(NF)

Tertiary Winding :-

In addition to the primary and Secondary windings, the transformers are Sometimes provided with third winding, called the tertiary or stabilizing winding. It is usually delta connected.

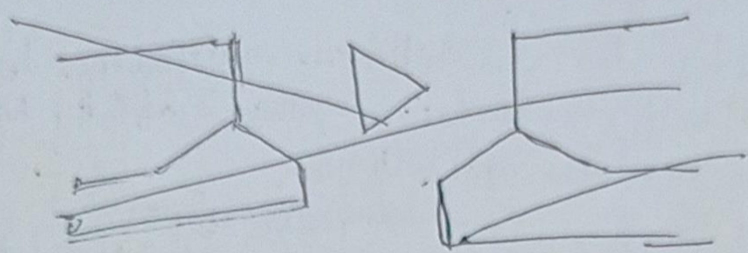
The various functions of ~~the~~ a tertiary winding are ~~as~~ as follows:-

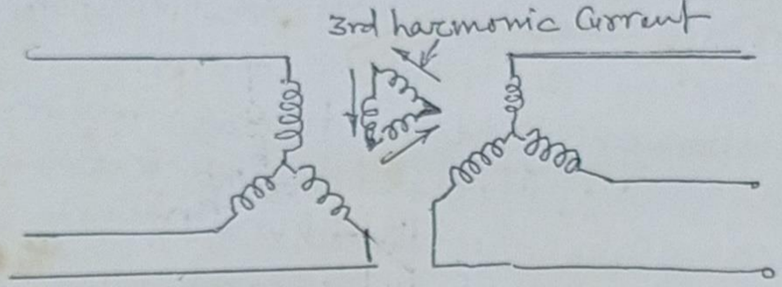
1. To supply the substation auxiliaries at a voltage different from those of the primary and secondary windings.
2. Static capacitors or Synchronous condensers may be connected to the tertiary winding for reactive power injection into the system for voltage control.
3. A delta-connected tertiary reduces the impedance offered to the zero Sequence currents thereby allowing a larger earth-fault current to flow for proper operation of protective equipment. Further, it limits voltage ~~impedance~~ imbalance when the load is unbalanced. It also permits the third harmonic current to flow thereby reducing third harmonic voltages.
4. Three windings may be used for interconnecting three transmission lines at different voltages.

5. Tertiary can serve the purpose of measuring voltage of an HV testing transformer.

When used for the purpose as stated in (iii) (3) above the tertiary winding is called a stabilizing winding.

~~Stabilization by tertiary winding~~:-





The provision of a delta connected tertiary-winding in star/star transformers permits the flow of third harmonic currents in it, therefore, the flux and emfs become almost sine wave as shown in Fig.

two points have already been discussed.

1·14. Tap-Changers on Transformers

The modern equipments, utilising electrical energy, are designed to operate satisfactorily at one voltage level. It is, therefore, of paramount importance to keep the consumers' terminal voltage within the prescribed limits. The transformer output voltage and hence the consumers' terminal voltage can be controlled by providing taps either on the primary or on the secondary.

The principle of regulating the secondary output voltage is based on changing the number of turns in the primary or secondary. Let V_1, N_1 and V_2, N_2 be the primary and secondary quantities. If N_1 is decreased, emf per turn on primary $\left(=\frac{V_1}{N_1}\right)$ increases, therefore, secondary output voltage $(V_1/N_1)\ N_2$ increases. On the other hand, if N_2 is increased keeping N_1 constant, the secondary output voltage $(V_1/N_1)\ N_2$ also increases. In other words, decreasing primary turns N_1 has the same effect as that of increasing the secondary turns N_2.

The taps which help in altering the turns ratio, may be placed on the primary or secondary side. The choice between the two sides should be based on maintaining the voltage per turn constant, as far as possible. If primary voltage per turn decreases, the core flux decreases and this results in poor utilisation of the core, though core losses are reduced. On the other hand, if primary voltage per turn increases, the core flux increases and this results in magnetic saturation of the core, more core losses, increased magnetizing current and pronounced third harmonic. In transformers at the generating stations, the primary voltage can be kept almost constant, consequently the taps should be provided on the secondary side. If transformer is energised from a variable voltage source, as at the receiving end of a transmission line, the taps should be provided on the primary side.

