MODULE 2

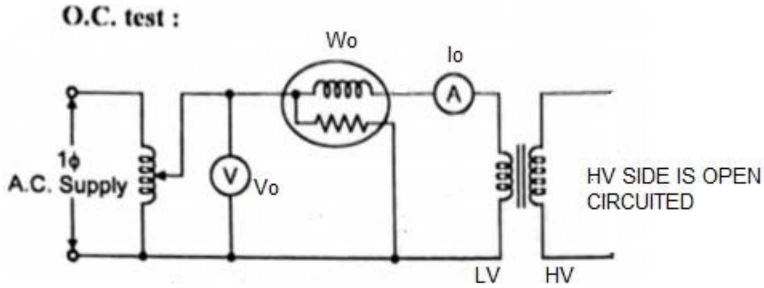
TESTING OF TRANSFORMERS AND INSTRUMENT TRANSFORMERS

TRANSFORMER TESTS

- Transformer performance can be judged if the parameters of equivalent circuit is known. That is
  1. R01 & R02
  2. X01 & X02
  3. Core loss resistance R_0
  4. Magnetising reactance X_0
- These 4 parameters can be determined by following 2 tests

1. O.C Test (Open Circuit Test)
2. S.C Test (Short Circuit Test)

1. O.C Test (Open Circuit Test)



- Circuit diagram for OC test is shown above
- OC test is also called **No load test**
- This test is conducted to determine core loss or iron loss and no load current I_0. Finding these values helps to find out value of R_0 and X_0
- In this test, Rated voltage is applied on LV side by keeping HV side open. The ammeter reads no load input current and LPF wattmeter reads no load input power.
- The power measured by LPF wattmeter includes copper loss on primary due to no load current I_0 and core loss
- Since I_0 is very small. The copper loss due to I_0 can be neglected. Hence the LPF wattmeter reads core loss of the transformer
- This test is conducted on LV side due to
  1. It is easy to arrange rated voltage supply in LV side rather than arranging rated voltage at HV side
  2. Since the measuring instruments are placed at LV side, the cost of instruments is very less
  3. Safety is more due to the testing on LV side

- Finding of R_0 and X_0

The two parameters which can be calculated from the open circuit test of transformer are R_o and X_o. They are calculated as follows.

If W_0 is the wattmeter reading,

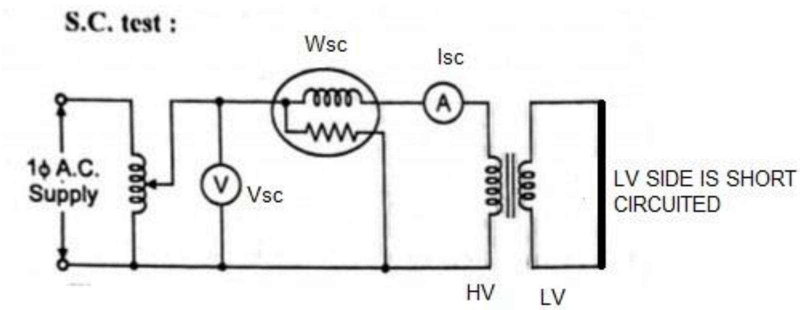
Then $W_0 = V_0 I_0 \cos(\Phi_0)$

Hence $\cos(\Phi_0) = \frac{W_0}{V_0 I_0}$

$I_w = I_0 \cos(\Phi_0)$ and $I_m = I_0 \sin(\Phi_0)$

$R_0 = \frac{V_0}{I_w}$ and $X_0 = \frac{V_0}{I_m}$

2. S.C TEST (Short Circuit Test)



- Circuit diagram of SC test is shown above
- This test is conducted to determine
    a. Full load copper loss of the transformer
    b. Equivalent resistance and Equivalent reactance of the transformer

- In this test, meters are connected on HV side and LV side is short circuited using thick wire. By varying auto transformer rated current is allowed to flow through HV side. The rated current on HV side can be achieved by 5 to 10% of normal rated voltage on HV side
- The wattmeter reads both core loss and copper loss. But the core loss at very small voltage is very small. Hence it can be neglected. So the wattmeter reading can be approximated to full load copper loss
- Finding of Equivalent resistance and Equivalent reactance of the transformer

Let W_{SC} is the wattmeter reading, V_{SC} is the voltmeter reading and I_{SC} is the ammeter reading obtained from SC test.

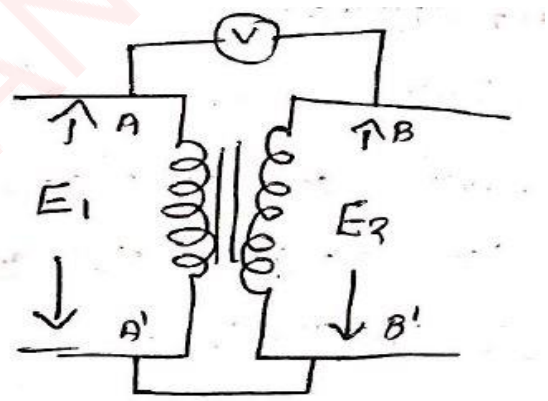
$W_{SC}={I_{SC}}^2 R_{01}$ = full load copper loss

Equivalent resistance referred to primary is, $R_{01} = \frac{W_{SC}}{I_{SC}2}$

Equivalent impedance referred to primary is, $Z_{01} = \frac{V_{SC}}{I_{SC}}$

Equivalent reactance referred to primary is, $X_{01} = \sqrt{{Z_{01}}^2 - {X_{01}}^2}$

Polarity test



- Used to find instantaneous polarity of transformer windings
- Polarity test is compulsory before parallel operation of transformers
- If input voltage V1 is applied to transformer primary winding and if the voltmeter reads E1+E2, Then we can say the A and B points of windings are instantaneously opposite- Additive Polarity
- If input voltage V1 is applied to the transformer primary winding and if the voltmeter reads E1- E2, Then we can say the A and B points of windings are instantaneously opposite- Subtractive Polarity

Voltage Regulation of a Transformer

- When a transformer is loaded, its applied primary voltage remains unchanged. But secondary terminal voltage changes.
- The change in secondary terminal voltage from no load to full load expressed as secondary no load voltage is known as regulation down

% Regulation down = $\frac{E_2{}^0 - V_2}{E_2{}^0}$ X 100

$E_2{}^0$ = No load secondary terminal voltage

V_2 = Full load secondary terminal voltage

- The change in secondary terminal voltage from no load to full load expressed as secondary full load voltage is known as regulation up

% Regulation up = $\frac{E_2{}^0 - V_2}{V_2}$ X 100

- If voltage regulation of a transformer is less, then the transformer will be better

The approximate voltage drop on a transformer reffered to primary

= $I_1(R_{01} Cos (\phi) \pm X_{01} Sin (\phi))$ + ...Lagging power factor

\- ......Leading power factor

The approximate voltage drop on a transformer reffered to secondary

= $I_2(R_{02} Cos (\phi) \pm X_{02} Sin (\phi))$ + ...Lagging power factor

\- ......Leading power factor

EFFICIENCY OF A TRANSFORMER

- % Efficiency of a transformer $= \frac{Output\ power}{Input\ power}$ x 100
- It can be also expressed as $\frac{Output\ power}{Output\ power\ +\ Losses}$ x 100
- The losses in a transformer are copper loss and core loss. Since the transformer is a static machine, there is no mechanical loss . Hence the total loss in a transformer is due to core loss and copper loss only and which is very small. Hence the transformer has high efficiency (90 to 99%)

