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Sequence Impedance Measurement of 3 Phase Transformer

M. Sathish Kumar[1], V. Malathi[2]
[1]M.E, [2]M.E, Phd, Department of Electrical and Electronics Engineering, Sri Chandrasekharendra Saraswathi Viswa Maha Vidayalaya , Kanchipuram – 631561

Abstract: The sequence impedance of the network describes the behaviour of the system under asymmetrical fault conditions. The performance of the system determines by calculating the impedance offered by the different element of the power system to the flow of the different phase sequence component of the current. Every power system component (static or rotating) has three values of impedance one for each symmetrical value of current. The sequence impedance of power system is of three types namely positive sequence impedance, negative sequence impedance and zero sequence impedance

I. INTRODUCTION

Usually power is generated and distributed in three phase system, and therefore it is obvious that we would need three phase transformers to step up and step down voltages. Although, it is practically possible to use three suitably interconnected 'single phase transformers' instead of one 'three phase transformer', the following advantages of three phase transformers encourage their use -

A. One 'three phase transformer' occupies less space than a gang of three 'single phase transformers'.
B. Single 'three phase' unit is more economical
C. The overall bus-bar structure, switchgear and installation of 'three phase transformer' is simpler.

II. WORKING METHODOLOGY

A. Theoretical Details And Block Diagram

The sequence impedance of the network describes the behaviour of the system under asymmetrical fault conditions. The performance of the system determines by calculating the impedance offered by the different element of the power system to the flow of the different phase sequence component of the current. Every power system component (static or rotating) has three values of impedance one for each symmetrical value of current. The sequence impedance of power system is of three types namely,

1) Positive sequence impedance
2) Negative sequence impedance
3) Zero sequence impedance.

B. Transformers

Transformers. Transformer phase shift. Wye-delta connections and impact on zero sequence. Inductance and capacitance calculations for transmission lines. GMR, GMD, L, and C matrices, effect of ground conductivity. Underground cables.

C. Equivalent Circuits

The standard transformer equivalent circuit used in power system simulation is shown below, where the R and X terms represent the series resistance and leakage reactance, and N1 and N2 represent the transformer turns. Note that the shunt terms are usually ignored in the model..

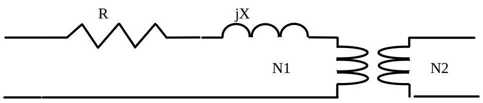

Figure 1. Power System Model for Transformer

Three-phase transformers can consist of either three separate single-phase transformers, or three windings on a three-legged, four-legged, or five-legged core. The high-voltage and low-voltage sides can be connected independently in either wye or delta.

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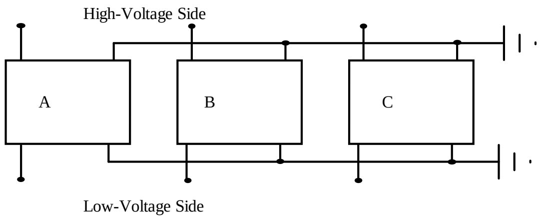

Figure 2. A Three-Phase Ground-Wye Grounded-Wye Transformer

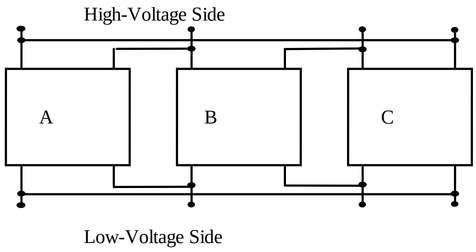

Figure 3. A Three-Phase Delta-Delta Transformer

The transformer impedances consist of winding resistances and leakage reactance's. There are no mutual resistances, and the mutual leakage reactance's between the separate phase a-b-c coils are negligible. Hence, in symmetrical components, $S = R + jX$, and $M = 0$, so that $S + 2M = S - M = R + jX$, so therefore the positive and negative sequence impedances of a transformer are $Z_1 = Z_2 = R + jX$ .One must remember that no zero sequence currents can flow into a three-wire connection. Therefore, the zero sequence impedance of a transformer depends on the winding connections. In the case where one side of a transformer is connected grounded-wye, and the other side is delta, circulating zero sequence currents can be induced in the delta winding. In that case, the zero sequence impedance "looking into" the transformer is different on the two sides.

