Three Phase transformer - Connections

Objectives: At the end of this lesson you shall be able to
- **state the transformer connections, angular divergence of the 3 phase transformers**
- **represent the phase difference between high voltage and low voltage windings for different types of connection by the hour hand of a clock**
- **state the vector group of the transformer**
- **explain the scott connection of transformer and its uses.**

Transformer Bank

Transformers, like other electrical devices, may be connected into series, parallel, two-phase or three-phase arrangements. When they are grouped together in any of these arrangements the group is called a transformer bank.

The high voltage and low voltage winding terminals of a three-phase transformer are connected either in star or in delta for connections to a three-phase system.

When the primary high voltage winding terminals are connected in, say, star and the secondary low voltage winding terminals are connected in, say, delta, it is said that the transformer windings are connected in star-delta(Y – Δ or Y – d). Similarly

star-star (Yy)

delta-delta (Dd)

and, delta-star (Dy) connections can be used.

Type of connection	High voltage side	Low voltage side
Delta	D	d
Star	Y	y
Zigzag	Z	z

Angular displacement (divergence)**:** There is a definite time phase relationship between the terminal voltages of the high voltage side and low voltage side for these connections. The time phase relationship between the voltages of high voltage side and low voltage sides will depend upon the manner in which the windings are connected.

If the high voltage side and low voltage side windings are connected in star-star (as in Fig 1a and 1b). The phase displacement will be zero. If, however, the low voltage winding connections are reversed, as shown in Figs 2(a) and (b), the time phase displacement in induced voltages between the high voltage and low voltage windings will be 180 degrees.

Fig 1

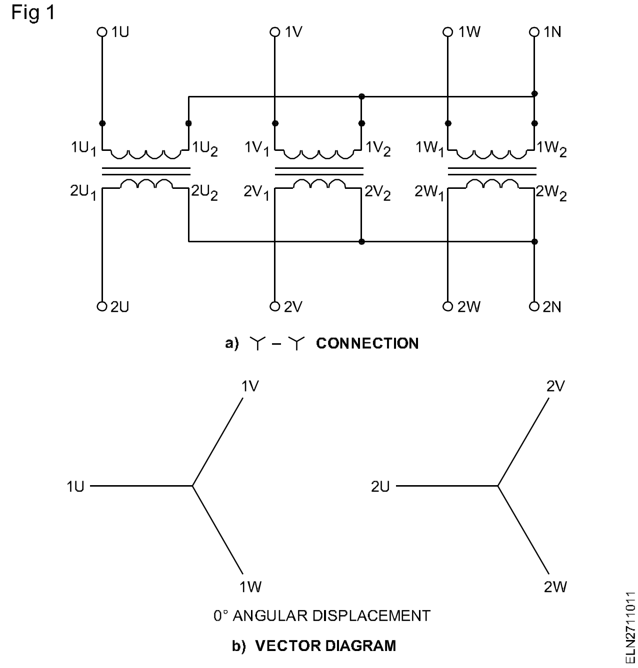
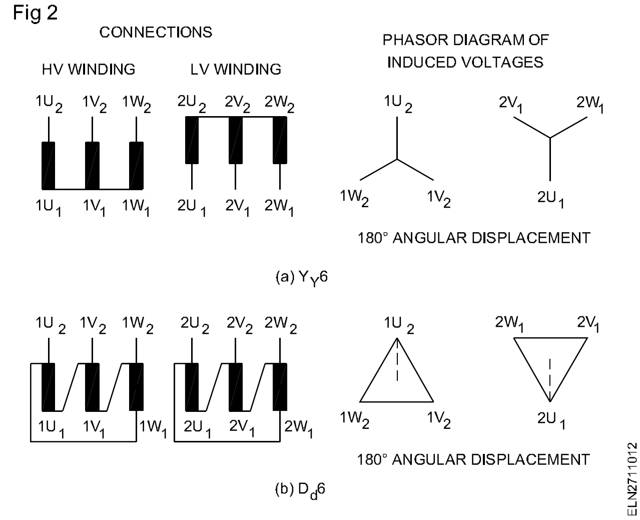


Fig 2



If the primary high voltage and secondary low voltage side windings are connected in Yd or Dy as shown in Figs 3(a) and (b), the phase displacement will be 30 degrees.

The displacement in the clockwise direction is negative. Anti clockwise is positive.

If the windings are connected in Yd or Dy as Figs 4 (a) & (b), the displacement of the terminal voltage will be + 30°.

Observe the change in connections made at the low voltage side in Figs 3(a) and Fig 4(a). Similarly the change in the high voltage side winding connections Figs 3(b) and Fig 4(b) causes the difference in displacement angle.

Fig 3

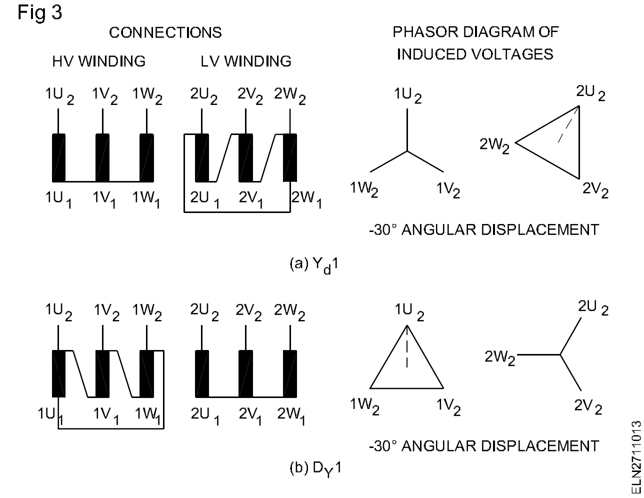
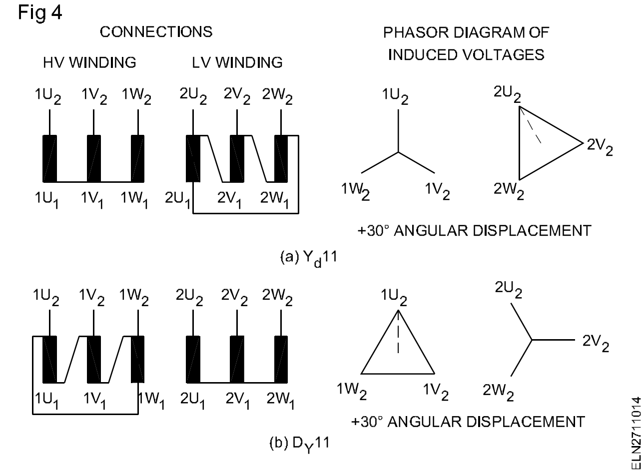


Fig 4



Representation of phase displacement by hour hand of a clock: The phase difference between the HV and LV windings for different types of connections can be represented by comparing it with the hour hand of a clock.

When the hour hand of the clock is at the 12° clock position it is considered zero displacement Fig 5(a).

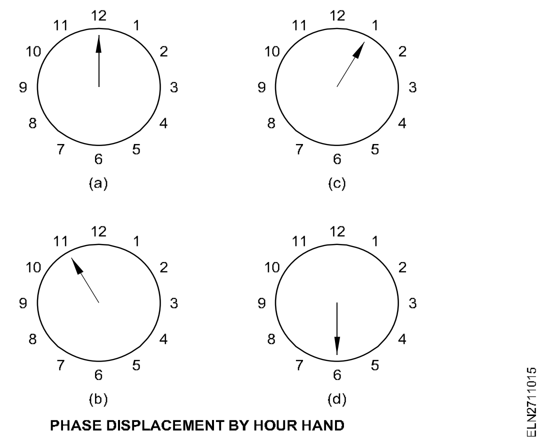
When the hour hand is at the 6° clock position the displacement is 180°

When the hour hand is at the 1° clock position the displacement is -30°.

When it is at the 11° clock position the displacement is +30 degrees. (Anticlockwise is positive.)

The connections of the Fig 1 to Fig 4 can respectively be represented.

Fig 5



Vector groups: Depending on the phase displacement of the voltages of HV and LV sides, transformers are classified into groups called 'vector groups'. Transformers with the same phase displacement between the HV and LV sides are classified into one group. Various vector group arrangements used and their connections symbols are given in Indian Standard IS:2026 (PartIV)-1977.

For satisfactory parallel operation of transformers, they should belong to the same vector group. Following are the typical of the connections for which, from the view- point of phase sequence and angular displacement, transformers can be operated in parallel.

Transformer 1:	Yy	Yd	Yd
Transformer 2:	Dd	Dy	Dy

Different groups	Types of connections	
0	Dd0	Yy0
1	Yd1	Dy1
5	Dy5	Yd5
6	Dd6	Yy6
11	Dy11	Yd11

Scott connection or T.T. connection: In certain special equipment the line voltage required for its 3-phase connection may not be of standard rating as available in the system. Further, the power consumption in these equipment may also be high. To meet this requirement Scott connected transformers are used. These Scott connected transformers enable transformation of 3-phase to 3-phase more economically.

This Scott connection can also be used for 3-phase to 2-phase transformation as explained subsequently.

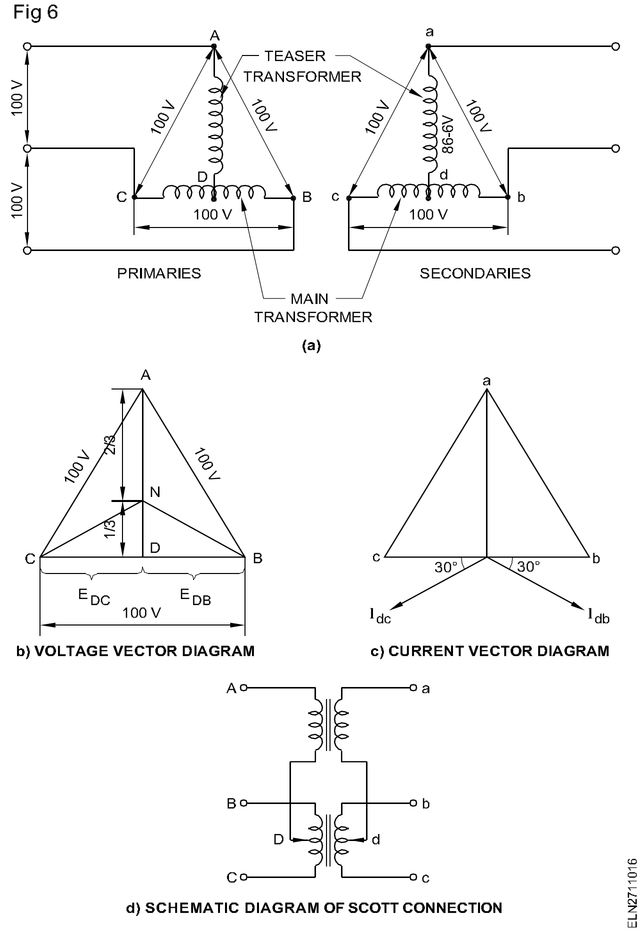
The main transformer has centre tapped primary and secondary windings Fig 6. The primary and secondary windings are indicated by CB and cb respectively in the Fig 6. Another transformer called teaser transformer has a 0.866 tap and one end of both the primary and secondary windings of the teaser transformer (say D and d) is joined to the centre tap of both primary and secondary of the main transformer.