Other factors, described below, may also be taken into consideration, while deciding upon the side to be provided with taps.

(*i*) Transformers with large turns ratio, are tapped on the h.v. side, since this enables a smoother control of the output voltage. On the other hand, taps on the l.v. winding, vary output voltage in large steps, which is usually undesirable.

(*ii*) Tap-changing gear on the h.v. side will have to handle low currents, though more insulation will have to be provided.

(*iii*) It is difficult to tap the l.v. winding, since it is placed next to the core due to insulation considerations. The h.v. winding, placed outside the l.v. winding, is easily accessible and can, therefore, be tapped without any difficulty.

A consideration of the foregoing points can help in deciding upon the side of the transformer to be tapped.

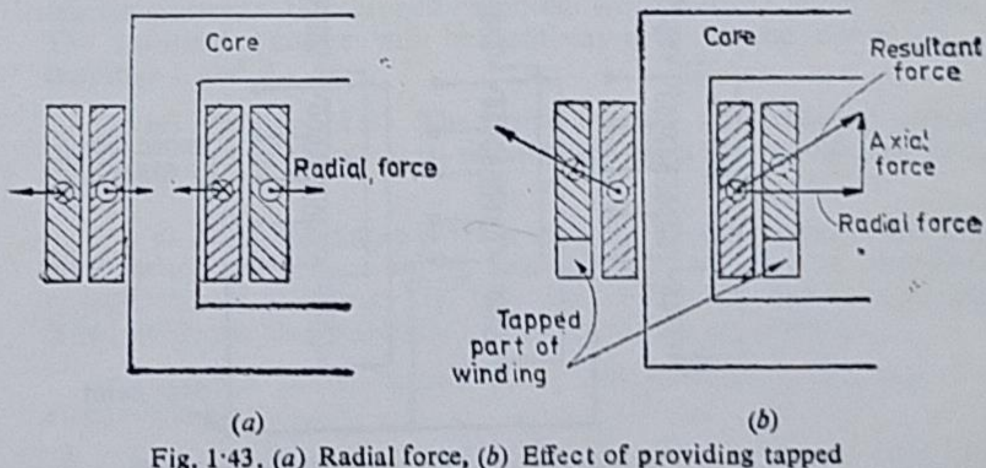


Fig. 1·43. (*a*) Radial force, (*b*) Effect of providing tapped coils at the end of a winding.

A further question arises about whether the transformer winding should be tapped at the end or in the middle. In order to investigate this, refer to Fig. 1·43 (*a*), where the currents in the primary and secondary coils must flow in oposite directions. These currents interact with leakage flux in between the two coils and produce a radial force, repelling each other. This radial force tends to compress the inner coil on to the core and burst the outer coil away from the core. The repelling force may be regarded as acting along the line joining the centres of gravity of the primary and secondary coils.

Suppose the winding is tapped at one end. When some of the turns are cut out by tap changer as shown in Fig. 1·43 (*b*) ; axial forces, in addition to radial forces, are also developed. Under short circuit conditions, the axial forces tending to compress the coils axially, are very large. In order to obviate this, the physical position of the tapped coils should be in the middle of winding, so that no axial forces arise after some turns are cut out. Electrically the tap-changer is connected where the voltage to neutral is minimum. For example, in a star-connected transformer, the tapped end of the windings are connected to form the star point, though physically the tapped coils are placed in the middle of the winding, see Fig. 1·44. This however is not possible in case of delta-connected transformers, where it is electrically essential to provide the tapped coils in the middle so that the tap-changing gear is far removed from the line and lightning surges.

