Y /Y CONNECTED TRANSFORMERS & SIGNIFICANCE OF TERTIATY WINDINGS FOR THIS CONFUGURATION.

Y/Y connected transformers have important advantages over other three-phase transformer connections. The primary and secondary circuits are in phase (no phase angle displacements). This is an important advantage where transformers are used to interconnect systems of different voltages in a cascading manner. As an example, suppose there are four systems operating at 500, 230, 138, and 69 kV that need to be interconnected. Substations can be constructed using Y/Y transformer connections to interconnect any two of these voltages. The 500 kV system can be tied with the 69 kV system through a single 500 to 69 kV transformation or through a series of cascading transformations at 230, 138, and 69 kV. If the neutral end of a Y-connected winding is grounded, reduced levels of insulation are required at the neutral end of the winding. A winding that is connected across the phases (delta) requires full insulation throughout the winding.

The first advantage is the major reason that Y/Y connected transformers are frequently found in substation installations. They may be appropriate when one is confident that the secondary load is sinusoidal and not comprised of non-linear loads such as variable speed drives and rectifier feeds. When providing power to non-sinusoidal loads however, serious consideration must be made to address and manage the harmonics. Triplen harmonics can pass through the transformer. Triplen harmonics are comprised of the *odd* multiples of the 3rd harmonic (ex. 3rd, 9th, 15th, 21st etc.). A harmonic is a component of a wave at a frequency that is a multiple of the fundamental (usually 60 Hz) power line frequency. Harmonics are attributed to loading from large amounts of electronic devices, using solid state power switching supplies for converting incoming AC to DC and/or industrial loads for rectifier feeds and induction heating. These non linear loads create harmonics by drawing current in abrupt short pulses, rather than in a smooth sinusoidal manner. Ground faults on the transformer secondary are seen as ground faults on the primary since the zero sequence (neutral) current passes directly through the transformer, making relay protection difficult. With a delta-Y transformer, the secondary ground faults do not cause zero sequence current to flow in the primary circuit.

On three-phase power systems, neutral current is the sum of the three line-to neutral currents. With balanced three-phase linear currents consisting of sine waves spaced 120 electrical degrees apart, the sum at any instant in time is zero, and so there is no neutral current. In most three- phase power systems supplying single-phase loads however, there will be some phase current imbalance and some neutral current. Small neutral current resulting from slightly unbalanced loads does cause problems for typical power distribution systems. Nonlinear loads however, such as rectifiers and power supplies, have phase currents which are not sinusoidal. The sum of balanced, non-sinusoidal, three-phase currents can be substantially above zero. These non-sinusoidal components are referred to as harmonics. Harmonics loading can result in waveform distortion. The triplen harmonics are of primary concern since their effect on the fundamental waveform are additive.

Tertiary winding is provided in electrical power transformer to meet one or more of the following requirements-

It reduces the unbalancing in the primary due to unbalancing in three phase load.

It redistributes the flow of fault current.

Sometime it is required to supply an auxiliary load in different voltage level in addition to its main secondary load. This secondary load can be taken from tertiary winding of three winding transformer.

As the tertiary winding is connected in delta formation in 3 winding transformer, it assists in limitation of fault current in the event of a short circuit from line to neutral.

In a star/star connection unbalanced load may result in neutral displacement and third-harmonic currents may circulate between lines and earth. These difficulties may be overcome by providing a delta connected stabilizing (tertiary) winding with a rating sufficient to take short-circuit fault currents.

Stabilization by Tertiary Winding of Transformer

In star-star transformer comprising three single units or a single unit with 5 limb core offers high impedance to the flow of unbalanced load between the line and neutral. This is because, in both of these transformers, there is very low reluctance return path of unbalanced flux. If any transformer has N turns in winding and reluctance of the magnetic path is R, then,

$Mmf=N*I=\Phi R_l$ ------ (1)

Where I and Φ are current and flux in transformer.

Induced voltage = $4.44\ \Phi f N$; $V \infty \Phi$

$\Phi = KV$ (where K is constant)--------- (2)

Now, from equation (1) & (2), it can be rewritten as,

$NI=KVR_l$

» $V/I=N/KR_l$

» $Z=N/KR_l$; » $Z \infty 1/R_l$

From above mathematical expression it is found that, impedance is inversely proportional to reluctance. The impedance offered by the return path of unbalanced load current is very high where very low reluctance return path is provided for unbalanced flux.