(b) Obtain the approximate equivalent circuit of a 200/400V, 50Hz 1ϕ transformer from the following test data :

OC test : 200V, 0.7A, 70W — on L.V side

SC test : 15V, 10A, 85W — on H.V side

Derivation

200 / 400V, 50Hz

oc test : 200V, 0.7A, 70W - lV

sc test : 15V, 10A, 85W - hV

From oc test :- (values referred to lV)

$W_0 = V_1 I_0 \cos\phi_0$; $\cos\phi_0 = 0.5$

$\therefore \phi_0 = 60^\circ$

$\sin\phi_0 = 0.866$

$I_W = I_0 \cos\phi_0 = 0.35A$; $I_M = I_0 \sin\phi_0$

$= 0.606A$

$\therefore R_0 = V_1/I_W = 571.4\Omega$

$X_0 = V_1/I_M = 330\Omega$

From SC test (values referred to hV side)

$Z_{02} = \frac{V_{sc}}{I_{sc}} = 15/10 = 1.5\Omega$

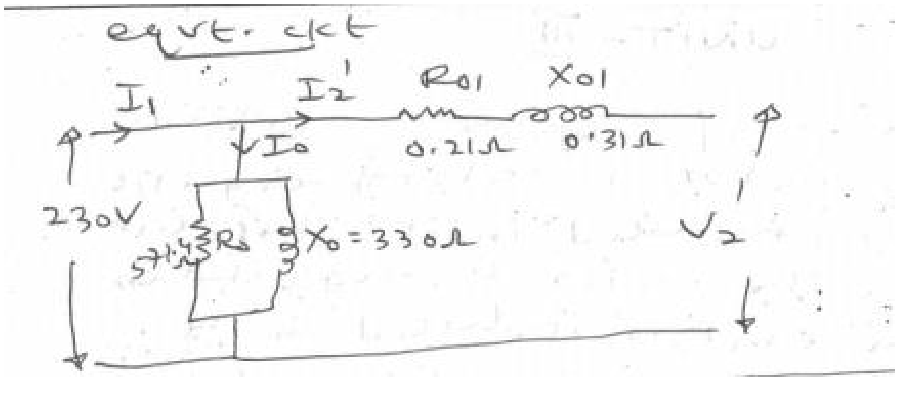
$I_{sc}^2 R_{02} = W_{sc}$; $R_{02} = \frac{W_{sc}}{I_{sc}^2} = \frac{85}{10^2} = 0.85\Omega$

Z_{02} & R_{02} referred to lV side

$Z_{01} = Z_{02}/K^2$, $R_{01} = R_{02}/K^2$; $\boxed{K = \frac{400}{200} = 2}$

$= 0.375\Omega$ // $= 0.21\Omega$

$\therefore X_{01} = \sqrt{Z_{01}^2 - R_{01}^2} = 0.31\Omega$



A 2 KVA, 250/25 V, 50 Hz Single phase transformer has following test results:
O.C test (low voltage side) : 250 V, 1.4 A, 105 W.
S.C test (high voltage side) : 104 V, 8 A, 320 W.
Compute the parameters of the approximate equivalent circuit referred to high Voltage side and draw the circuit.

O.C test

$W_0 = V_1 I_0 \cos\phi_0$

$\therefore \cos\phi_0 = 0.3$

$I_w = I_0 \cos\phi_0 = \underline{\underline{0.42\,A}}$ | $I_\mu = I_0 \sin\phi_0 = \underline{\underline{1.33\,A}}$

$R_0 = \frac{V_1}{I_w} = \underline{\underline{595.2\,\Omega}}$ | $X_0 = \frac{V_1}{I_\mu} = \underline{\underline{187.2\,\Omega}}$

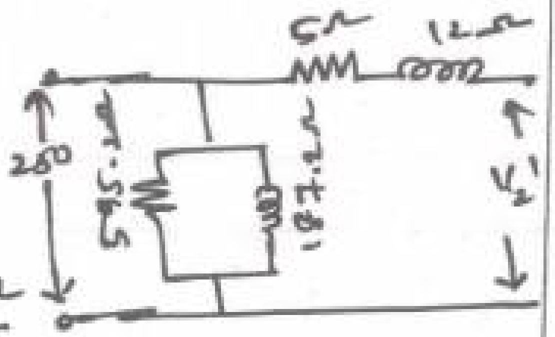
S.C test

$W_s = I_s^2 R_{01}$

$\therefore R_{01} = \frac{320}{8^2} = \underline{\underline{5\,\Omega}}$

$Z_{01} = \frac{V_s}{I_s} = 12\,\Omega$

$\therefore X_{01} = \sqrt{Z_{01}^2 - R_{01}^2} = \underline{\underline{12\,\Omega}}$



Derive an equation to determine the efficiency and regulation of transformer from open circuit and short circuit tests.

Open Circuit Test : The two components of no load current can be given as

$I\mu = I_0 \sin\Phi_0$ and $Iw = I_0 \cos\Phi_0$.

$\cos\Phi_0$ (no load power factor) = W / ($V1I_0$). ... (W = wattmeter reading)

From this, shunt parameters of equivalent circuit parameters of equivalent circuit of transformer (X_0 and R_0) can be calculated as

$X_0 = V_1/I\mu$ and $R_0 = V_1/Iw$.

(These values are referring to LV side of the transformer.)

Hence, it is seen that open circuit test gives core losses of transformer and shunt parameters of the equivalent circuit.

Short Circuit Test : The ammeter reading gives primary equivalent of full load current (Isc).The voltage applied for full load current is very small as compared to rated voltage. Hence, core loss due to small applied voltage can be neglected. Thus, the wattmeter reading can be taken as copper loss in the transformer.

Therefore, $W = Isc^2 Req$....... (where Req is the equivalent resistance of transformer)

$Zeq = Vsc/Isc$.

Therefore, equivalent reactance of transformer can be calculated from the formula $Zeq^2 = Req^2 + Xeq^2$.

These, values are referred to the HV side of the transformer.

Hence, it is seen that the short circuit test gives copper losses of transformer and approximate equivalent resistance and reactance of the transformer.
From this total loss can be measured by OC and SC test
Efficiency = output / input x 100
= output/ output + losses.
$= V_2 I_2 \cos\theta / (V_2 I_2 \cos\theta + Pi + x^2 Pe)$
Regulation = ($I_2 R_2eq \cos\theta + I_2 X_2eq \sin\theta$/ no load voltage) X 100

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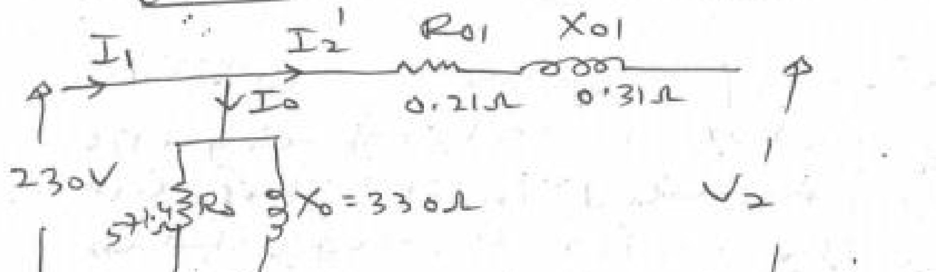
eqvt. ckt



Condition for Maximum Efficiency

$$\text{Cu loss} = I_1^2 R_{01} \quad \text{or} \quad I_2^2 R_{02} = W_{cu}$$

$$\text{Iron loss} = \text{Hysteresis loss} + \text{Eddy current loss} = W_h + W_e = W_i$$