The other end A of the teaser transformer and the two ends B and C of the main transformer primary are connected the 3-phase supply.

3-phase supply is taken out from one end 'a' of the teaser transformer secondary and the two ends b and c of the secondary of the main transformer.

For convenience unity transformation ratio is choosen and the supply line voltage is assumed as 100V the (Fig 6).

Fig 6



By analysing the vector diagram Fig6b, it is found that voltage E_{DC} and E_{DB} are each 50V and differ in phase by 180^0 because both the coils DB and DC are in the same magnetic circuit and are connected in opposition. Fig 1d shows the schematic connection diagram.

Each side of the equilateral triangle represents 100V. The voltage E_{DA} being the altitude of the equilateral triangle is equal to $\sqrt{3}/2 \times 100 = 86.6V$ and legs behind the voltage across the main by 90^0. The same relation holds good for the secondary voltages. The transformer rating is restricted to 86.6% of its KVA rating. By suitable turn ratio the trnsformer rating can be improved to 92.8%.

Example: Two scott connected transformers are used to supply a 660V 33 KVA balanced load from a balanced 3-phase supply of 11000V. Calculate (a) voltage and current rating of each coil (b) KVA rating of the main and teaser transformer.

Voltage across primary 11000V

Voltage across the teaser primary = 0.866x11000

Current is same in the teaser and the main and equal to

$$\text{line current} = I_{LP} = \frac{KVA \times 1000}{\sqrt{3}EL}$$

$$= \frac{33 \times 1000}{\sqrt{3} \times 11000} = \frac{3}{\sqrt{3}} = 1.732A$$

Secondary voltage across the mains = 660V

Teaser secondary voltage = 660 x 0.866 = 572V.

$$\text{The secondary line current } I_{LS} = \frac{I_{LP}}{k} = \frac{1.732}{\frac{660}{11000}}$$

$$= \frac{1.732 \times 11000}{660}$$

$$= \frac{173.2}{6} = 28.87A$$

Main KVA rating = 11000 x 1.732 x 10^{-3}

= 19.05KVA.

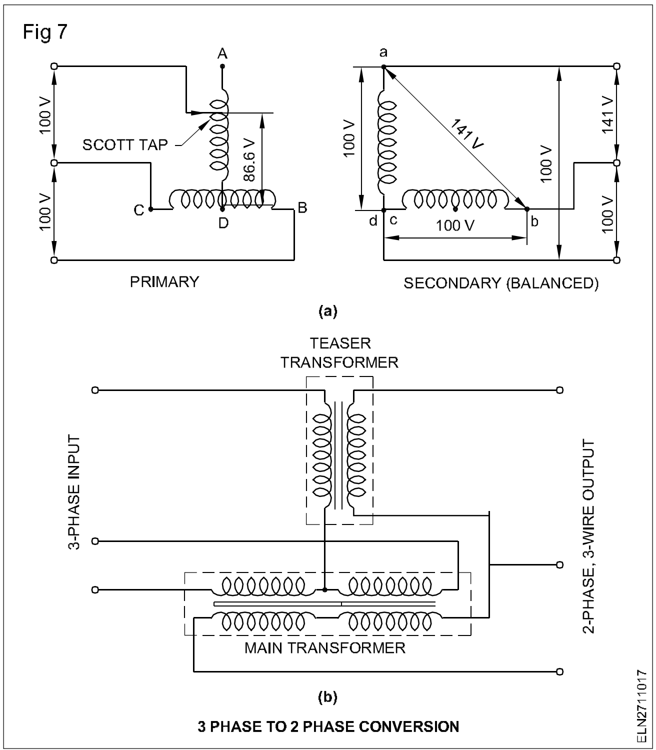
Teaser KVA = 0.866 x main KVA

= 0.866 x 19.05 = 16.4 KVA.

3-phase to 2-phase conversion and vice versa: In industrial application of electric power supply certain equipment like electric furnaces and welding transformers require two phase supply.

At present, the available electrical supply is in variably three phase it is necessary to convert the 3 phase supply to 2 phase supply. This is accomplished by Scott connection.

For convenience 100V supply and the tranformation ratio of unity are chosen Fig 7. But the transformer could be designed for required voltage and suitable tranformation ratio. Fig 7(a) shows the arrangement of connection where as Fig 7(b) shows the circuit arrangement.



Three single phase transformers for three phase operation

Objectives: At the end of this lesson you shall be able to
- **list and interpret the four types of connections of primary and secondary windings**
- **state the phase and line values of current and voltage.**

There are various methods available for transforming 3-phase voltages, that is for handling a considerable amount of power. There are four possible ways in which the primary and secondary windings of a group of three transformers may be connected together to transfer energy from one 3-phase circuit to another. They are:

Primaries in Y, Secondaries in Y

Primaries in Y, Secondaries in Δ

Primaries in Δ, Secondaries in Δ

Primaries in Δ, Secondaries in Y.

Star/Star or Y/Y connection: Fig 1 shows the connection of a bank of 3 trans-formers in a star-star. This connection is most economical for small, high voltage transformers because the number of turns per phase and the amount of insulation required is minimum. This connection works satisfactorily only if the load is balanced. For a given voltage V between lines, the voltage across the terminals of a Y connected transformer is $V/\sqrt{3}$; the coil current is equal to the line current I.

Star - Delta or Y/Δ connection: In primary side 3 transformers are connected in star and the secondary consist of their secondary connected in delta as shown in Fig 2. The ratio between the secondary and primary line voltage is $1/\sqrt{3}$ times the transformation ratio of each transformer. There is a 30° shift between the primary and secondary line voltages. The main use of this connection is at the substation end of the transmission line.

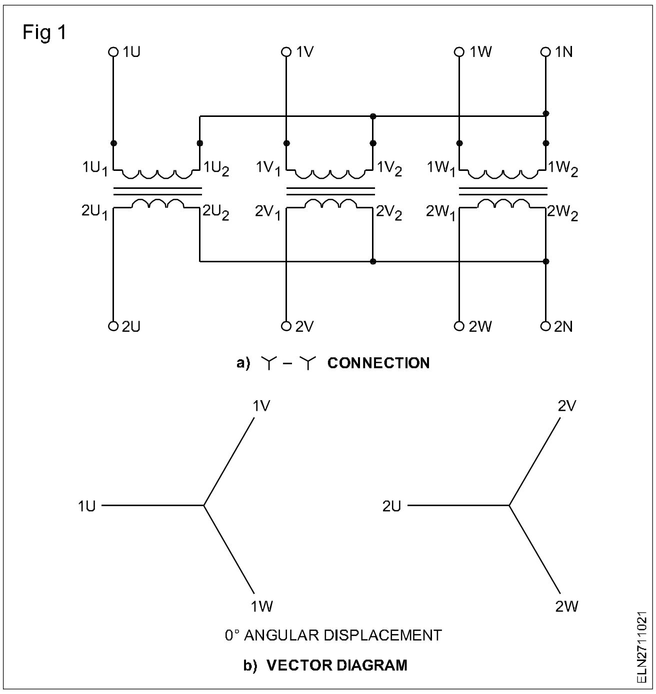
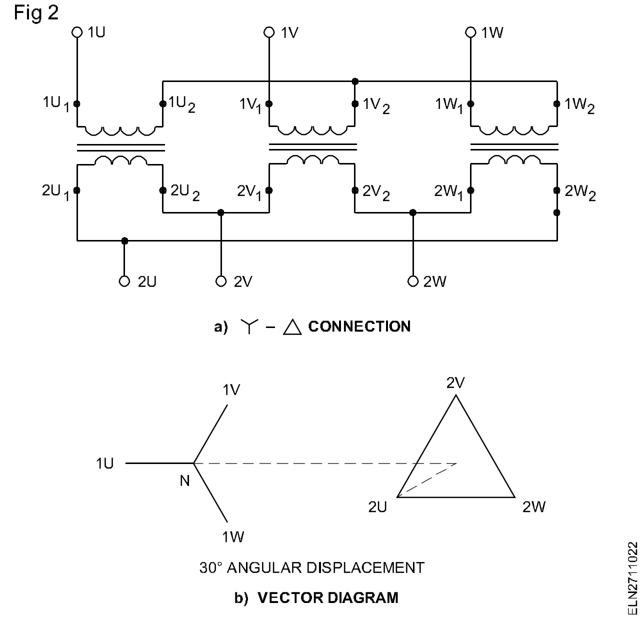


Fig 2



Delta - Delta or Δ/Δ connection: Fig 3 shows three transformers, connected in Δ on both primary and secondary sides. There is no angular displacement between the primary and secondary line voltages. An added advantage of this connection is that if one transformer becomes disabled, the system can continue to operate in open-delta or in V-V. In V-V it can be operated with a reduced capacity of 58% and not 66.6% of the normal value.

Delta - Star or Δ/Y connection: (Fig 4) This connection is generally employed where it is necessary to step up the voltage, as for example, at the beginning of high tension transmission system.

The primary and secondary line voltages and line currents are out of phase with each other by 30°. The ratio of secondary to primary voltage is $\sqrt{3}$ times the transformation ratio of each transformer.