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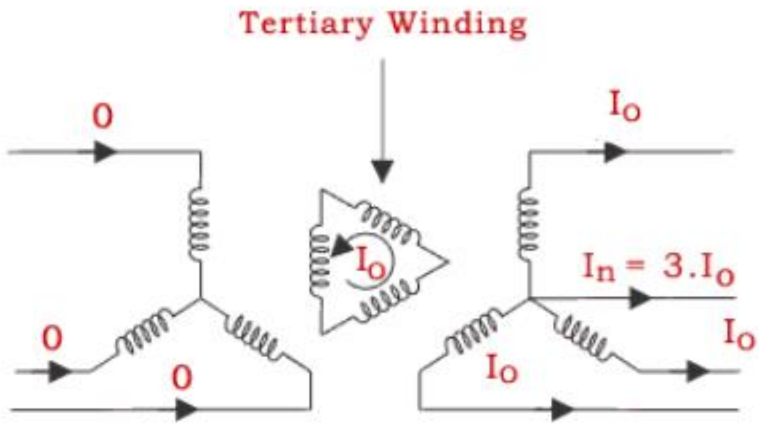

In other words, very high impedance to the flow of unbalanced current in 3 phase system is offered between line and neutral. Any unbalanced current in three phase system can be divided into three sets of components likewise positive sequence, negative sequence and zero sequence components. The zero sequence current is actually co-phasial current in three lines. If value of co-phasial current in each line is I, then total current flows through the neutral of secondary side of transformer is I = 3.I. This current cannot be balanced by primary current as the zero sequence current cannot flow through the isolated neutral star connected primary. Hence the said current in the secondary side set up a magnetic flux in the core. As we discussed earlier in this chapter, low reluctance path is available for the zero sequence flux in a bank of single phase units and in the 5 limb core consequently; the impedance offered to the zero sequence current is very high. The delta connected tertiary winding of transformer permits the circulation of zero sequence current in it. This circulating current in this delta winding balances the zero sequence component of unbalance load, hence prevents unnecessary development of unbalance zero sequence flux in the transformer core. In few words it can be said that, placement of tertiary winding in star - star-neutral transformer considerably reduces the zero sequence impedance of transformer.

Third Harmonic Suppression

The most common three-winding transformer is star/star connected with a delta tertiary to provide a path for z.p.s. currents. If third-harmonic distortion of the main flux (and, hence, of the secondary voltage wave form) is to be avoided, a tertiary must be used on any configuration of core that provides a low-reluctance path for third-harmonic components of the flux. A three-phase three-limb core-type transformer has no ferromagnetic return path for third-harmonic flux components, so suppressing z.p.s. distortion of the flux, and it will operate satisfactorily provided that the load is not significantly unbalanced. For an unbalance exceeding 10% or if a low zero sequence impedance is required for protection purposes it would be prudent to include a tertiary. However, a two-winding transformer called upon to supply zero-sequence loads could alternatively be provided with an external source of zero-sequence power (a) by a direct connection between the transformer in question and the neutral of a stand-by unit having a delta winding, or (b) by the installation of a zig-zag connected `earthing transformer. If several star/star units are acquired and undue unbalanced loading is not expected, it would be preferable on grounds of cost to specify them without tertiary windings, subsequent remedial action being taken if and when it becomes desirable. Whether or not third-harmonic problems arise depends on the complete installation and how it is operated. The transformer characteristics do not alone determine the issue; other factors are

(a) the level of the transformer core flux density (and, hence, the magnitude of the third-harmonic component of magnetizing current);

(b) the expected degree of load unbalance;

(c) the impedance of external sources of zero-sequence current; and

(d) the proximity of telecommunication circuits to the external zero-sequence current path.

Tertiary windings fitted only for harmonic suppression and not connected to external terminals must be rated to withstand the effects of primary and secondary earth fault currents: tertiary current then depends on the positive phase sequence, negative phase sequence, and zero phase sequence impedances of both the supply and the transformer. As such fault currents persist for only a few seconds, the temperature rise of the tertiary winding is determined by its thermal capacity.

Rating of tertiary winding of transformer depends upon its use. If it has to supply additional load, its winding cross - section and design philosophy is decided as per load, and three phase dead short circuit on its terminal with power flow from both sides of HV & MV. In case it is to be provided for stabilizing purpose only, its cross - section and design has to be decided from thermal and mechanical consideration for the short duration fault currents during various fault conditions single line -to-ground fault being the most onerous.