Considering primary side,

$$\text{Primary input} = V_1 I_1 \cos\phi_1$$

$$\eta = \frac{V_1 I_1 \cos\phi_1 - \text{losses}}{V_1 I_1 \cos\phi_1} = \frac{V_1 I_1 \cos\phi_1 - I_1^2 R_{01} - W_i}{V_1 I_1 \cos\phi_1}$$

$$= 1 - \frac{I_1 R_{01}}{V_1 \cos\phi_1} - \frac{W_i}{V_1 I_1 \cos\phi_1}$$

Differentiating both sides with respect to I_1, we get

$$\frac{d\eta}{dI_1} = 0 - \frac{R_{01}}{V_1 \cos\phi_1} + \frac{W_i}{V_1 I_1^2 \cos\phi_1}$$

For η to be maximum, $\frac{d\eta}{dI_1} = 0$. Hence, the above equation becomes

$$\frac{R_{01}}{V_1 \cos\phi_1} = \frac{W_i}{V_1 I_1^2 \cos\phi_1} \quad \text{or} \quad \boxed{W_i = I_1^2 R_{01} \quad \text{or} \quad I_2^2 R_{02}}$$

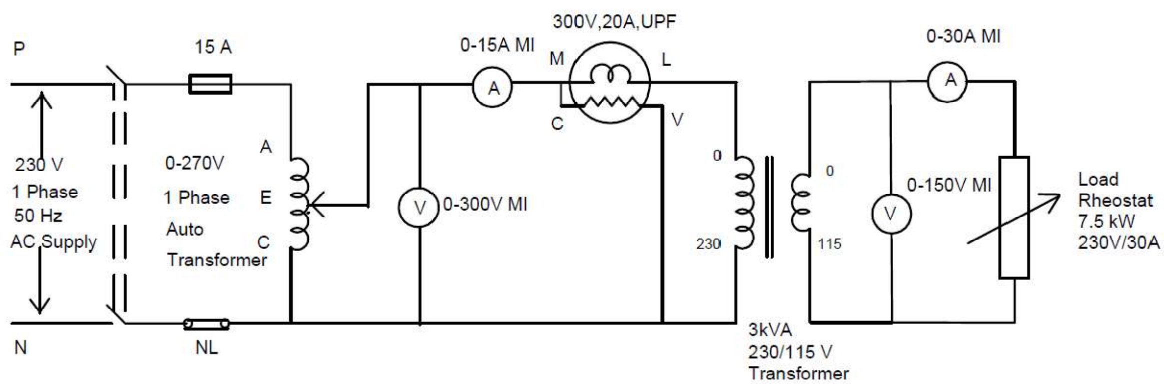
or $\quad$ **Cu loss = Iron loss**

- **Hence efficiency of a transformer is maximum, when Copper loss is equal to Core los**

LOAD TEST ON SINGLE PHASE TRANSFORMER

Load test is done on a single phase transformer to determine the efficiency of it at different stages of loads. The voltage applied is the rated voltage. The transformer is loaded step by step till the final value of rated current is obtained. The efficiency of the transformer is given by
% Efficiency = (Output/Input) ×100 = $(V_2I_2/ W_1)\times100$
Voltage regulation is defined as the change in secondary terminal voltage, expressed as difference of the secondary rated voltage, when loaded the given primary applied voltage remain constant with reduced power factor.

Circuit Diagram



PROCEDURE:

1. Make connection as shown in connection diagram.
2. Switch on the supply by keeping the autotransformer kept at minimum position.
3. Rated voltage is applied on the primary side by adjusting the autotransformer. No load readings are taken out.
4. Gradually loaded the transformer till the rated current flows. At each time note the corresponding meter reading.

CALCULATION:

1. To determine the efficiency:-

Output power = V_2I_2 Watts
Input power = W_1 Watts
% Efficiency = (Output/Input) ×100 = $(V_2I_2/ W_1)\times100$
Where V_2 = Secondary voltage
I_2= Secondary current
W_1= Input power

2. To determine the regulation:-

% Regulation = $((V_{02}-V_2)/ V_{02})\times100$
Where V_{02}= Secondary voltage at no load
V_2= Secondary voltage at load

ALL DAY EFFFICIENCY

- Ordinary efficiency=$\frac{\text{Output in watts}}{\text{Input in watts}}$
- In the case of distribution transformer , the output power is not constant. It changes according to the time of a day. Thus for such transformers the expressing of efficiency in terms of ordinary efficiency is not correct. Thus the term all day efficiency came
- All day efficiency is the ratio of output power in KWH to input power in KWH during the whole day (That is 24 hrs)
- The All day efficiency = $\frac{\text{Output in KWH}}{\text{Input in KWH}}$ for 24 hrs

Parallel operation of a transformer

- Sometimes, it is necessary to connect more than one [transformers]() in parallel. For example, for supplying excess load which is more than the rating of existing transformer.

- If two or more transformers are connected to a same supply on the primary side and to a same load on the secondary side, then it is called as parallel operation of transformers

Why we need Parallel Operation(Necessity of parallel operation)

Transformers are connected in parallel

- To supply load which is more than the rating of existing transformer
- To meet the additional demand on the power system
- To reduce the cost of stand by transformer
- To increase the reliability of the power supply
- To make the maintenance of the transformer running parallel easy
- To allow the transformers running at full load so that the overall efficiency increases

Conditions for parallel operation of single phase transformers

1. Same voltage ratio
2. Same percentage impedance
3. Same polarity
4. Same resistance to reactance ratio
5. Same frequency