Fig 3

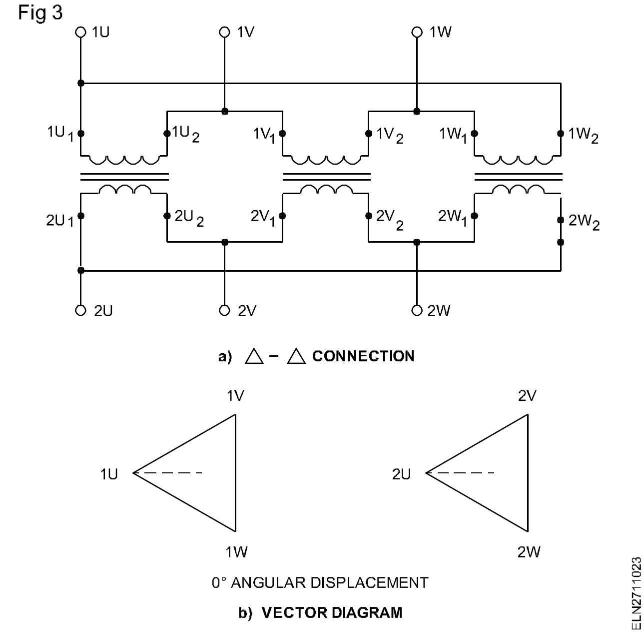
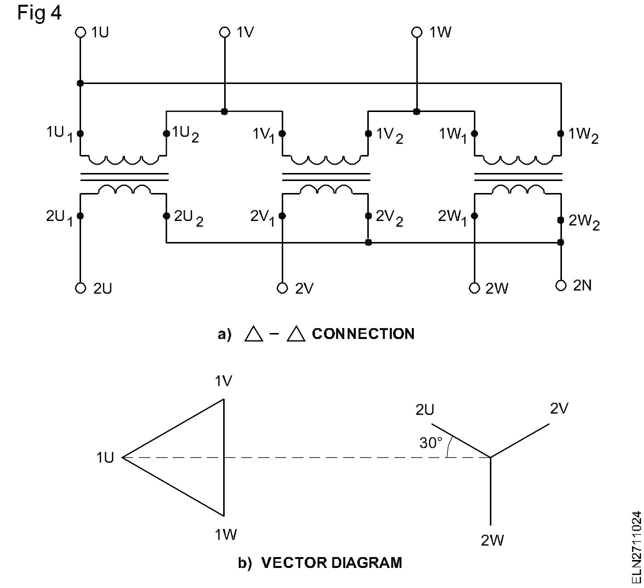


Fig 4



Parallel operation of 3-phase transformer

Objectives: At the end of this lesson you shall be able to

- **Define parallel opration**
- **States the conditions for parallel operation of 3 phase transformer**
- **Sates the necessity of parallel opertion.**

Parallel operation

Operating two or more transformers by connecting their primaries in parallel to a common supply line and connecting their respective secondaries in parallel with a common load-busbars (Fig 1) is called as parallel operaion of transformers.

Conditions for pararllel opertion of transformers:

When operating two or more transformer in parallel, the following conditions have to be satisfied for the best performance of the transformer.

1 The voltage ratio must be same.

2 The per unit impedance or percentage impedance should be same i.e., the ratio between the equivalent leakage reactance and the equivalent resistance(X/R)should be same.

3 The polarities must be same.

4 For three phase transformers

i) The phase sequence must be same

ii) The vector group must be same (i.e., The relative phase displacement between the secondary line voltages must be zero)

Parallel operation of 3-phase transformer:

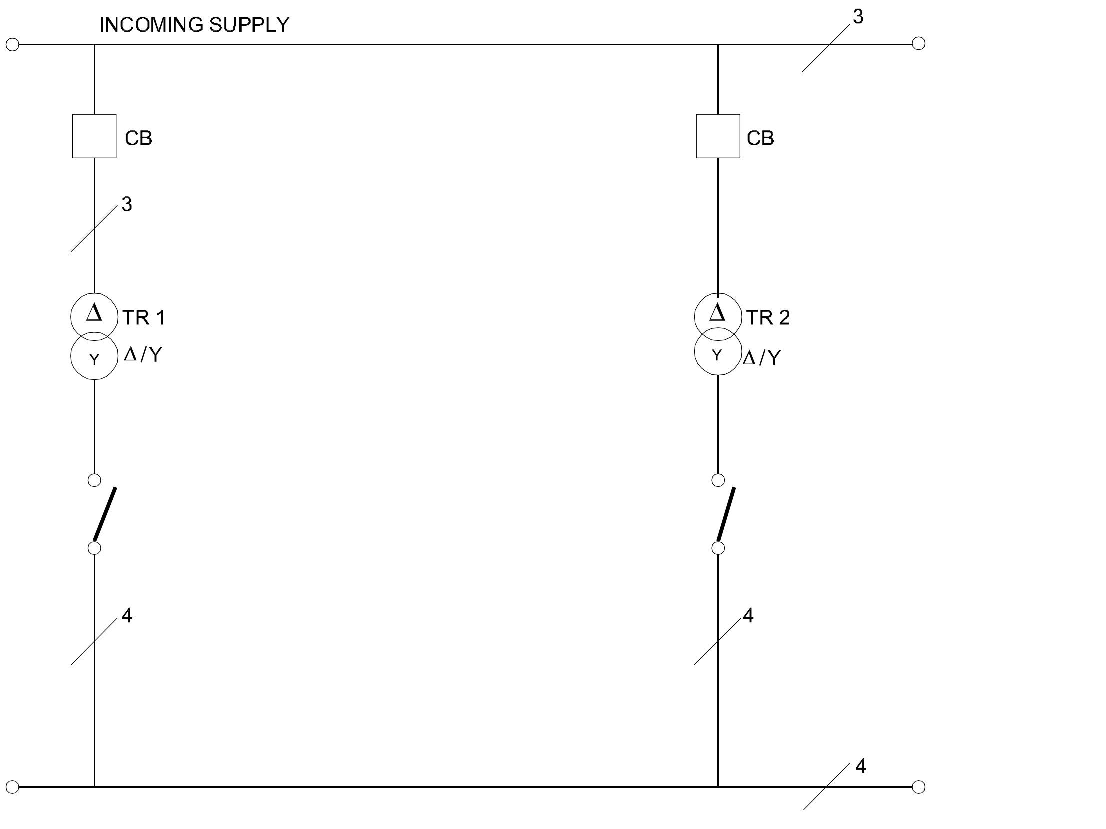
Fig 2 shows the connection diagram for parallel operation of two numbers of 3-phase transformers. In this case, the connection of both of transformer 1 and 2 are (delta - star)same.

However to operate the 2 transformers of having Y/Δ and connection, their primary and secondary line voltage Δ/Y must be same. In this case,the turns ratio may not be equal, but the voltage ratio between the terminal voltage of primary and secondary must be same.

If two transformers having different ratings, are connected in parallel the their percentage impedance must be same, where as the numerical impedance of transformer 1 will have half the impedance of transformer 2. In this case both the transformers will share the common load in propertional to their KVA ratings.(Fig 2)

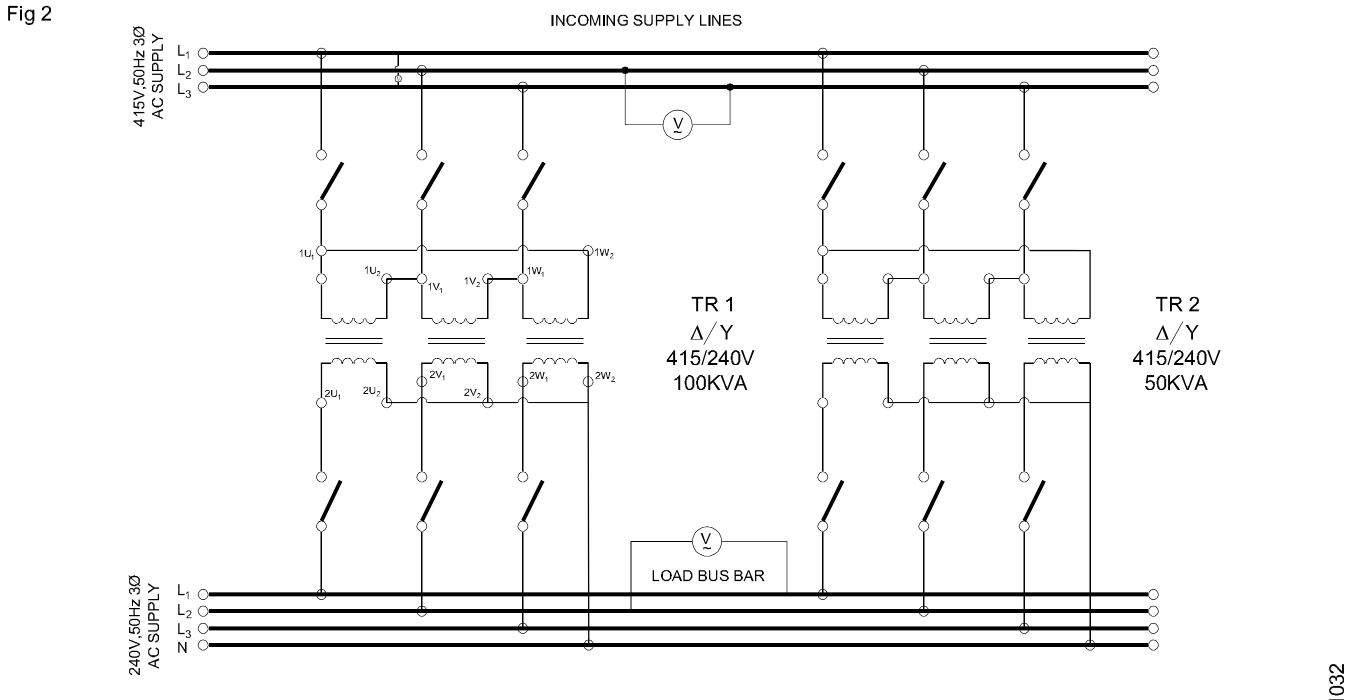
For best performance of the parallel operation, the regulation of both the transformers must be same . If the percentage impedance of both the transformers are different. Than one transformer will be operating at a higer power factor and other will be operating at a lower power factor.

Fig 1



PARALLEL OPERATION - 3PHASE TRANSFORMER

Fig 2



PARALLEL OPERATION - 3 PHASE
TRANSFORMER - CONNECTION DIAGRAM

Cooling of transformer - Transformer oil and testing

Objectives: At the end of this lesson you shall be able to
- **explain the necessity of cooling**
- **state the methods of cooling.**

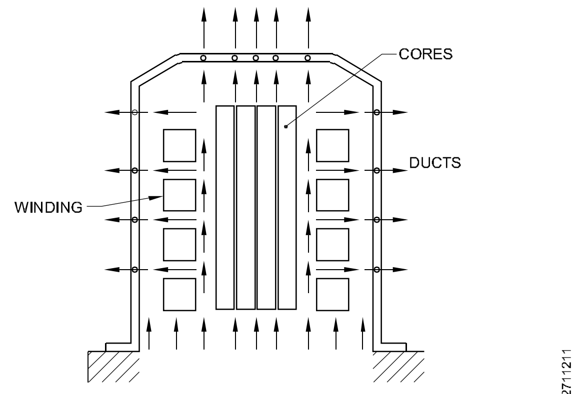
Necessity of cooling

Transformer is heated up when current flows through its, winding. This causes the liberation of heat. In large size transformer, where power rating is high, large amount of heat is liberated. This will affect the insulation of the windings as well as reduction of transformer efficiency. This heat should be transformed from transformer winding and dissipated in the atmosphere .