The zero sequence equivalent circuits for three-phase transformers is given in Figure 4.

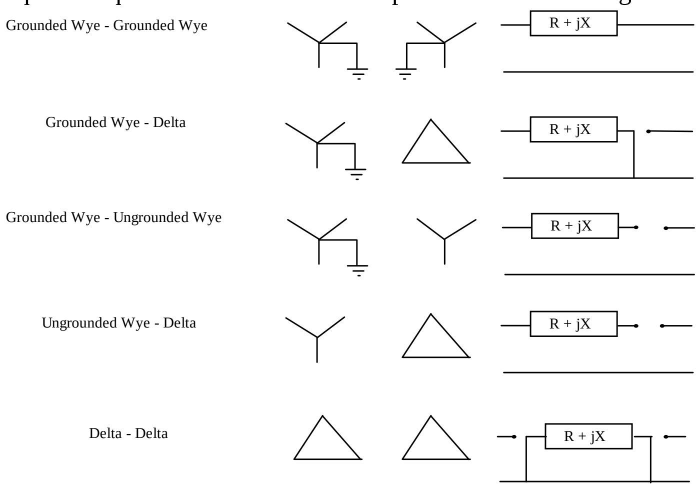

Figure 4. Zero Sequence Impedance Equivalent Circuits for Three-Phase Transformers

A wye-delta transformer connection introduces a 30o phase shift in positive/negative sequence voltages and currents because of the relative shift between line-to-neutral and line-to-ground voltages. Transformers are labeled so that

1) High side positive sequence voltages and currents lead those on the low side by 30o.
2) High side negative sequence voltages and currents lag those on the low side by 30o.
3) There is no phase shift for zero sequence.

Transformer tap magnitudes can be adjusted to control voltage, and transformer phase shifts can be adjusted to control active power flow. The effect of these "off-nominal" adjustments can be incorporated into a pi-equivalent circuit model for a transformer.

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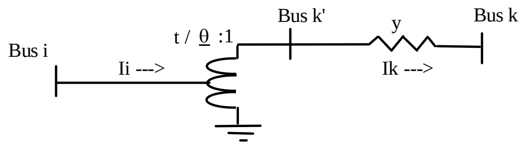
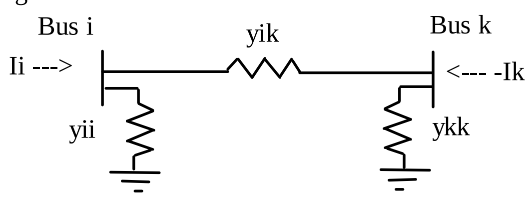
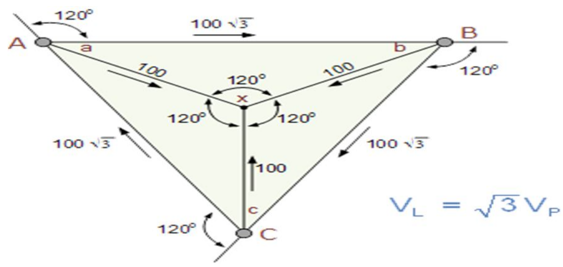


Figure 5. Off-Nominal Transformer Circuit Model

Assume that the transformer in Figure 5 has complex "off-nominal" tap $t\angle\theta_t$ and series admittance y. The relationship between the voltage on opposite sides of the transformer tap is $\tilde{V}_{k'} = \frac{\tilde{V}_i}{t\angle\theta_t}$, and since the power on both sides of the ideal transformer must be the same, then $\tilde{V}_i\tilde{I}_i^* = \tilde{V}_{k'}\tilde{I}_{k'}^*$, implying that $\tilde{I}_{k'} = \tilde{I}_i t\angle-\theta_t$. Now, suppose that the transformer can be modeled by the following pi-equivalent circuit of Figure 6:

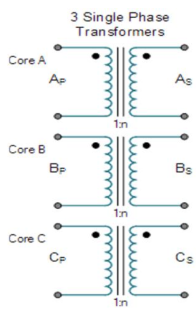


D. Three Phase Voltages and Currents



Where: V_L is the line-to-line voltage, and V_P is the phase-to-neutral voltage.
A transformer can not act as a phase changing device and change single-phase into three-phase or three-phase into single phase. To make the transformer connections compatible with three-phase supplies we need to connect them together in a particular way to form a Three Phase Transformer Configuration.
A three phase transformer or 3φ transformer can be constructed either by connecting together three single-phase transformers, thereby forming a so-called three phase transformer bank, or by using one pre-assembled and balanced three phase transformer which consists of three pairs of single phase windings mounted onto one single laminated core.The advantages of building a single three phase transformer is that for the same kVA rating it will be smaller, cheaper and lighter than three individual single phase transformers connected together because the copper and iron core are used more effectively. The methods of connecting the primary and secondary windings are the same, whether using just one Three Phase Transformer or three separate Single Phase Transformers. Consider the circuit below:

E. Three Phase Transformer Connections



Primary Configuration		Secondary Configuration	
Delta (Mesh)	Δ	Delta (Mesh)	Δ
Delta (Mesh)	Δ	Star (Wye)	Y
Star (Wye)	Y	Delta (Mesh)	Δ
Star (Wye)	Y	Star (Wye)	Y
Interconnected Star		Delta (Mesh)	Δ
Interconnected Star		Star (Wye)	Y

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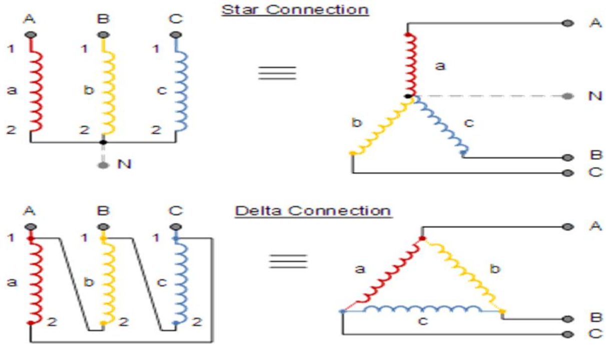
The primary and secondary windings of a transformer can be connected in different configuration as shown to meet practically any requirement. In the case of *three phase transformer* windings, three forms of connection are possible: “star” (wye), “delta” (mesh) and “interconnected-star” (zig-zag).The combinations of the three windings may be with the primary delta-connected and the secondary star-connected, or star-delta, star-star or delta-delta, depending on the transformers use. When transformers are used to provide three or more phases they are generally referred to as a Polyphase Transformer.

F. Three Phase Transformer Star and Delta Configurations

But what do we mean by “star” (also known as Wye) and “delta” (also known as Mesh) when dealing with three-phase transformer connections. A three phase transformer has three sets of primary and secondary windings. Depending upon how these sets of windings are interconnected, determines whether the connection is a star or delta configuration.The three available voltages, which themselves are each displaced from the other by 120 electrical degrees, not only decided on the type of the electrical connections used on both the primary and secondary sides, but determine the flow of the transformers currents.With three single-phase transformers connected together, the magnetic flux’s in the three transformers differ in phase by 120 time-degrees. With a single the three-phase transformer there are three magnetic flux’s in the core differing in time-phase by 120 degrees.The standard method for marking three phase transformer windings is to label the three primary windings with capital (upper case) letters A, B and C, used to represent the three individual phases of RED, YELLOW and BLUE. The secondary windings are labelled with small (lower case) letters a, b and c. Each winding has two ends normally labelled 1 and 2so that, for example, the second winding of the primary