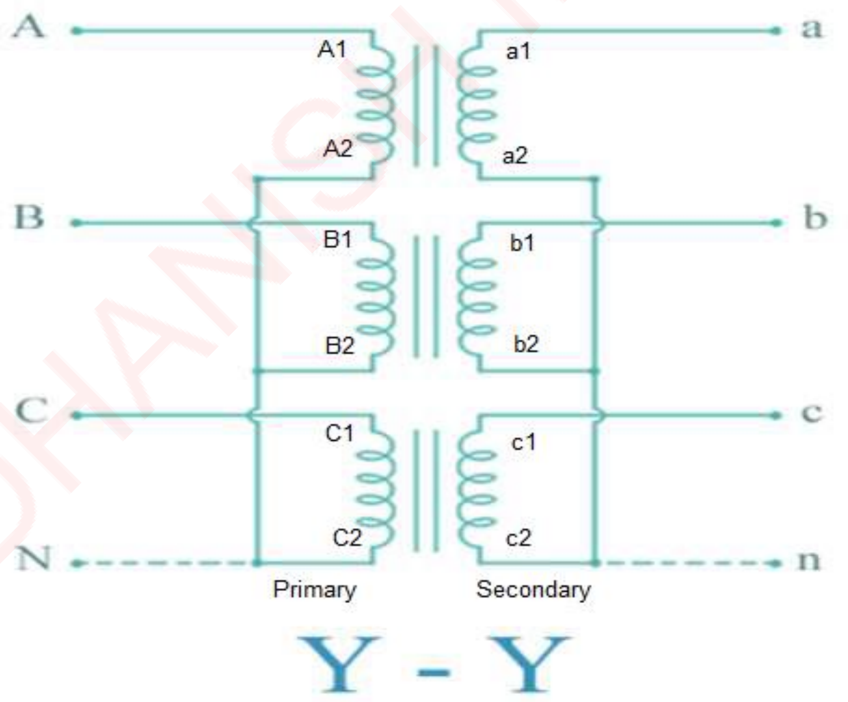
THREE PHASE TRANSFORMER

THREE PHASE TRANSFORMER CONNECTIONS

Windings of a three phase transformer can be connected in various configurations

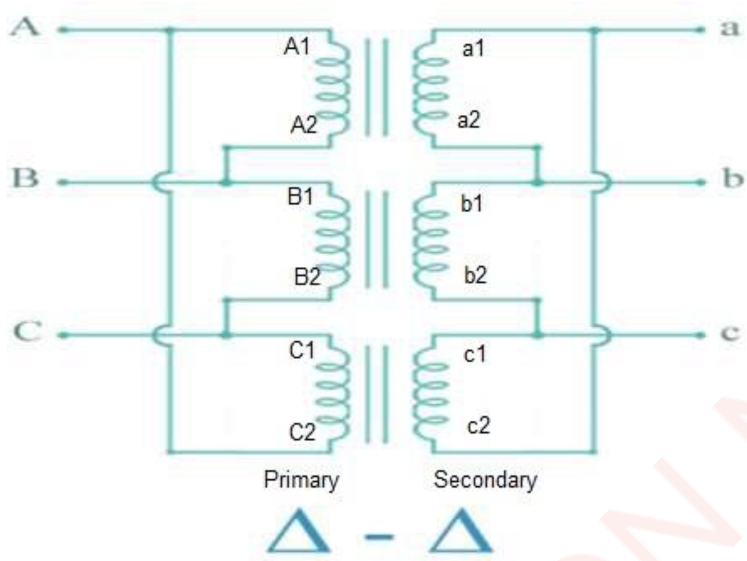
1. star-star
2. delta-delta
3. star-delta
4. delta-star

1. Star-Star (Y-Y)



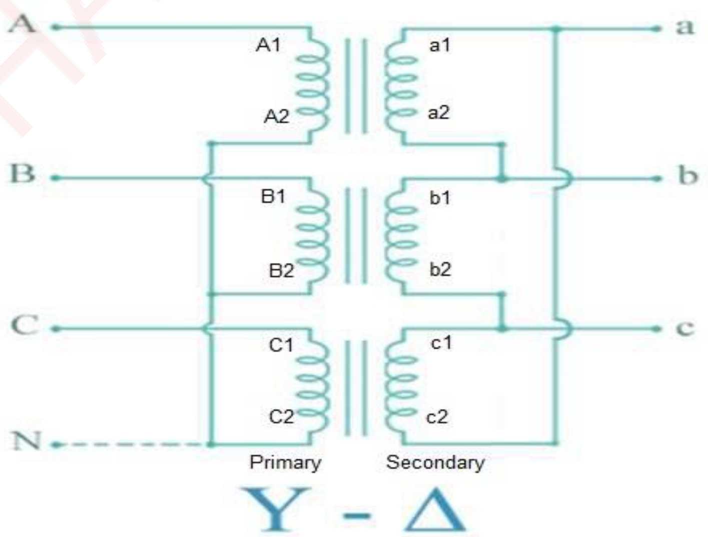
- Here the primary and secondary is star connected
- Star-star connection is generally used for small, high-voltage transformers. Because of star connection, number of turns/phase is reduced (as phase voltage in star connection is 1/√3 times of line voltage only). Thus, the amount of insulation required is also reduced.
- There is no phase displacement between primary and secondary voltages
- This connection can be used only if the connected load is balanced

2. Delta- Delta (Δ - Δ)



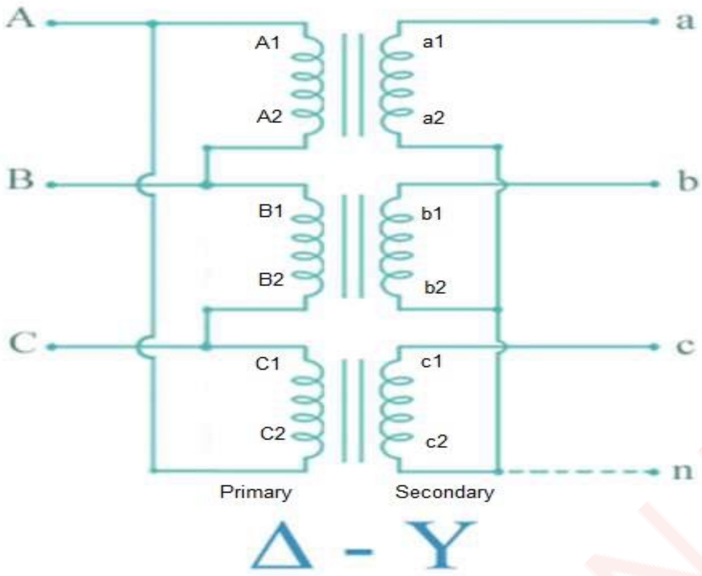
- Here the primary and secondary is delta connected
- This connection is generally used for large, low-voltage transformers
- There is no phase displacement between primary and secondary voltages
- The cross sectional are of conductor is reduced, because the phase current is less in delta connection by √3 times
- The voltage distortion is not present. Because the third harmonic current can flow in delta connected primary windings
- This connection can work well if the connected load is unbalanced also
- Another advantage of this type of connection is that even if one transformer is disabled, system can continue to operate in open delta connection but with reduced available capacity

3. Star- Delta (Y- Δ)



- The primary winding is star (Y) connected with neutral grounded and the secondary winding is delta connected.
- This connection is mainly used in step down transformer at the substation end of the transmission line.
- There is 30° shift between the primary and secondary line voltages. (Hence star delta transformer cannot be connected in parallel with delta-delta or star-star transformers)

4. Delta- star (Δ-Y)



- The primary winding is connected in delta and the secondary winding is connected in star with neutral grounded. Thus it can be used to provide 3-phase 4-wire service.
- This type of connection is mainly used in step-up transformer at the beginning of transmission line.
- There is 30° shift between the primary and secondary line voltages.

Condition For Parallel Operation of Three Phase Transformer

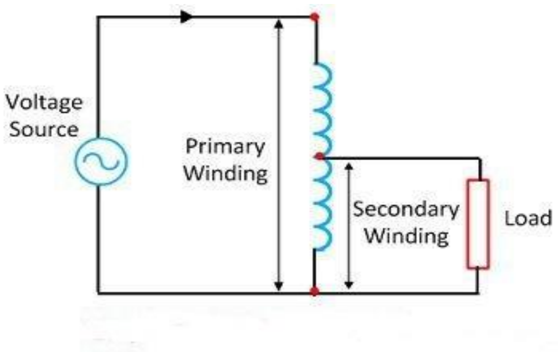
1. Percentage impedance should be same
2. The polarity of transformers should be same
3. Phase sequence of transformers should be same
4. Ratio of resistance to reactance of transformers should be same
5. The no load transformation ratio should be same
6. The phase displacement between primary and secondary of all transformers in parallel should be same

SPECIAL TRANSFORMERS

Other than power transformers, almost all transformers are called special transformers
Eg:

1. Auto transformer
2. Instrument transformer
3. Welding transformer
4. Booster transformer
5. CVT (Constant voltage transformer)
6. Tap changing transformer

Auto transformer



It is a single winding transformer. In this transformer a part of the winding is common to both primary and secondary. Here both primary and secondary are magnetically and electrically connected. So in a autotransformer, unlike a common transformer both primary and secondary are not electrically isolated