Methods for cooling transformers: Following are the methods of cooling employed in transformers. Any one or more methods could be adopted depending upon the size, application and location of the transformer.

- Natural air method
- Air blast method (Fig 1)

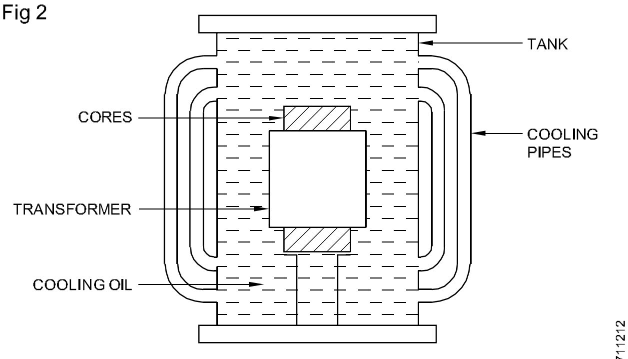
Fig 1



AIR BLOWER FAN

- Natural oil cooled method (Fig 2)

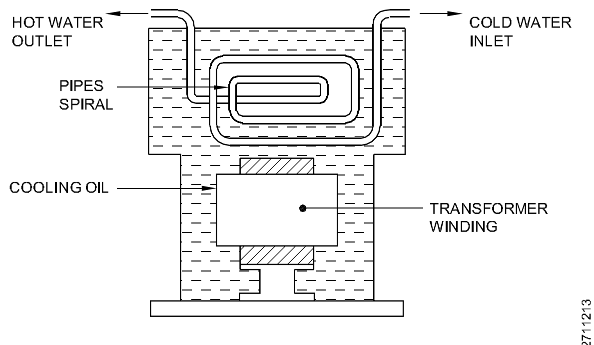
Fig 2



OIL - COOLED TRANSFORMER

- Oil blast method
- Forced circulation of oil
- Oil and water cooled (Fig 3) and
- Forced oil and water cooled

Fig 3



OIL AND WATER COOLED TRANSFORMER

Natural air cooling method is generally adopted for low capacity distribution transformer upto 100KVA. The natural circulation of the surrounding air is used to carry away the heat from the transformer winding.

In air blast method, the fans are used to blow the air on the surface of the transformer thereby the heat generated is carried away by the air blast.

Transformer of 200KVA above capacity are cooled by using an insulating oil. The winding and core are immersed in oil. The area of the tank is increased by using cooling tubes. (Radiator tubes)

In oil and water cooled system, the low pressure water tubes through the heated oil used to remove the heat from the transformer.

Transformer oil and testing

Objectives: At the end of this lesson you shall be able to
- **define the transformer oil**
- **name three insulating oils used in transformer**
- **list the important properties of a transformers oil**
- **state the necessity of transformer oil**
- **state the causes for deterioration of oil**
- **explain the methods of testings the oil for its parameter.**

Transformer oil :

It is an insulating liquid, used to cool and insulate the transformer windigs and core.A cooling liquid is also considered as a part of the transformer.

Three kinds of cooling oils/liquids are used in transformers today.

- Mineral oil (inflammable)
- Silicon liquids(low flammable) and
- Hydrocarbon liquids (non-flammable)

The common transformer oil is a mineral oil obtained by refining crude petroleum. Clean and dry mineral oil is an excellent insulator. Its loss by evaporation is small. But it is an inflammable liquid and readily absorbs moisture from the air. Great care should be taken to keep the oil away from flame and moisture.

Synthetic liquids do not catch fire easily. Synthetic liquids are therefore replace mineral transformer oils of those transformers used in

- underground mines
- refineries and hazardous location
- tunnels
- workshop and plants of metal processing theatres and cinemas etc.

Transformer oil consists of organic compounds, namely paraffin, naphthalene and aromatics. All these are hydro carbons, hence insulating oil/transformer oil/ synthetic transformer oil known as ASKARELS and PYROCLORE are also in use.

Properties of transformer oil

A good transformer oil should have the following properties.

1 High specific resistance so that high insulation resistance

2 Better heat conductivity, (i.e) higher specific heat.

3 High firing point, so that not to catch fire at low temperature.

4 Do not absorb moisture easily, when exposed to air.

5 Low viscosity

Necessity of transformer oil

Large capacity distribution transformers produces more heat due to losses like core losses and copper losses, on load. It is necessary to stablize the heat within temperature class by providing suitable insulating materials.

Transformer oil acts as a good electrical insulating material. Thus it reduces electrical break down. Transformer oil will also act as cooling agent. Thus it brings thermal stability to all the internal parts of transformer.

Causes for deterioration of transformer oil

When the oil cooled transformers are in use, the oils of the transformers are subjected to normal deterioration due to the conditions of the use.

For example

1 The oil may come in contact with the air, there by presence of moisture and dust in the oil. The presence of moisture is harmful and affects the electrical characteristics of oil and will accelerate deterioration of insulating materials.

2 Sediment and precipitable sludge may be formed on the winding and core surfaces. It will reduce the cooling rate and hence it may lead to deterioration of the insulating materials.

3 The presence of certain solid iron, copper and dissolved metallic compounds will increase the acidity. In such cases, the resistivity decreases, and electrical strength also decreases, and it is also the causes for deterioration of transformer oil.

Testing of transformer oil

For reliable use and maintenance of oil cooled transformer, the transformer oil shall be tested before initial filling of the oil as well as during service of the transformers. As per the test result it may be required to filter the transformer oil or in some cases, new oil may be recommended for safe and better maintenance of oil cooled transformers.

The following tests are conducted periodically to decide the performance of the transformer oil.

1 Field test of insulation oil

2 Crackle test of insulating oil

3 Dielectric test of insulating oil

4 Acidity test.

1 Field test of insulating oil

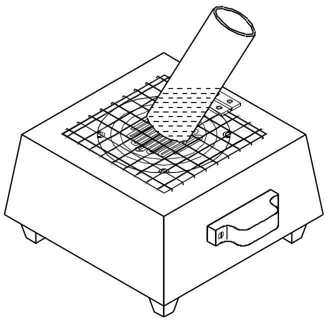
A drop of transformer oil, when placed slowly from a pipette on the still surface of a distilled water contained in heater should retain its shape when the oil is new.

In the case of used cyclo-octane oils (or) paraffin oils (even though unused) the drop usually flattened. If this flattened drop occupies an area of diameter less than 15 to 18 mm, the oil may be used. Otherwise, it has to be reconditioned. Oils with the longer spreads are unsuitable.

2 Crackle test of transformer oil (Fig1)

A rough test may be made, by closing one end of steel tube, and heating the closed end to just dull red hot. (Fig 1) When the oil sample is plunging into the tube, a sharp Crackle sound will be heard, if the oil contains much moisture. Dry oil will only sizzle.

Fig 1

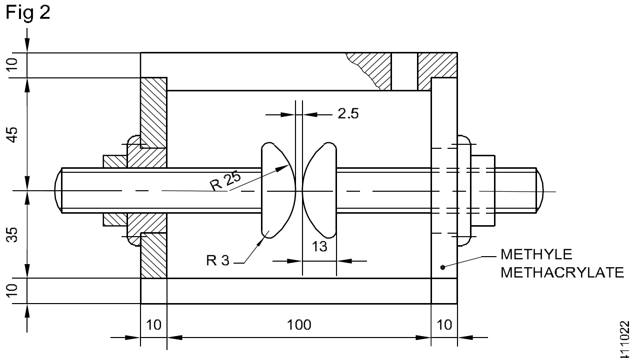


CRACKLE TEST

3 Dielectric test of transformer oil

This test is preferably conducted using standard oil test set. The oil test set consists of a container/cell made up of glass or plastic.(Fig 2)

Fig 2



OIL TEST CONTAINER/CELL

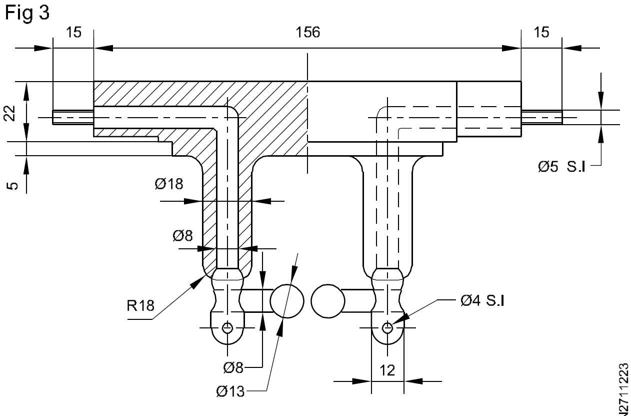
The cell shall have an effective volume between 300 to 500 ml. It should be preferably closed. Section view of container. (Fig 3)

Two numbers of the copper, brass, bronze or stainless steel in the shape of sphere of diameter 12.5 to 13 mm elliptical are mounted on a horizontal axis at 2.5 mm apart, is used as electrodes, for oil test of 11KV transformer.

The cell is mounted on a test set. HT connection to the electrodes, is made by the point contact arrangements.

The test set is also provided into step up transformer where the voltage can be varied from zero to 60KV. In some designs, the voltage is varied by electric motor, with the operation of push button switch.

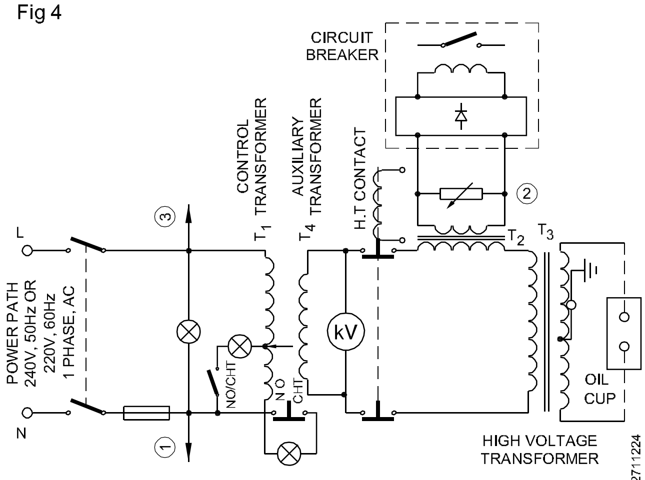
Fig 3



DIELECTRIC TEST

Electrical circuit diagram of dielectric test unit (Fig 4)

Fig 4



CIRCUIT DIAGRAM OF DIELECTRIC TEST

For conducting dielectric test on transformer oil, the oil is to be gently agitated and turned over several times so that homogeneous distribution of the impurities contained in the oil is spread all over.