G. Transformer Star and Delta Configurations



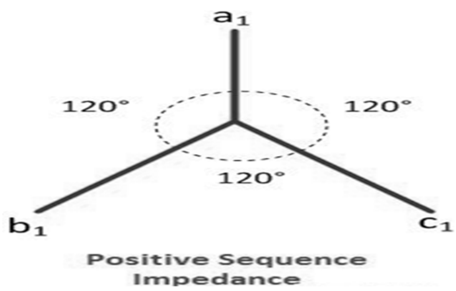
Symbols are generally used on a three phase transformer to indicate the type or types of connections used with upper case Y for star connected, D for delta connected and Z for interconnected star primary windings, with lower case y, d and z for their respective secondaries. Then, Star-Star would be labelled Yy, Delta-Delta would be labelled Dd and interconnected star to interconnected star would be Zz for the same types of connected transformers.

H. Transformer Winding Identification

Connection	Primary Winding	Secondary Winding
Delta	D	D
Star	Y	Y
Interconnected	Z	Z

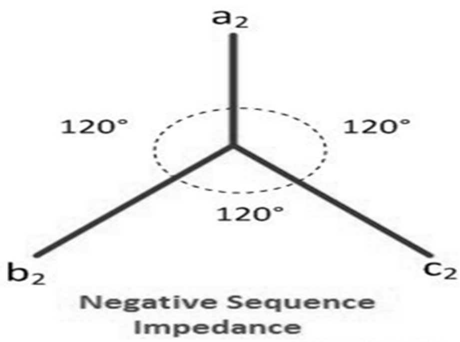
I. Positive Sequence Impedance

The impedance offered by the network to the flow of positive sequence current is called the positive sequence impedance. The positive sequence means all the electrical quantities are numerically equal and displaces each other by 120º.



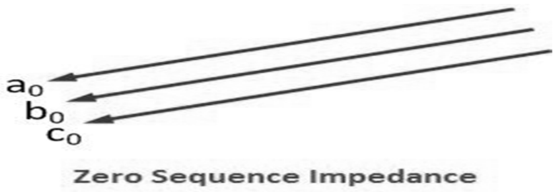
J. Negative Sequence Impedance

The negative sequence impedance means the impedance offered by the network to the flows of negative sequence current.



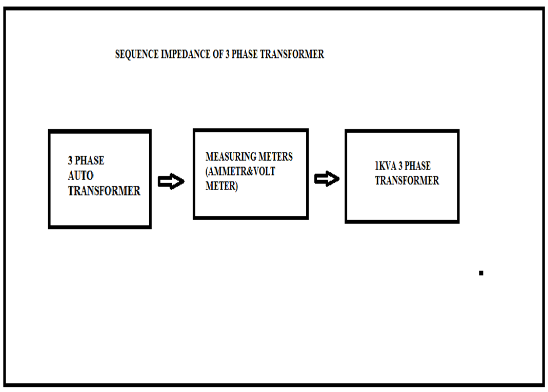
K. Zero Sequence Impedance

The impedance offered to zero sequence current is called the zero sequence impedance.



The impedance of the positive, negative and zero sequence components are given by the ratio of the phase sequence voltage to the phase sequence current of the system. There is no mutual impedance between various symmetrical components. The each sequence impedance considered separately, which simplifies the calculation of asymmetrical fault calculations.

Block Diagram



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L. Three Phase Transformer

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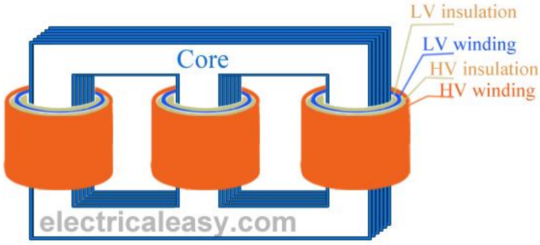
One 'three phase transformer' occupies less space than a gang of three 'single phase transformers'.
Single 'three phase' unit is more economical
The overall bus-bar structure, switchgear and installation of 'three phase transformer' is simpler.