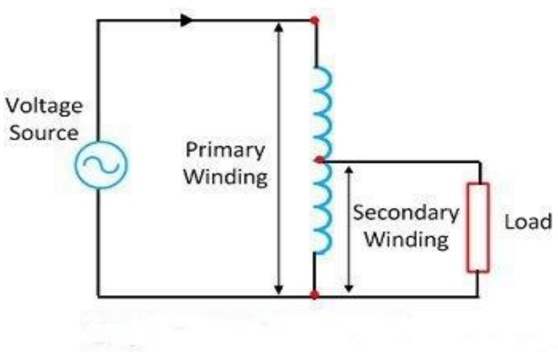
Advantages of auto transformer

- It can give continuous variable output voltage
- Size of this transformer is very small
- Cost of this transformer is very small
- Losses are very less
- Efficiency is high
- Construction is simple

Application of autotransformer

1. Used as starter for induction motor and synchronous motor
2. Used as voltage booster in power cables
3. Used in testing laboratories
4. Used as voltage regulators

Construction details of auto transformer



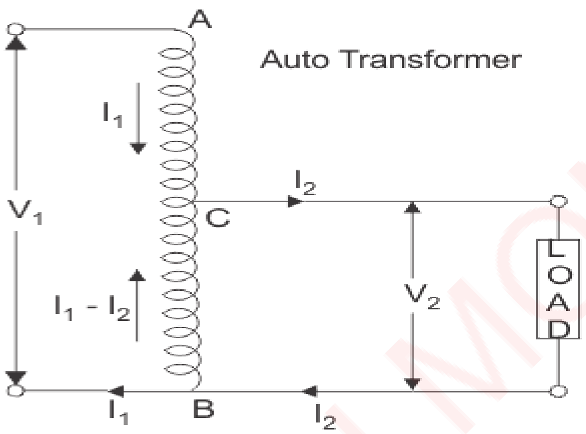
• Auto transformer is a single winding transformer with a part of this winding is Common to both primary and secondary. Tapping points are provided on the winding to take voltage to load

• Windings are made up of copper.

• These primary and secondary windings are wound on the magnetic core.

• Core is made up of silicon steel. This core is laminated to reduce eddy current loss

Comparison of copper requirements or Copper savings equation of Auto transformer



Consider an auto transformer in which section AB is primary winding having N_1 turns and BC is secondary winding having N_2 turns. The current in section BC is I_2 -I_1

The volume and weight of copper is proportional to length and cross sectional area of conductors. In transformers, length of conductors is proportional to number of turns and cross sectional area depends on current.
Hence weight of the copper is proportional to product of number of turns and current

Weight of copper in section AC α $(N_1 - N_2)\, I_1$
Weight of copper in section BC α $N_2\,(I_2 - I_1)$

Total weight of copper in auto transformer α $(N_1 - N_2)\, I_1 \;+\; N_2\,(I_2 - I_1)$..........(1)

If we use two winding transformer for doing same duty as performed by auto transformer, then the
Weight of copper required for the primary winding in 2 winding transformer α $N_1\, I_1$
Weight of copper required for the secondary winding in 2 winding transformer α $N_2\, I_2$

Total weight of copper required for 2 winding transformer α $N_1\, I_1 \;+\; N_2\, I_2$............(2)

Hence $\dfrac{\text{weight of copper in auto transformer}}{\text{weight of copper required for 2 winding transformer}} = \dfrac{(N_1 - N_2)\, I_1 \;+\; N_2\,(I_2 - I_1)}{N_1\, I_1 \;+\; N_2\, I_2}$ ....(3)

$= 1 \;-\; \dfrac{2K}{1 + K.\frac{1}{K}}$ where $\dfrac{N_2}{N_1} = K$ and $\dfrac{I_2}{I_1} = \dfrac{1}{K}$

$= 1 \;-\; \dfrac{2K}{2}$

$= 1 - K$

Hence weight of copper in auto transformer = (1 - K) x weight of copper required for 2 winding transformer

weight of copper in auto transformer - weight of copper in 2 winding transformer
= K X weight of copper required for 2 winding transformer

Hence the copper saving when an auto transformer is used instead of 2 winding transformer for the same purpose = K X weight of copper required for 2 winding transformer

INSTRUMENT TRANSFORMER

Instrument Transformers are used in AC system for measurement of electrical quantities i.e. voltage, current, power, energy, power factor, frequency. Instrument transformers are also used with protective relays for protection of power system.
Basic function of Instrument transformers is to step down the AC System voltage and current. The voltage and current level of power system is very high. It is very difficult and costly to design the measuring instruments for measurement of such high level voltage and current. Generally measuring instruments are designed for 5 A and 110 V.
The measurement of such very large electrical quantities, can be made possible by using the small rating measuring instruments with the help of instrument transformers. Therefore these instrument transformers are very Popular in modern power systems.

Advantages of instrument transformers

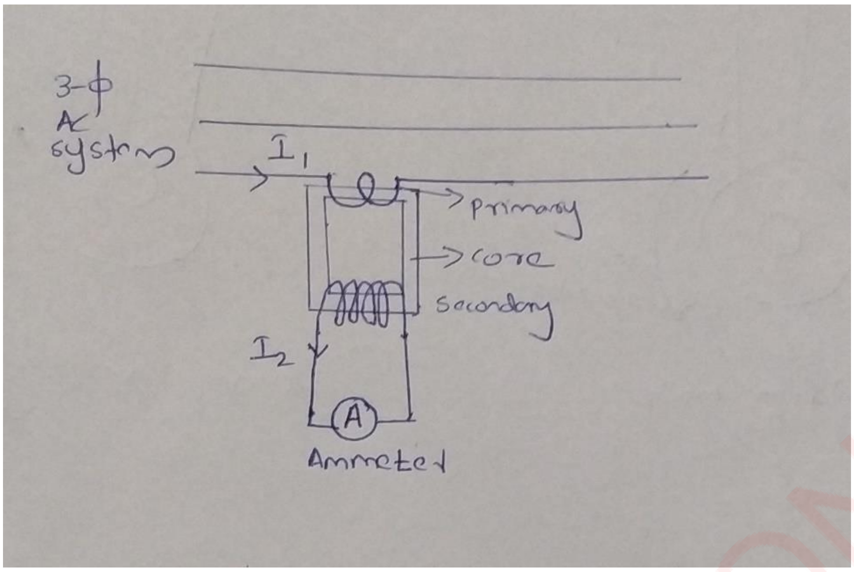
- The electrical measurements become safe because it provide electrical isolation between measuring circuit and power circuit
- It reduces overall cost of measuring equipment's
- It helps to measure large quantities using small rated instruments
- By using instrument transformers other measuring instruments can be standardised
- Power consumption by instrument transformer is low

Types of Instrument Transformers

Instrument transformers are of two types

1. Current Transformer (C.T.)
2. Potential Transformer (P.T.)

1. CURRENT TRANSFORMER(CT)



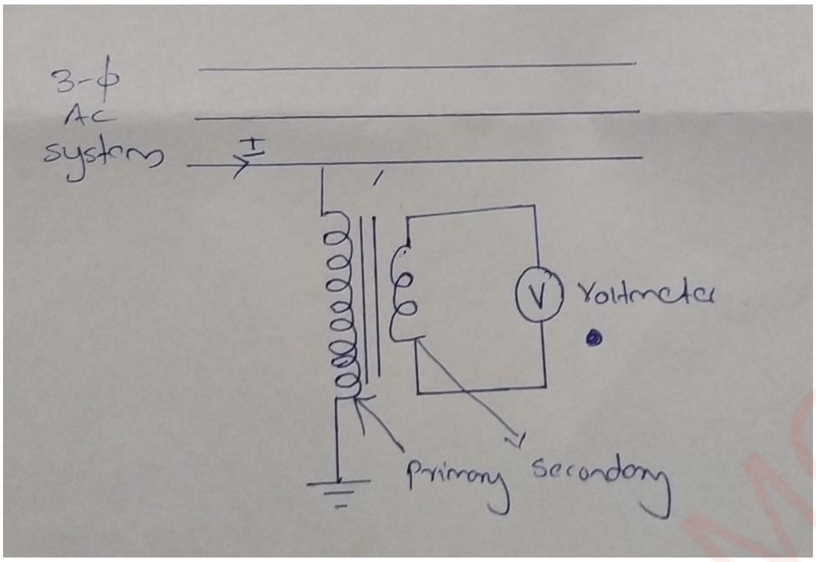
- It is a instrument transformer used for current measurement and protection purposes
- Working principle of CT is same as step up transformer in which It step downs the current in the primary according to CT ratio. So, In CT, the current in secondary will be less than current in primary but voltage in secondary will be more than voltage in primary