Immediately after this, the oil is poured down into the test cell slowly in order to avoid air bubbles. The operation is carried out in a dry place free from dust. The oil temperature at the time of test shall be same as that of ambient.

After fulfilling the above conditions the cover of the cell is placed in position. The cell is placed in the test unit and power is switched “ON”.

The AC voltage across the electrode of frequency 40 to 60Hz is increased uniformly at the rate of 2KV RMS starting from ‘O’ up to the value of producing break down. The break down voltage is the voltage reached during the test at the time the first spark occurs between electrodes.

The circuit is opened automatically if an arc is established between electrodes. The break down voltage is recorded and the reading is interpreted according to the standard ratings. The requirements as per IS-335-1983 is: Electrical Strength (break down voltage)

1 New unfiltered transformer oil - 30KV (RMS)

2 After filtration transformer oil - 50KV (RMS)

It is recommended to filter the transformer oil if the break down voltage does not attain 30KV (RMS).

The test shall be carried out 6 times on the same cell filling. The electric strength shall be the arithmetic mean of the 6 results which have been obtained.

Acidity test

The acid products are formed by the oxidation of the oil. This oxidation will deteriorate the insulating materials like insulating paper and press boards used in transformer windings. It is therefore essential to detect and monitor the acidity formation.

To conduct this test portable test kit is available consisting of:

1 Two polythene bottles containing 100ml each of ethyl alcohol and sodium carbonate solution of 0.0085N concentration.

2 An indicator bottle containing universal indicator.

3 Four clean glass test tube.

4 Three graduated droppers, which serves as pipettes.

5 Colour chart with acidity range.

6 Instruction booklet.

PROCEDURE

The test is conducted by taking 1.1 ml of insulating oil (to be tested) in test tube, 8 ml oil 1 ml of rectified spirit is added and mixture is to be gently shakened. Further 1 ml of solution of 0.008 5 N sodium carbonate added. After shaking the test tube once again 5 drops of universal indicator is added. The resulting mixture develops a colour depending on the acidity value of the mixture.

The approximate colour range will be as follows:

Total acidity value in No.	Colour
0.00	Black
0.2	Green
0.5	Yellow
1.0	Orange

Any how the colour chart will be provided with the test kit to indicate exact value.

Small transformer winding - Winding machine

Objectives: At the end of this lesson you shall be able to
- **state the important data to be taken for rewinding the transformer**
- **explain the rewinding procedure for small transformers**
- **calculate the number of turns per volt using the formula and determine primary and secondary turns**
- **read and interpret the tables pertaining to the rewinding of transformers and determine the dimensions of the transformer, size of bobbin and size of winding wire**
- **explain the tests to be carried out after winding the transformer.**

Rewinding of small transformer:

It is necessary to rewind a transformer when the winding is burnt out or badly damaged.

While dismantling transformers, care should be taken to record the necessary particulars (data) by which the rewinding process becomes easy and the original performance of the transformer is assured.

Recording the data : The following data have to be taken from the transformer before and during disassembling.

1 Number of windings/turns/ layers.

2 Size of wires and insulation.

3 Input/output voltages & currents.

4 KVA ratings.

5 Conncetion diagrams.

6 Terminal marking / lead position

7 Types of cores / number of stampings

8 Physical condition of bobin / core.

9 Insulation schemes like size and specification of bindings, layer,interlayer,inter windings, bobin,lead wires, sleeves etc.

If the old bobbin is reused for winding, it shall be cleaned well and shall be free from any break or crack. If a new bobbin is used it shall be checked with the stamping (core) for proper assembly to avoid too much air gap or too tight a fitting.

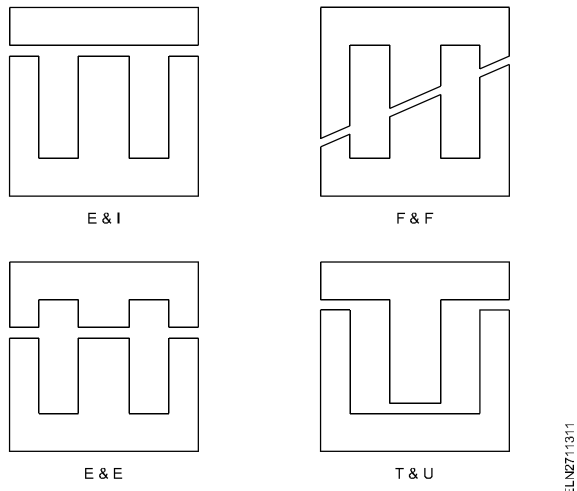
For winding, a suitable size of wire shall be selected from the data and the size of wire shall be measured as per I.S. 4800 (Part - I) 1968.

The size of the wire can be measured with insulation but it shall be within the limit of tolerance. The insulation scheme shall be followed as per the data taken. Where proper material is not available an equivalent type and size may be selected. Turns and tapping of the winding shall be made as in the original.

Method of stacking : Before stacking the core, stampings shall be checked for dents, bends and core insulation. Dents on the core shall be removed, and any mangled core shall be set right. Stacking shall be done as in the original sequence and pattern.

All the stampings available for the transformer shall be stacked without leaving out any. Fig 1 shows the different shapes of cores used for a shell type transformer. Leads shall be properly sleeved and terminated.

Fig 1



Procedure of rewinding a transformer: As stated above, if all the necessary winding details are obtained while disassembling the burnt out transformer, the rewinding procedure is more or less easy. However, if you have to prepare a new transformer the following information will be of great help.

Designing a transformer : Small transformers are generally of 'SHELL TYPE'. In shell type, both the primary and secondary windings are mounted on the centre limb of the core. For designing of a small power transformer proceed as stated below.

STEP NO.1

Find the total output power from the load voltage and current of the transformer.

$P_2 = E_2 \times I_2$ ....Formula 1.

The following example is given for your guidance.

Primary voltage - 240 V

Secondary voltage - 6V

Secondary total current - 2A

Frequency - 50 Hz

From the example the output power is calculated as 6 x 2 = 12VA.

STEP NO.2

Find the input watts.

$$P_1 = \frac{P_2}{\%\ \text{Efficiency}} \quad \text{....... Formula 2}$$

Normally the efficiency of a transformer will be 80 to 90. As in the example

$$P_1 = \frac{6 \times 2 \times 100}{80} = 15\ \text{VA.}$$

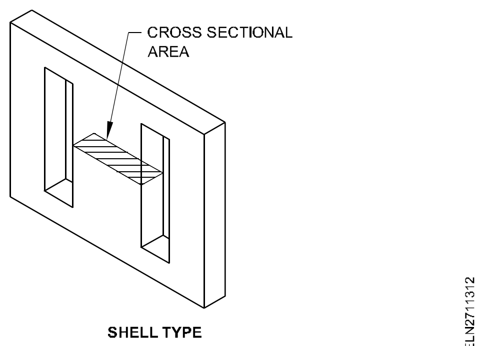
STEP NO.3

Determine the required cross-sectional area of the core of the transformer.

For finding the cross-sectional area, certain parameters like the flux density of the metal used for laminations, frequency of supply, allowable current density in the winding wire and power input to the transformer need to be known.

The cross-sectional area to be considered for a shell type and core type transformers respectively (Figs 2 and 3)

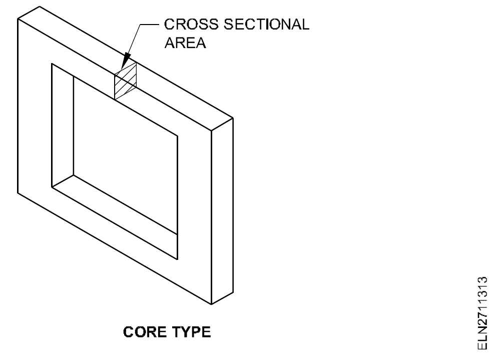
Fig 2



Area of cross-section required for a transformer under specified conditions is given as

$$A = 3.8 \times \sqrt{\frac{P_1}{B \times f \times S \times 10^{-1}}} \quad \text{..... Formula 3.}$$

Fig 3



where

A - is the area of cross-section of the iron core in cm^2

B - is the flux density in tesla

f - is the frequency of supply in Hertz

S - is the current density of the winding wire in ampere/ mm^2.

P_1 - is the input power of the transformer in watts.

Out of the above parameters the frequency of the main supply could be taken as 50 Hertz. Power in VA could be determined from step 1 and step 2. However the value of B could be determined from the following information depending upon the material with which the core is made.

Normal iron metal sheet B = 0.6 to 0.8 tesla

Dynamo steel sheet B = 1.2 to 1.3 tesla

High alloy sheet B = 1.5 to 1.9 tesla

Manufacturers of the stampings specify the flux density value of their product on request.

Further the current density (S) could be taken for super-enamelled copper wire for transformer is approx.as under.

1. 2.5 KVA and above 1A/mm^2
2. 0.75 to 2.4 KVA 1.5A/mm^2
3. 0.3 to 0.74 KVA 2A/mm^2
4. below 0.29 KVA 3A/mm^2

For intermittent working, the current could be multiplied by factor 1.5.

According to the example taken, the required effective area of the cross-section of the core, for the input of 15VA will be

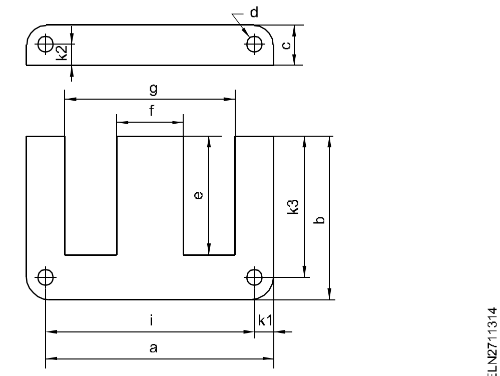
$$A = 3.8 \times \sqrt{\frac{15}{0.8 \times 50 \times 3 \times 10^{-1}}} = 4.248\ \text{cm}^2$$

Assumption made in the above calculation are a normal iron core of 0.8 tesla is used and the current density is 3A/ mm^2. For the core area 4.248 sq.cm we can use the core of dimension having 20 mm as width and core thickness of 21 mm.

