the volume of the oil is increased, the air above the oil level in conservator will come out. Again at low oil temperature, the volume of the oil is decreased, which causes the volume of the oil to be decreased which again causes air to enter into conservator tank.

The natural air always consists of more or less moisture in it and this moisture can be mixed up with oil if it is allowed to enter into the transformer. The air moisture should be resisted during entering of the air into the transformer, because moisture is very harmful for transformer insulation. A silica gel breather is the most commonly used way of filtering air from moisture. Silica gel breather for transformer is connected with conservator tank by means of breathing pipe.

working principle of silica gel breather: silica gel crystal has tremendous capacity of absorbing moisture. when air passes through these crystals in the breather, the moisture of the air is absorbed by them. Therefore, the air reaches to the conservator is quite dry, the dust particles in the air get trapped by the oil in the oil seal cup. The oil in the oil sealing cup acts as barrier between silica gel crystal and air when there is no flow of air through silica gel breather. The color of silica gel crystal is dark blue but, when it absorbs moisture, it becomes pink.

when there is sufficient difference between the air inside the conservator and the outside air, the oil level in two components of the oil seal changes until the lower oil level just reaches the rim of the inverted cup, the air then moves from high pressure compartment to the low pressure compartment of the oil seal. Both of these happens when the oil acts as core filter and removes the dust from the outside air.

Buchholz Relay

A Bucchholz relay is a safety device mounted on (some) oil-filled power transformers and reactors, equipped with an external overhead oil reservoir called a "conservator". Buccholz relays are used as protective device, as they are sensitive to the effects of dielectric failure that can occur inside the equipment they protect. Bucchholz relays are a type of gas detection relay.

Bucchholz relays have two main elements. The upper element consists of a float. The float is attached to hinge in such a way that it can move up and down depending upon the oil level in the buchholz relay container. A mercury switch is fixed on the float. The allignment of the mercury switch hence depends upon the position of the float.

The lower element consists of a baffle plate and a mercury switch. This plate is fitted on a hinge just in-front of the inlet (main tank side) of the Buchholz relay in a transformer in such a way that when oil enters in the relay from that inlet in high pressure the allignment of the baffle plate along with the mercury switch attached to it, will change. In addition to these main elements, a Bucchholz relay has gas release pockets on top. The electrical leads from both mercury switches are taken out through a molded terminal block.

Transformer bushings

The two most common types of bushings used on transformers as main lead entrances are solid porcelin bushings on smaller transformers and oil-filled condenser bushings on larger transformers. Solid porcelain bushings consist of high-grade porcelain cylinders that conductors pass through. Outside surfaces have a series of skirts to increase the leakage path distance to the grounded metal case. High-voltage bushings are generally oil-filled condenser type.

Explosion vent: It provides an exit path to the gases produced in the transformer due to all kinds of faults. Diaphragm is used to discharge excess pressure in the atmosphere when excess pressure is developed inside the transformer during loading.

Radiators and fans

when a transformer is loaded, the current starts flowing through it's windings. Due to this flowing of electric current, heat is produced in the windings, this heat ultimately rises the temperature of transformer oil. We know that the rating of any electrical equipment depends upon its allowable temperature rise limit. Hence, if the temperature rise of the transformer insulating oil is controlled, the capacity or rating of transformer can be extended up to significant range. The Radiator of transformer accelerates the cooling rate of transformer. Thus, it plays a vital role in increasing loading capacity of an electrical transformer.

under loaded condition, warm oil increases in volume and comes to the upper portion of the main tank. Then this oil enters in the radiator through top valve and cools down by dissipating heat through the thin radiator wall. This cold oil comes back to the main tank through the bottom radiator valve. This cycle is repeated continuously till the load is connected to the transformer. Dissipation of heat in the transformer radiator, can be accelerated further by force air provided by means of fans. These fans are fitted either on the radiator bank but all the fans must be faced towards the radiator. Sometime, the cooling rate of convectional circulation of oil is not sufficient. That time an oil pump may be used for speeding up oil circulation.