- Primary of CT consists of one turn and in secondary, more turns are present. Windings of CT are made up of copper. Cross sectional area of primary winding in CT will be more than cross sectional area in secondary due to large current in primary than secondary
- The primary of CT is connected in series with line and secondary is connected to ammeter.
- Standard secondary current rating of CT is 5A
- THE MAIN DIFFERENCE BETWEEN NORMAL TRANSFORMER AND CT IS , THE NORMAL TRANSFORMER CAN BE OPERATED WITH SECONDERY IN OPEN CONDITION. BUT CT NEVER OPERATED WITH SECONDERY LEFT OPEN. IF IT OPERATED WITH SECONDERY LEFT OPEN A HIGH VOLTAGE WILL COME ACROSS THE TERMINALS OF CT SECONDERY IT DAMAGES CT

Why secondary of CT never open circuited when primary is connected?

In a CT core primary ampere turns and secondary ampere turns will be opposite. So, the net flux in the core will be depending on resultant ampere turn. If secondary is left open while primary is connected to line. So, a current will always flow through primary irrespective of secondary. So primary ampere turns are present in the core of CT. Sif secondary of CT is left open, there is no secondary ampere turns to oppose primary ampere turns in the core. So, the net flux in the core will be very high. It causes very high core losses and also it causes formation of dangerously high voltage across secondary. these will damage CT. So, CT never operate with secondary left open

2. POTENTIAL TRANSFORMER(PT)



1. It is a instrument transformer used for voltage measurement and protection purposes
2. Working principle of PT is same as step down transformer in which It step downs the voltage in the primary according to PT ratio. So, In PT voltage in secondary will be less than voltage in primary but current in secondary will be more than current in primary
3. Primary of PT consists of more turns and in secondary, less number of turns are present. Windings of PT are made up of copper. Cross sectional area of secondary winding in PT will be more than cross sectional area in primary due to large current in secondary than primary
4. Primary of PT is connected parallel to the the line (between line and ground) and secondary is connected to voltmeter.
5. Standard secondary voltage rating of PT is 100V or 120V
6. SECONDERY OF PT CAN BE OPERATED IN OPEN CONDITION

Difference between C.T. and P.T.

Few differences between C.T. and P.T. are listed below –

Sl. No.	**Current Transformer (C.T.)**	**Potential Transformer (P.T.)**
1	Connected in series with power circuit.	Connected in Parallel with Power circuit.
2	Secondary is connected to Ammeter.	Secondary is connected to Voltmeter.
3	Secondary is never be open circuited.	Secondary can be used in open circuit condition.
4	Works similar to step up transformer	Works similar to step down transformer
5	Secondary works almost in short circuited condition.	Secondary works almost in open circuited condition.

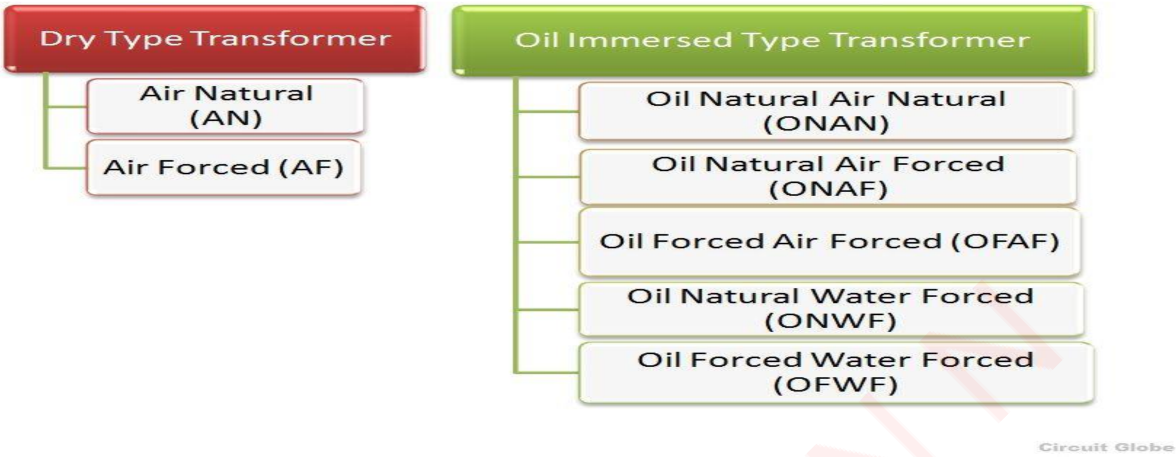
COOLING OF TRANSFORMER

- Cooling of Transformer is the process by which heat generated in the transformer is dissipated.
- Cooling is achieved by various cooling methods of transformer available.

Why cooling is needed in transformer

- The major factor for the generation of heat in the transformer is the various losses like hysteresis, eddy current, iron, and copper loss.
- Among all the various losses the major contributor of the heat generation is the copper loss or I^2R loss.
- If the temperature of the transformer will continue to increase rapidly, it will result in the degradation of the insulation used in the transformer resulting in the damaging of the various parts and hence the failure of the transformer. Thus, proper removal or treatment of heat is necessary for the efficient working, longer life and higher efficiency of the transformer.
- The various coolants used for the cooling purpose of the transformer are air, synthetic oils, mineral oils, gas, water

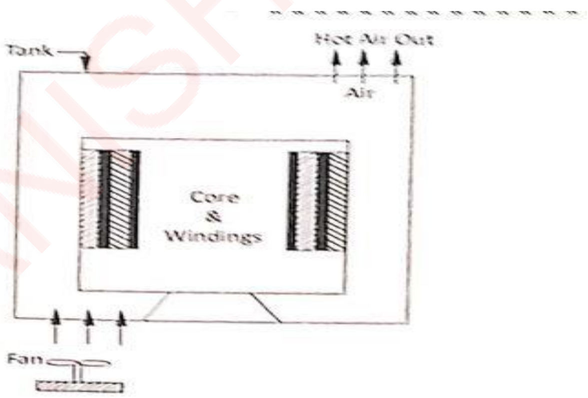
Different cooling methods of transformers are



1. Natural Air Cooling (AN)

- This method is used for cooling the smaller output transformer rating that is up to **5KVA**
- The generated heat in the transformer is cooled by the circulation of natural air.