Cross section = 20 x 21=420 sq.mm or 4.2 sq. cm

Table 1 gives the standard size of stampings having E and I type laminations as available in the market which is given for your guidance. Fig 4 gives the dimensions of the stampings.

Fig 4



The nearest size sheet should be selected from the standard size of the stamping table. Here we assume the centre limb width to be 20 mm, and hence, the core E.I. 60 is selected. However, you may select any other type to suit the cross-section. But the other details like the number of stampings and the bobbin dimensions may change accordingly.

STEP NO.4

The next step is to calculate the voltage per turn using Formula 4.

$e = 4.44 \times B \times A \times f \times 10^{-4}$ ....Formula 4.

where e - voltage per turn

B - flux density in tesla

A - area of iron core in cm^2

f - frequency in Hertz

Example

$e = 4.44 \times 0.8 \times 4.24 \times 50 \times 10^{-4} = 0.0753$ volts.

STEP NO.5

Calculate the primary coil turns.

$$N_1 = \frac{240}{0.0753} = 3187 \text{ turns (approx.)}$$

Calculate the secondary coil turns.

$$N_2 = \frac{6}{0.0753} = 80 \text{ turns (approx.)}$$

Add 10% to compensate the voltage drop (internal) in the secondary winding i.e. N_2 = 88 turns.

STEP NO.6

Calculate the size of wire with respect to the input power.

P = E x I ; I = P/E and according to the example,

Primary current = I_1 = 15/240 = 0.0625A

Secondary current = I_2 = 15/6 = 2.5A.

Cross-section of primary conductor considering 3A/mm^2 as current density will be

A = 0.0625/3 = 0.020833 mm^2

Diameter = 0.1628 mm

Say i.e. = 0.160 mm dia. or 37 SWG approximately

Cross-section of secondary conductor considering 3A/ mm^2 as current density will be

A = 2.5/3A = 0.8333 mm^2

Diameter = 1.029 mm

Say = 1.00 mm dia. Hence 19 SWG.

STEP NO.7

Fig 5 gives the general dimensions of a bobbin and Table 2 gives the standard sizes of bobbins available in the market to suit the standard stampings. Here the bobbin selected is EI 60/21 which suits the core thickness of the centre limb taken earlier as 21 mm and core width as 20 mm.

Fig 5

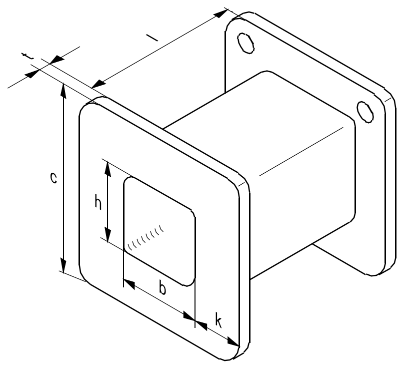


Table 1
Standard size of stampings

Specification of stampings	a	b	c	d	e	f	g	i	k1	k2	k3
EI42	42	28	7	3.5	21	14	28	35	3.5	—	24.5
EI48	48	52	8	3.5	24	16	32	40	4	—	28
EI54	54	36	9	3.5	27	18	36	45	4.5	—	31.5
EI60	60	40	10	3.5	30	20	40	50	5	—	35
EI66	66	44	11	4.5	33	22	44	55	5.5	—	38.5
EI78	78	52	13	4.5	39	26	52	65	6.5	—	45.5
EI84	84	56	14	4.5	42	28	56	70	7	—	49
EI92	92	62.3	11.3	4.5	51	23	69	82	5	6.5	57.5
EI106	106	70.5	14.5	5.5	56	29	77	94	6	8.5	64.5
EI130	130	87.5	17.5	6.8	70	35	95	115	7.5	10	80
EI150	150	100	20	7.8	80	40	110	135	7.5	12.5	92.5
EI170	170	117.5	22.5	8	95	45	125	150	10	12.5	107.5
EI195	195	134.5	25.5	9.5	109	51	144	171	12	13.5	122.5
EI231	231	166	29	10	137	58	173	204	13.5	15.5	152.5
Nominal thickness of stampings:0.35 mm and 0.5 mm.											

Table 2
Standard size of bobbins

Specification of bobbins	b	h	c	k	L
EI 42/15	14.5	14.8	30.2	5.1	18.6
EI 48/16	16.5	16.8	34.2	6.0	21.6
EI 54/18	18.5	18.8	38.2	6.8	24.2
EI 60/21	20.6	21.0	42.7	7.7	26.7
EI 66/23	22.6	23.0	48.7	8.7	28.6
EI 78/27	26.6	27.5	56.2	10.7	34.6
EI 84/29	28.6	29.5	60.2	11.7	37.6
EI 84/43		43.5	74.2		
EI 92/24	24.5	75.0	20.2	46.6	23.5
EI 92/33		33.5	84.0		
EI 106/33	29.6	33.5	88.1	20.6	46.6
EI 106/46		46.5	101.1		
EI 130/38	35.7	37.7	105.4	25.9	64.5
EI 130/48		47.7	115.4		
EI 150/42		41.7	122.5		
EI 150/52	40.7	51.7	132.5	29.8	70.1
EI 150/62		61.7	142.5		
EI 170/57		56.7	151.7		
EI 170/67	45.7	66.7	161.7	33.7	85.1
EI 170/77		76.7	171.7		
EI 195/58		51.7	186.7		
EI 195/71	51.7	70.7	199.7	40.2	109.4
EI 195/86		85.7	214.7		
EI 231/65		64.7	215.7		
EI 231/81	58.7	80.7	232.7	47.5	127.4
EI 231/100		99.7	250.7		

STEP NO.8

Check the feasibility of accommodating the number of turns of primary and secondary within the winding space.

Though the number of turns in the primary is to be 3187 of 37 SWG and the secondary to be 88 turns of 19 SWG super enamelled copper wire, it is atmost important to check whether these windings along with the respective insulation could be accommodated within the winding space of the core. This has to be determined before taking up the winding.

Table 3 gives information regarding the number of turns of the winding wire which could be accomodated in one square centimetre area. With the help of the Table 3 we could predetermine whether it is possible to accommodate the winding in the space.

Winding space available in bobbin = l x k.

(See Fig 5 and refer Table 2 for selected bobbin EI 60/21) = 26.7 x 7.7 sq. mm = 2.055 sq.cm.

Use Table 3 to find the area required for primary and secondary turns.

Primary number of turns = 3187

Gauge of wire = 37 SWG

As per Table 3 the winding wire 37 SWG of 2820 turns could be accommodated in 1 sq. cm space. As such for 3187 turns the space required

$$= \frac{3187 \times 1}{2820} = 1.130 \text{ cm}^2$$

Secondary number of turns = 88

Gauge of wire = 19 SWG

As per Table 3 the winding wire 19 SWG of 85 turns could be accommodated in 1 sq. cm space. As such for 88 turns the space required.

$$= \frac{88 \times 1}{85} = 1.035 \text{ sq.cm.}$$

Total space required =

space required for primary + space required for secondary

= 1.130 + 1.035 = 2.165 sq.cm.

Hence the space required is just sufficient. You may choose the next larger core for the transformer and the next larger bobbin but these are not necessary considering economy and experience. The number of turns given in Table 3 includes the normal insulation used in the winding. As such insulation allowance need not be separately taken into account.

CONCLUSION

For the transformer as in the example, the derived winding data is as follows.

Transformer rating

Primary - 240V

Secondary - 6V

Frequency - 50 Hz

Volt ampere input - 15 VA

Table 3

Wire size in mm.	SWG	Turns per sq.cm.
1.60	16	34
1.40	17	44
1.22	18	60
1.00	19	85
0.90	20	104
0.80	21	132
0.710	22	172
0.600	23	233
0.560	24	279
0.500	25	333
0.450	26	411
0.425	27	493
0.375	28	605
0.345	29	705
0.315	30	860
0.295	31	976
0.274	32	1131
0.250	33	1302
0.230	34	1550
0.212	35	1860
0.190	36	2247
0.170	37	2820
0.150	38	3565
0.132	39	4758
0.122	40	5487
0.112	41	6742
0.100	42	7874
0.090	43	10198
0.080	44	12632
0.071	45	16119
0.061	46	22000
0.050	47	30533

Core : Core area 20 x 21 mm as decided in Step 3.

Bobbin: Breadth 20.6 mm, height 21 mm, length 26.7 mm and the total height of the flange 42.7 mm as decided in step 7.

Wire sizes and turns

Primary - 3187 turns of size 0.16 mm or 37 SWG

Secondary - 88 turns of size 1.00 mm or 19 SWG

Stampings: Considering the thickness of each stamping as 0.35 mm, from the Table 1 for the total thickness of 21 mm we may require 60 stampings. Considering the space between stampings and the stacking we may require 55 stampings only. Hence EI 60/21 type 55 numbers of stampings having 0.35 mm thickness are to be procured.

Testing of transformer after rewinding: After rewinding the core assembly, the transformer is to be inspected for proper tightness of the core and coil as well as proper termination of the end leads.

Insulation resistance test : Insulation resistance is measured between windings and core with a 500 volts Megger. The reading so obtained shall be infinity and in no case below one megohm.

Transformation ratio test: Keeping the transformer secondary open, the primary shall be connected to the rated AC voltage. With the help of suitable voltmeters both the primary and secondary voltage shall be measured. The readings so obtained shall be of the ratio designed.

Load test : The transformer shall be connected with a suitable load, so that the full load secondary current flows through the secondary of the transformer winding. The raise in the winding temperature shall be observed by a suitable industrial thermometer, on the load.

The transformer temperature will raise initially and after some time the temperature will come to a standstill. This raise in temperature shall be noted and it shall be within the limit of class of insulation of the transformer designed.

Short circuit test : Where it is not possible to load the transformer directly, the secondary winding of the transformer shall be short circuited and the low voltage on the primary shall be adjusted through a dimmerstat so that full load secondary current flows through the secondary winding of the transformer. The transformer so switched on shall be tested for raise in temperature to ascertain the class of insulation.

Generally oil-cooled transformers are of class-A where-as air-cooled transformers may be class 'A' or 'E'.