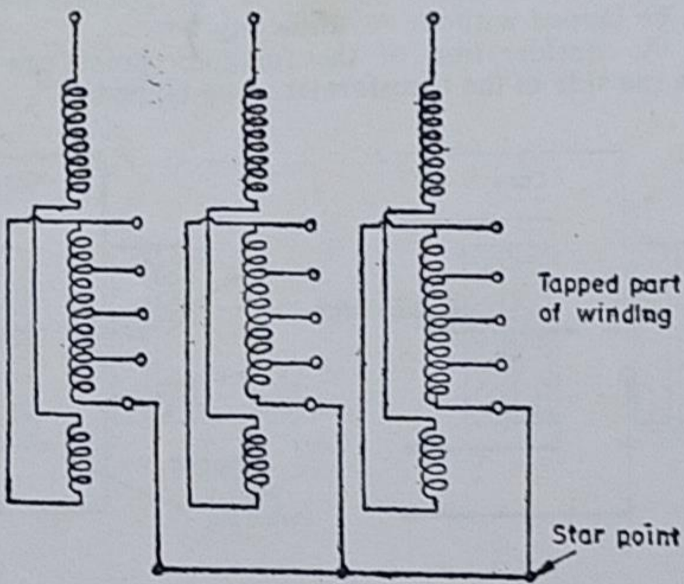


Fig. 1·44. Star connection of the tapped coils.

If the tap-changer is designed to operate with the transformer out of circuit, it is then called *off load* (or no-load) *tap-*

changer. A tap-changer designed to operate with the transformer in circuit, is called *on-load tap-changer*.

1·14·1. No-Load (or off-load) tap changer. This tap changer is used for seasonal voltage variations. An elementary form of no-load tap changer is illustrated in Fig. 1·45. It has six studs marked from one to six. The winding is tapped at six points, equal to the number of studs. The tapping leads are connected to six correspondingly marked stationary studs arranged in circle. The face plate carrying the six studs, can be mounted anywhere on the transformer, say on the yoke or on any other convenient place. The rotatable arm *R* can be rotated by means of handwheel, from outside the tank.

If the winding is tapped at 2·5% intervals, then with the rotatable arm *R* ;

(*i*) at studs 1, 2 ; full winding is in circuit ;

(*ii*) at studs 2, 3 ; 97·5% of the winding is in circuit ;

(*iii*) at studs 3, 4 ; 95% of the winding is in circuit ;

(*iv*) at studs 4, 5 ; 92·5% of the winding is in circuit ; and

(*v*) at studs 5, 6 ; 90% of the winding is in circuit.

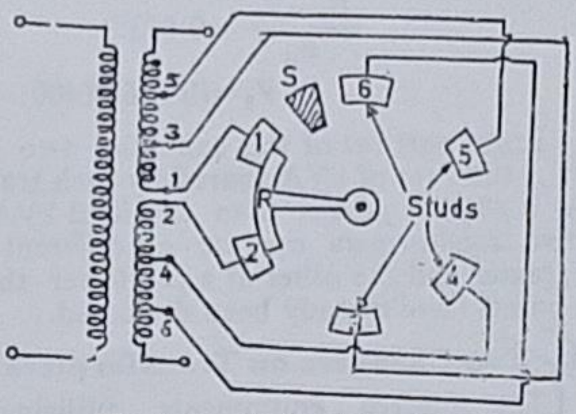


Fig. 1·45. No-load tap changer.

Stop *S* fixes the final position and prevents the arm *R* from being rotated clockwise. In the absence of stop *S*, the arm *R* may come in contact with studs 1 and 6. In such a case, only the lower part of the winding is cut out of circuit and this is undesirable from mechanical-stress considerations.

The tap-changing must be carried out only after the transformer is disconnected from the supply. Suppose arm *R* is at studs 1 and 2. For bringing arm *R* at studs 2 and 3, the transformer is first de-energised and then the arm *R* is rotated to bridge studs 2 and 3. After this, transformer is switched on to the supply and now 97·5% of the winding remains in circuit.

1·14·2. On-load tap-changer. This tap-changer is used for daily or short period voltage alterations. The output voltage can be