M. Construction Of Three Phase Transformer

Three phase transformers can be of core type or shell type (just like single phase transformers). The constructional details of core type as well as shell type three phase transformers are as follows.

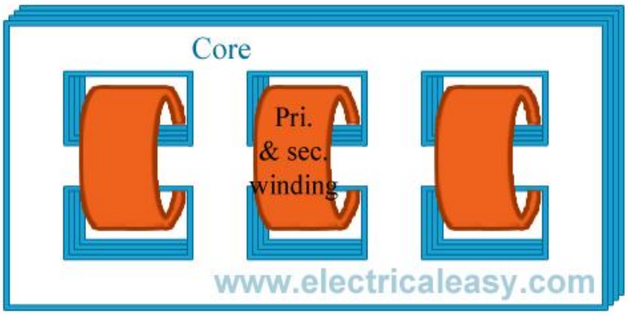
N. Core Type construction



Core type three phase transformer

The construction of a core type three phase transformer is as shown in the figure. The core consists of three legs or limbs. As usual, the core is made up of thin laminated sheets to reduce eddy current losses. Each limb has primary and secondary windings in cylindrical shape (former wound) arranged concentrically. The construction is well illustrated in the figure.

O. Shell Type Construction



Shell type three phase transformer

In a shell type three phase transformer, three phases are more independent than they are in core type. Each phase has its individual magnetic circuit. The construction of shell type three phase transformer is illustrated in the figure at right. The construction is similar to that of three single phase shell type transformers kept on the top of each other

The basic working principle of a three phase transformer is similar to the working principle of a single phase transformer. Power from primary is transferred to the secondary by the phenomenon of mutual induction.
The main drawback in a three phase transformer is that, even if fault occurs in one phase, the whole transformer is removed from service for repairs.

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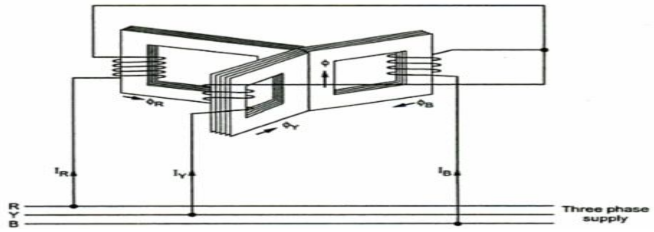
P. Working of Three Phase Transformers

Consider the below figure in which the primary of the transformer is connected in star fashion on the cores. For simplicity, only primary winding is shown in the figure which is connected across the three phase AC supply. The three cores are arranged at an angle of 120 degrees to each other. The empty leg of each core is combined in such that they form center leg as shown in figure.



Q. Working Of A Transformer

When the primary is excited with the three phase supply source, the currents IR, IY and IB are starts flowing through individual phase windings. These currents produce the magnetic fluxes ΦR, ΦY and ΦB in the respective cores. Since the center leg is common for all the cores, the sum of all three fluxes are carried by it. In three phase system, at any instant the vector sum of all the currents is zero. In turn, at the instant the sum of all the fluxes is same. Hence, the center leg doesn't carry any flux at any instant. So even if the center leg is removed it makes no difference in other conditions of the transformer. Likewise, in three phase system where any two conductors acts as return for the current in third conductor, any two legs acts as a return path of the flux for the third leg if the center leg is removed in case of three phase transformer. Therefore, while designing the three phase transformer, this principle is used.