Method of measuring the winding wire size - Parts of winding machine

Objectives: At the end of this lesson you shall be able to
- **explain the method of measuring the winding wire size as per the recommendations of I.S.4800 Part - I 1968**
- **interpret the details from a winding table**
- **explain the major parts of the winding machine and their functions**

Method of measuring the winding wire size: An enamelled solid conductor (mostly copper and in some cases aluminium) of circular section is used for winding the no-volt coil.

The conductor shall be checked for diameter by a micrometer in the case of thick conductors, and in the case of thin conductors the size of the winding wire is derived by measuring the resistance of the unit length of the conductor (i.e. one metre) and Table 1 shows the diameter and resistance relations as per I.S. 4800(Part I) - 1968.

Table 1

Diameter in mm	Measurement
Less than 0.071	Only by resistance
Over and including 0.071 up to including 1.000	By resistance and diameter
Over 1.000	Only by diameter

Table 2 shows the conductor size and resistance values as recommended by I.S 4800 (Part 1) - 1960.

Coil winding machine: No-volt coils are normally wound by coil winding machines. In coil winding machines the following facilities are normally provided as shown in Figs 1 and 2.

1 Number of turns indicator or counter.

2 Wire-feed control as per arrangement - setting pitch according to diameter of wires.

3 Coil length/coil width setting.

4 Mandrel.

5 Reel/spool carrier.

6 Wire guides etc.

Turn indicator : Turn indicators have digital display normally. They are provided with reset arrangements to bring back the counter display to Zero. For determining the exact number of turns in a coil, the counter has to be set for zero initially. The initial readings of the counter have to be noted at the starting in the case of successive windings.

Wire-feed control arrangements or setting pitch : The wire-feed has to be adjusted depending upon the size (diameter) of the wire. The adjustment shall be made so that the wires do not overlap nor should a gap exist between the wires.

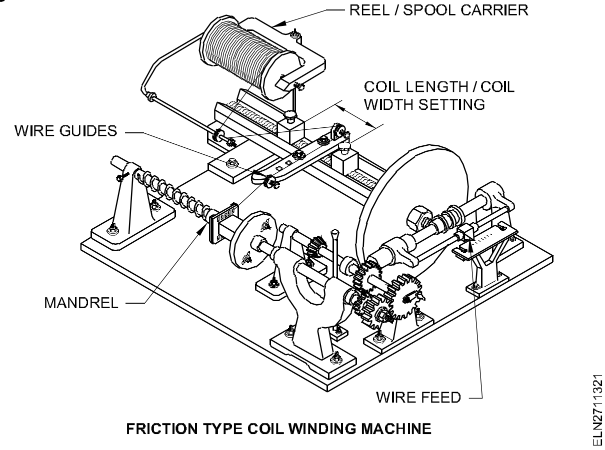
Hence before actually winding the coil, a trial run has to be made to ascertain a uniform layer of winding without overlap or gap exists. The feed controls are adjusted by selecting proper gear/pulley ratio or by setting proper friction depending on the design of the machine. Figs 1 and 2 shows wire feed arrangement by friction and gear respectively.

TABLE 2

Diameters and resistance of round conductors

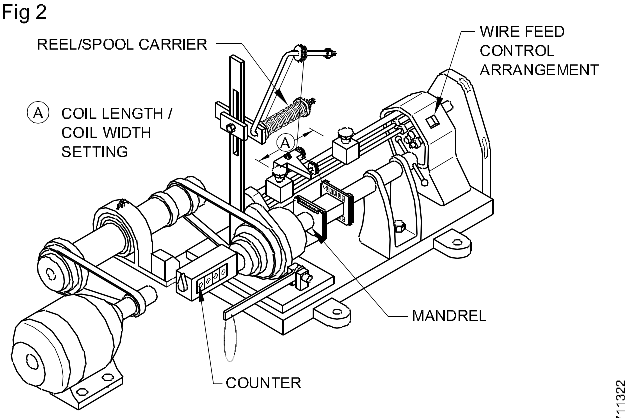
Nominal Conductor Diameter mm. (1)	Tolerance mm. (2)	Resistance in ohms per metre at 20°C					
		Copper			Aluminium		
		Nominal (3)	Max. (4)	Min. (5)	Nominal (6)	Max. (7)	Min. (8)
0.020	-	54.88	65.31	46.63	-	-	-
0.025	-	35.12	41.09	30.55	-	-	-
0.032	-	21.44	24.44	18.87	-	-	-
0.040	-	13.72	15.37	12.21	-	-	-
0.050	-	8.781	9.559	7.903	-	-	-
0.063	-	5.531	6.029	5.033	-	-	-
0.071	0.003	4.355	4.725	3.985	-	-	-
0.080	0.003	3.430	3.704	3.156	-	-	-
0.090	0.003	2.710	2.913	2.507	-	-	-
0.100	0.003	2.195	2.349	2.041	-	-	-
0.112	0.003	1.750	1.864	1.646	-	-	-
0.125	0.003	1.405	1.488	1.328	-	-	-
0.140	0.003	1.120	1.180	1.064	-	-	-
0.160	0.003	0.8575	0.8983	0.8192	-	-	-
0.180	0.003	0.6775	0.7068	0.6499	-	-	-
0.200	0.003	0.5488	0.5706	0.5282	0.8913	0.9317	0.8528
0.224	0.003	0.4375	0.4534	0.4224	0.7105	0.7404	0.6820
0.250	0.004	0.3512	0.3659	0.3374	0.5704	0.5975	0.5447
0.280	0.004	0.2800	0.2907	0.2698	0.4547	0.4747	0.4357
0.315	0.004	0.2212	0.2289	0.2139	0.3593	0.3739	0.3453
0.355	0.004	0.1742	0.1797	0.1689	0.2829	0.293	0.2727
0.400	0.005	0.1372	0.1419	0.1327	0.2228	0.2318	0.2142
0.450	0.005	0.1084	0.1118	0.1051	0.1761	0.1826	0.1697
0.500	0.005	0.08781	0.09037	0.08534	0.1426	0.1476	0.1378
0.560	0.006	0.07000	0.07215	0.06794	0.1137	0.1178	0.1097
0.630	0.006	0.05531	0.05687	0.05381	0.08982	0.09287	0.08688
0.710	0.007	0.04355	0.04481	0.04234	0.07072	0.07317	0.06836
0.750	0.008	0.03903	0.04022	0.03788	0.06338	0.06568	0.06116
0.800	0.008	0.03430	0.03530	0.03334	0.05570	0.05765	0.05383
0.850	0.069	0.03038	0.03131	0.02950	0.04934	0.05113	0.04762
0.900	0.009	0.02710	0.02789	0.02634	0.04401	0.04555	0.04253
0.950	0.010	0.02432	0.02506	0.02362	0.03950	0.04092	0.03813
1.000	0.010	0.02195	0.02259	0.02134	0.03565	0.03689	0.03445
1.060	0.011	0.01954	-	-	0.03173	-	-
1.120	0.011	0.01750	-	-	0.02842	-	-
1.180	0.012	0.01577	-	-	0.02560	-	-
1.250	0.013	0.01405	-	-	0.02282	-	-
1.320	0.013	0.01260	-	-	0.02046	-	-
1.400	0.014	0.01120	-	-	0.01819	-	-
1.500	0.015	0.009757	-	-	0.01584	-	-
1.600	0.016	0.008575	-	-	0.01393	-	-
1.700	0.017	0.007596	-	-	0.01234	-	-
1.800	0.018	0.006775	-	-	0.01100	-	-
1.900	0.019	0.006081	-	-	0.009876	-	-
2.000	0.020	0.005488	-	-	0.008913	-	-
2.120	0.021	0.004884	-	-	0.007932	-	-
2.240	0.022	0.004375	-	-	0.007105	-	-
2.360	0.024	0.003941	-	-	0.006401	-	-

Fig 1



FRICTION TYPE COIL WINDING MACHINE

Fig 2

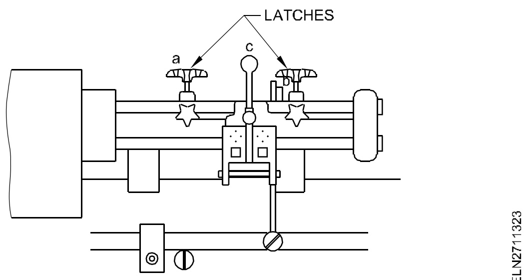


GEAR TYPE COIL WINDING MACHINE

Coil length setting or layer width setting: To wind the coil of a designated length i.e. within the inner length of the bobbin two latches are provided on the transverse pulley mechanism to stop and reverse the feed at the desired point (Fig 3).

Both these latches have to be set such that the wire is wound to the full length of the coil/bobbin and does not go out of the flanges of the bobbin. For this setting, several test runs are required before actually starting the winding of a coil.

Fig 3



Mandrel : Normally along with winding machines, different sizes and types of mandrels are supplied. In case they are not provided they have to be prepared from wood to the required shape and size. The mandrel assists to hold the bobbin firmly. A mandrel and a wooden block in (Fig 4 and Fig 5)

Fig 4

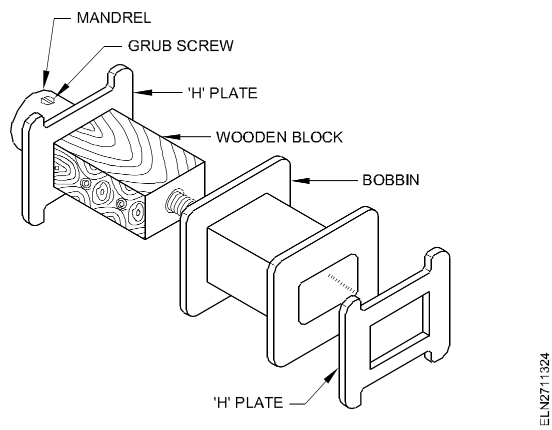
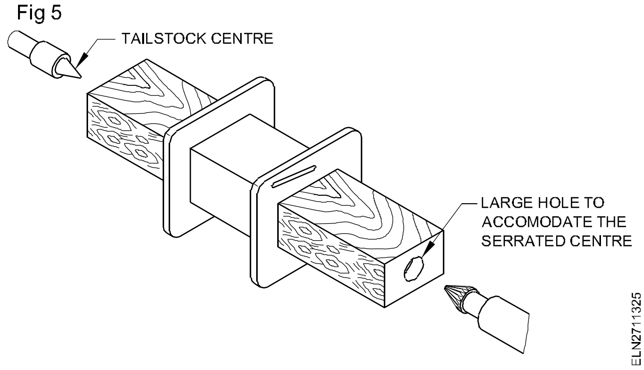


Fig 5



Reel spool carrier : Particularly for the fine wire, the over end de-reeling is provided to ensure that there are no restrictions preventing the wire from running freely. (Figs 1 and 2)

Wire guides : From the reel, the winding wire is taken through the wire guides to ensure that the wire is under proper tension between the pulley and the bobbin. Wire guides. (Figs 1 and 2)

For setting and operating details of the winding machine available in your section refer to the manufacturer's leaflet or seek advice from your instructor.