2. Forced air or Air Blast cooling



- In this method, the heat generated is cooled by the **forced air circulation**.
- With the help of fans and blowers, high velocity of air is forced on the core and the windings of the transformer.
- As the temperature inside the transformer goes beyond the standard safe level, an alarm is activated, and the fans and blowers are switched ON automatically
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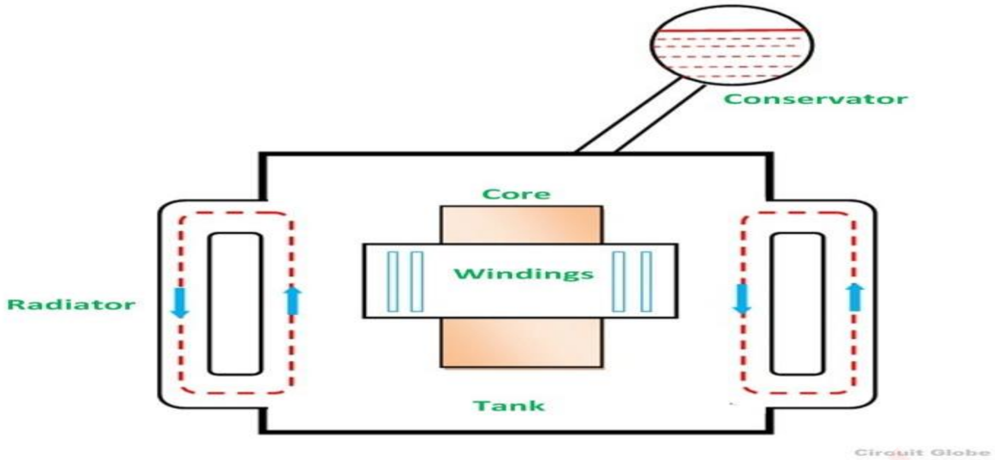
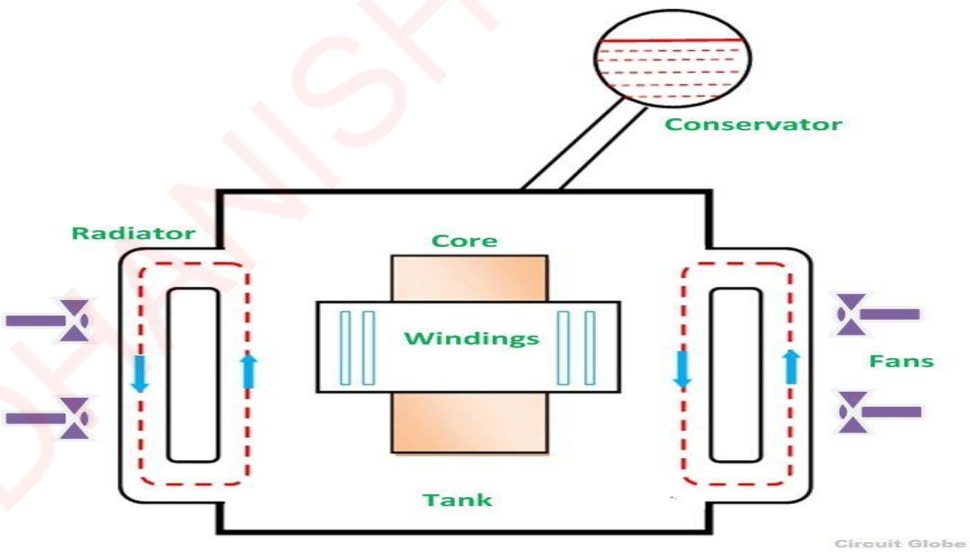
3. Oil Natural Air Natural (ONAN)



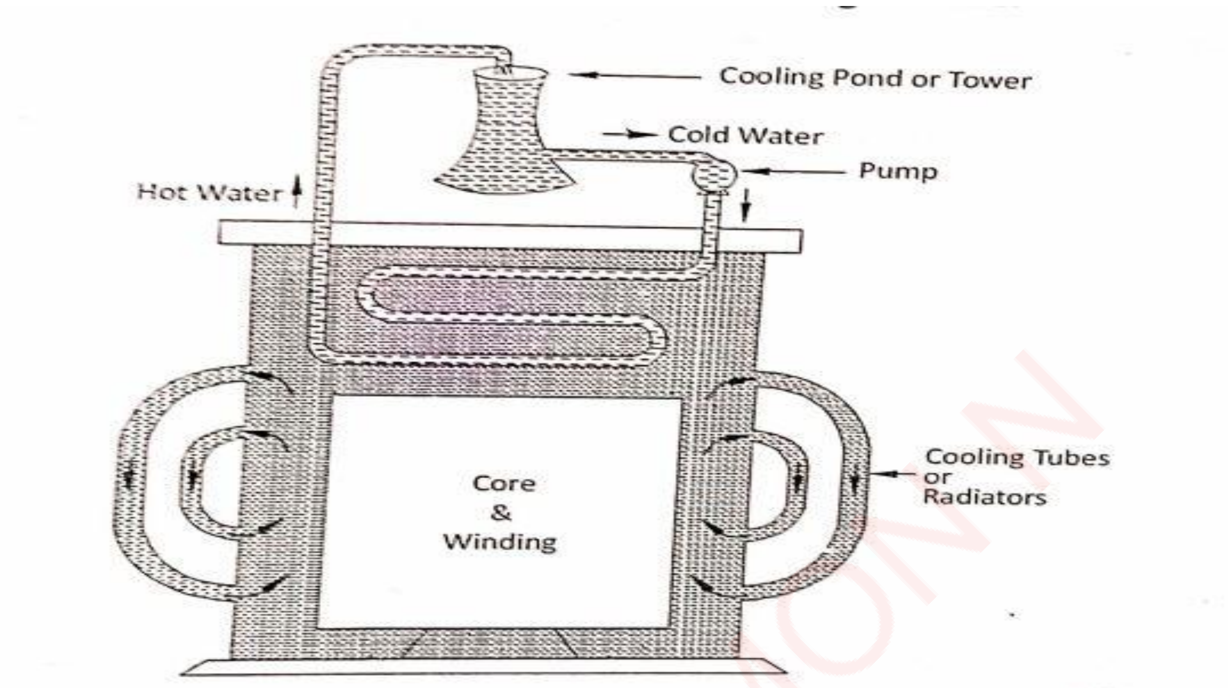
- It is the most common cooling method used in oil filled transformer
- This type of cooling is used for the transformer rating up to **500KVA**
- In this the core and winding is completely immersed in the oil. The heat produced in the core and windings is carried by the transformer oil moves up ward. The heated oil transfer this heat to surface of tank and cools and comes to the bottom of the tank.
- As the rate of heat dissipation from the transformer tank surface is directly proportional to effective surface area of the tank, an additional heat dissipating surface in the form of tube called radiator is connected.