General maintenance of three-phase transformers

Objectives: At the end of this lesson you shall be able to
- **explain the need and advantages of maintenance of transformer**
- **state the factors affecting the life of transformers**
- **state the various periodical maintenance to be carried out in a transformer.**

Necessity of maintenance

Power transformer is required to give a long and trouble free service, It should be under constant attention and maintenance as it is a costly device.

A rigid system of inspection and preventive maintenance will ensure long life, trouble free service and low maintenance cost. Maintenance shall consists of regular inspection, testing and reconditioning wherever necessary.

Causes of breakdown: Generally the causes of breakdown of transformers may be classified as follows.

i faulty design or construction

ii incorrect installation or use

iii overloading

iv wear and tear, other deterioration

v negligence, accidents, environmental hazards

vi natural calamity.

Principal object of maintenance: The principal object of maintenance is to maintain the insulation in good condition. Moisture, dirt and excessive heat in contact with oxygen are the main causes of insulation deterioration and avoidance of these will keep the insulation in good condition.

There will be a decline in the quality of insulation during the ageing process due to chemical and physical effects. The decay of the insulation follows the chemical reaction rate and if the sustained operating temperature exceeds the normal operating temperature of 75^0C by about 10^0C the life of the transformer will get shortened.

FACTORS AFFECTING THE LIFE OF TRANSFORMERS

1 Effect of moisture

Transformer oil readily absorbs moisture from air. The effect of water in the oil is to decrease the dielectric strength of the oil. Therefore preventive steps should be taken to guard against moisture penetration to the inside of transformers. This will include blocking of all openings for free access of air and frequent reactivation of breathers in service.

2 Effect of oxygen

Oxygen present inside the transformer due to air in oil, reacts on the cellulose of insulation. Due to decomposition of the cellulose product, an organic acid soluble in oil is formed which will lead to a thick sludge. This sludge blocks the free circulation of the oil and deposited in bottom there by causing damage to coils/cores.

3 Effect of solid impurities

The dielectric strength of oil is diminished by minute quantities of solid impurities present in the oil. It is therefore a good practice to filter the oil after it has been in service for a short time.

4 Effect of varnishes

Some varnishes particularly of oxidizing type reacts with transformer oil and precipitate sludge on the windings. This should be kept in mind by the maintenance engineer when rewinding and replacing the coils during repairs.

5 Effect of slackness of windings

Slackness of windings may cause a failure due to repeated movement of coils which may wear the conductor insulation at some places and lead to an inter turn failure, momentary short circuit which may cause electric and magnetic unbalance. It is a good practice to lift the core and windings of a transformer and take up any slackness which may have developed by tightening the tie rods.

MAINTENANCE PROCEDURE

1 Safety precautions

i Before starting any maintenance work the transformers should be isolated from the supply and the terminals are earthed.

ii The oil level should be noted before unsealing the tank.

iii No fire should be kept near the transformer while maintenance work is going on.

2 Breather

Generally two types of breathers are used namely

a) Silicagel breather

b) Oil filled silicagel breather

a) Silica gel breather

The colour of the crystals changes from blue to pink as the crystals absorbs moisture. When the crystals gets saturated with moisture they become predominantly pink and it should be reactivated / reconditioned.

b) Oil filled silicagel breather

Oil available in the oil chamber attached with silicagel breather should be replaced, if it is gel condeminated.

External connections: All terminal connections should be tight. If they appear blackened or corroded, remove the connection and clean down to bright metal with emery paper. Remake the connection and give it a heavy coating of grease.

Earth connections: All earth connections should be properly maintained. A small copper loop to bridge the top cover of the transformer and the tank may be provided to avoid earth fault current passing through the bolts when there is a lightening surge, high voltage surge or failure of bushings.

Bushings: Clean the bushing projection and examine them for cracks and chips. It is recommended to have a spare in stock. In transformers located in control areas to avoid salt formation, a thin coating of grease pasted on the bushings.

Recommended maintenance schedules for transformers of rating less than 1000 KVA and for ratings of 1000KVA and above are given in Table 1 and 2 respectively.

Table 1

Maintenance schedule for transformers of capacities less than 1000 KVA

Sl.No.	Inspection Frequency	Items to be inspected	Inspection Notes	Action required during inspection if defects are noticed
1	Hourly	Load (Amperes)	Check against rated figures	Regulated with the values
2	Hourly	Voltage	- do -	- do -
3	Daily	De-hydrating breather	Check that air passages are clear. Check the colour of silica gel.	If silicagel is pink colour re place it or reactivate it.
4	Monthly	Oil level in transformer	Check transformer oil level	If low top-up with dry oil. Examine for oil leakage.
5	Quarterly	Bushings	Examine for cracks and dirt deposits	Clean or replace.
6	Half-yearly	Non-conservator transformer	Check for moisture under cover	Improve ventilation. Check oil
7	Yearly	Oil in transformer	Check dielectric strength acidity and sludge	Restore the quality of oil
8	Yearly	Earth resistance	Check the connection - nuts & bolts	Take suitable action if earth resistance is high.
9	1 year	Relay, alarms their circuits etc.	Examine relay and alarm contacts, their operation fuses etc.,check relay accuracy.	Clean the components, replace contacts change the setting if required
10	2 year	Non-conservator transformers	Internal Inspection	Filter oil regardless of condition
11	3 year	All parts	Overall inspection by lifting of core and coils	Wash by Flushing down with clean dry oil.

Table 2

Maintenance schedule for transformers of capacities of 1000KVA and above

Sl.No.	Inspection Frequency	Items to be inspect	Inspection Notes	Action required during inspection if defects are noticed
1	Hourly	Ambient temp	Check with normal values	Preventions/pre production from direct sum rays in summer season
2	Hourly	Winding,oil Temperature	Check that temperature rise is reasonable	Shut down the transformer and investigate whether it is higher than normal persistenly.
3	Hourly	Load (current) Voltage	Check against rated figures.	Regulates to normal values
4	Daily	Oil level in transformer	Check against transformer Oil level mark	If low top-up with dry oil. Examine for leakage.
5	Daily	Oil level in bushing leakage of water into cooler radiator fan	Check any leakage in coolents	Arrest the leakge if any
6	Daily	Relief Diaphragm	Leatheriod/ glass	Replace if cracked or broken.
7	Daily	Dehydrating breather	Check air passages are free, colour of silica gel. Check oil level in oil cap.	If silica gel is pink colour replace it or reactivate it. If oil level is low, top - up.
8	Quarterly	Bushing	Examine for cracks and dirt deposits	Clean or replace
9	Quarterly	Oil in transformer	Check for dielectric strength	Take suitable action to restore quality of oil.
10	Quarterly	Cooler fan bearings, motors and operating mechanisms	Lubricate bearings, check gear box. Check manual control and interlocks box.	Replace burnt or worn out contacts or other parts.
11	Half -yearly	Oil cooler	Test for pressure	Restore the requried prenure level
12	1 year	OLTC	Oil BDV (dielectrical strength) and moisture (PPM) content	Recondition or replace the oil, if the necessary .
13	1 year	Buchholz relay	Mechanical inspection for floats	Take suitable action if it found no free movement of floats
14	1 year	Oil in transformer	Check for acidity and moisture	Filter or replace.
15	1 year	Oil filled bushings.	Test oil	Filter or replace.
16	1 year	Gasket joints.	indication for leakage	Replace gaskets if leaking.

Sl.No.	Inspection Frequency	Items to be inspect	Inspection Notes	Action required during inspection if defects are noticed
17	1 year	Cable boxes	Check for sealing arrange-ments for filling holes, check compound for cracks.	Tighten the bolts to avoid unevenpressure.
18	1 year	Surge diverter and gaps.	Examine for cracks and dirt deposits	Clean or replace.
19	1 year	Relays, alarms their circuits etc.	Examine relay and alarm contacts, their operation and fuses.Check relay accuracy etc.	Clean the components, replace contacts, fuses if necessary. Change the setting if necessary
21	1 year	Insulator resistance	Check the IR value of primary and secondary windings	Take suitable actions if required
22	1 year	Ohmic value	Check the ohmic value of primary and secondary	Take suitable action it required windings
23	2 year	Oil temperature and winding temperature	Check and calibrate the OTI/WTI along with their	Replace or recalibrate them it required thermistor/CT.
20	1 year	Earth resistance	Earth conductor connection	Take suitable action if earth resistance is high.
24	5 year	1000-3000KVA	Overall inspection including lifting of core and coils.	Wash by Flushing down with clean dry oil.
25	7-10 year	Above 3000KVA	Overall inspection including lifting of core and coils.	Wash by Flushing down with clean dry oil.

Project work

Objectives: At the end of this lesson you shall be able to
- **define project work**
- **state the purpose of project work**
- **state the steps involving in project works.**

Project work

It is a type of activities which allow the trainees/ students to study, investigate, research, develop a model or find a conclusion/ solution and submit the report for a particular issues/ assignments towards the interest of public, nation and resources etc by applying their skill, ability, knowledge and experience.

Purpose of project work: The general purpose of any project should fulfill anyone or more of the following:

- Overcome the problems/ risks available in existing activities or technology etc.
- Simplifying the existing procedure/ activities of any operation or works.
- Reducing the cost of production or maintenence and increasing the productivity.
- Increasing the safety towards human lives/ machineries.
- Conserve the natural resources.
- Use of renewable energy sources such as wind, tide and solar etc.
- Using of new technology/ concept which is not available in market.
- Broadcasting or predicting any dangers/ risk involves in human lives/ machineries .. etc.

Steps involved in project works

- Deciding the objectives – purpose
- Deciding what to do – investigating and planning
- Find out the cost – costing
- Arranging the requirements – organising
- Selecting the right people – staffing
- Giving the instructions – directing
- Participating in works – involving
- Arranging the sequence – assembling or compiling
- Executing the project – testing or surveying
- Submitting the result conclusion – reporting

List of projector works may be assigned to the group of trainees as per syallabus

1 Overload protection of electrical equipments.
2 Automatic control of street light/ night lamp.
3 Fuse and power failure indicator using relays.
4 Door alarm/ indicator.
5 Decorative light with electrical flasher.