4. Oil Natural Air Forced (ONAF)



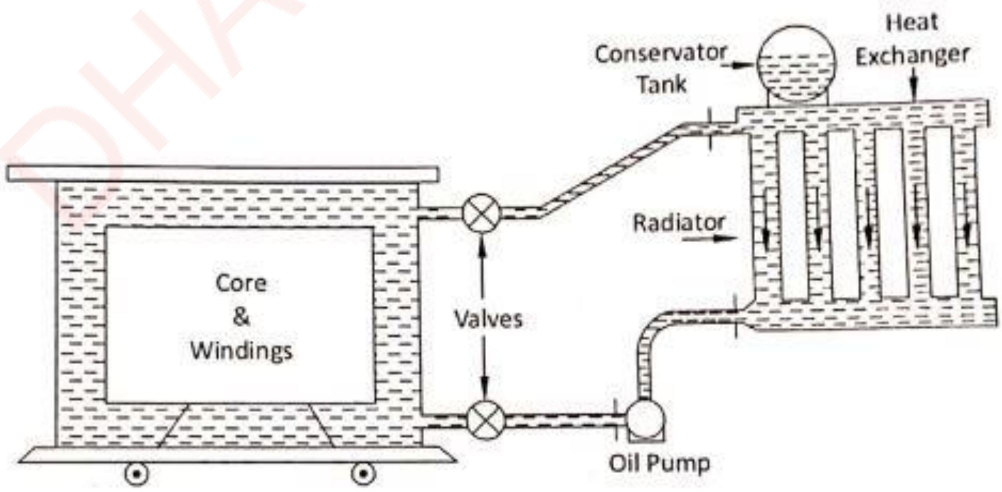
- The winding and core is immersed in the oil
- The heated oil in the transformer tank moves upward and comes to transformer tank surface and radiator tubes.
- As the fans and blowers are installed, a high velocity of air is forcefully applied to the radiator ,which will help in cooling oil more quickly and efficiently.
- Its cost is higher as compared to ONON due to fan and blower

5. Oil Natural Water Forced (ONWF)



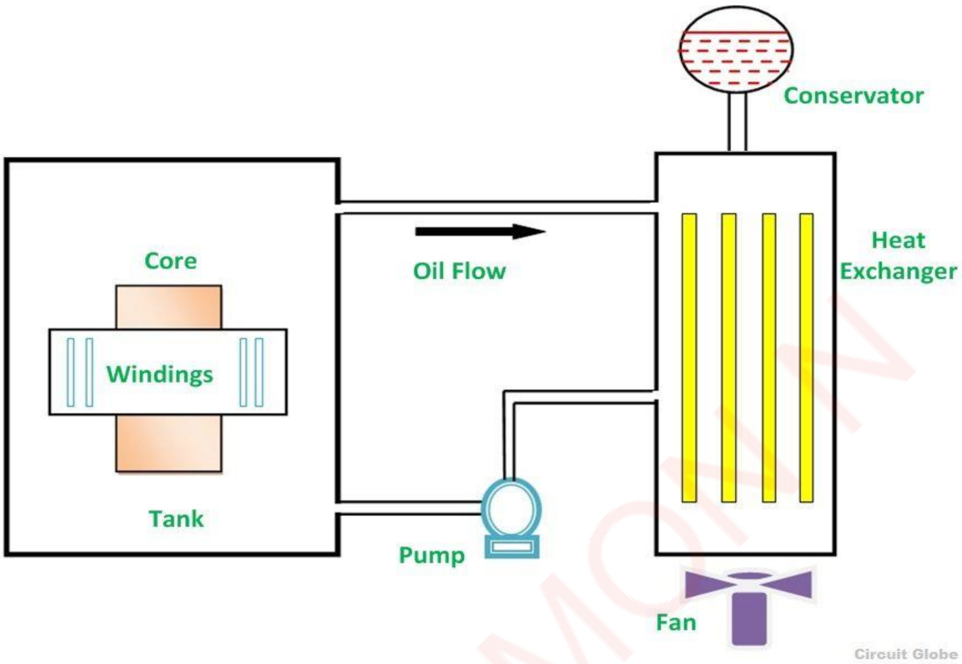
- In Oil Natural Water Forced cooling method, the transformer core and the windings are immersed in the oil tank.
- It have circulating cooling tube in which water is circulated using pump.
- The cold water is pumped to cooling tubes using pump and water in the cooling tube collects the heat from the heated transformer oil.
- The hot water is cooled using cooling tower and again circulated to the tank through cooling tubes

6. **Oil forced air natural cooling (OF AN)**



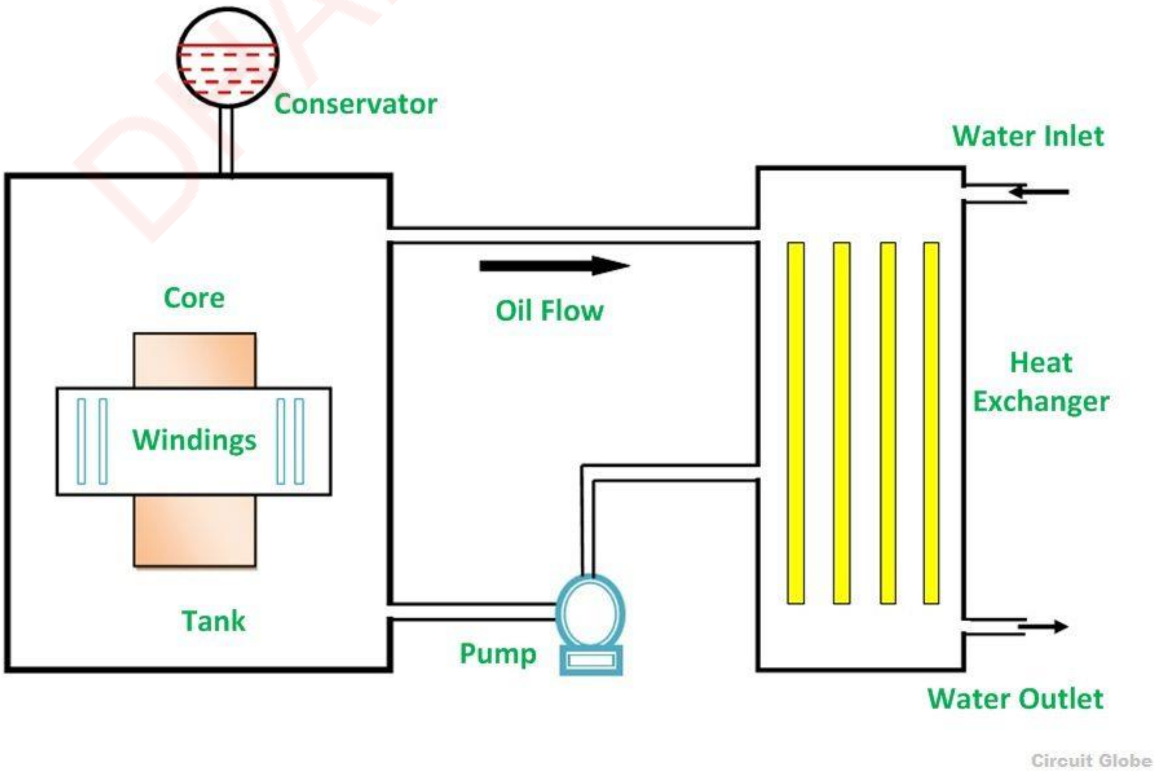
- The oil is circulated through the transformer with the help of pump and heated oil is cooled in the heat exchanger by natural air circulation
- To get fast heat dissipation, the heat exchanger surface area is more

7. Oil Forced Air Forced (OFAF)



- The oil is circulated through the transformer with the help of pump and heated oil passed through heat exchanger.
- Air is forced to pass on the heat exchanger with the help of high-speed fans and cools the oil
- This method is used for the transformer rating up to 5MVA

8. Oil Forced Water Forced (OFWF)



- The oil is circulated through the transformer with the help of pump and heated oil passed through heat exchanger.
- Water is forced to pass on the heat exchanger with the help of pump and it collect heat from the oil and cools the oil.
- The heated water is cooled using cooling tower and again circulated to heat exchanger
- This method is used for the transformer rating up to 10MVA

Why transformer is rated in KVA

1. In a transformer mainly 2 losses are present. Core loss and copper loss. This core loss mainly depends on voltage and copper loss is mainly depend on current. Hence transformer is rated in KVA

2. A transformer manufacturer never knows the power factor of load which is going to connect across transformer. Hence transformer is rated KVA