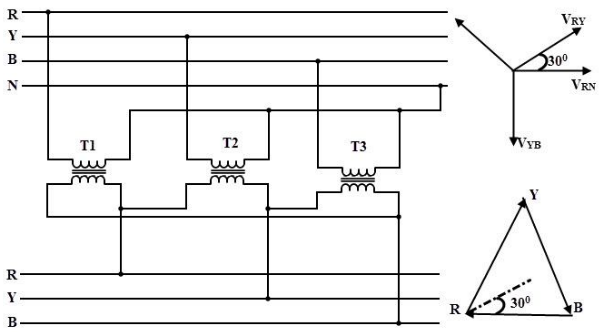
These fluxes induce the secondary EMFs in respective phase such that they maintain their phase angle between them. These EMFs drives the currents in the secondary and hence to the load. Depends on the type of connection used and number of turns on each phase, the voltage induced will be varied for obtaining step-up or step-down of voltages.

R. Three Phase Transformer Connections

As discussed above, either by a single three phase transformer or by three single phase transformers combination, three phase transformations can be carried out. The way of connecting the windings for three phase transformation is same whether the three windings of a three phase transformer or three windings of three single phase transformers are used. The primary and secondary windings are connected in different ways, such as in delta or star or combination of these two. The voltage and current ratings of the three phase transformer is depends on suitable connection. The most commonly used connections are

1) Star-delta
2) Delta-star
3) Delta-delta & Star –star

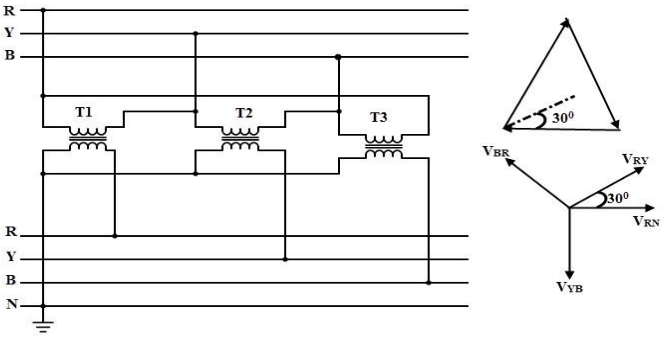
S. Star – Delta Connection



This type of connection is commonly used to step-down the voltages to a lower value in transmission end substations. Utility companies use this connection to reduce the voltage levels for distribution systems.

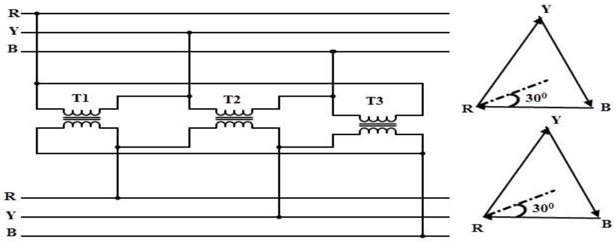
1) In this, the primary winding of the transformer is connected in star and secondary in delta connection.
2) The neutral point on the primary or high voltage side can be grounded which is desirable in most of the cases.
3) The line voltage ratio between secondary and primary is 1/√3 times the transformation ratio of each transformer.
4) There exists 30 degrees phase difference between primary and secondary line voltages.
5) Since the actual primary coil voltage is 58% of the primary line voltage, the insulation requirements for HV windings is reduced by using this winding.
6) In this connection balanced three phase voltage are obtained at the secondary or LV side, even when the unbalanced currents are flowing the in the primary or HV side due to neutral wire. The neutral wire grounding also provides lightning surge protection.

T. Delta – Star Connection



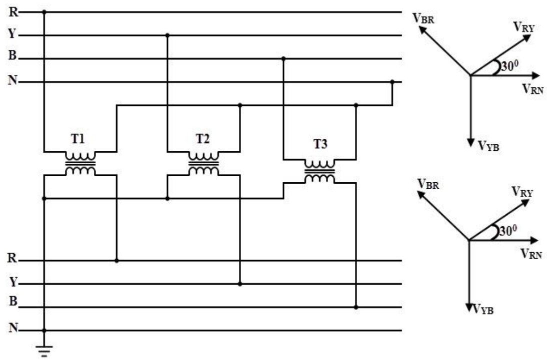
1) This connection is used to step-up the voltage level and is commonly employed in sending end or starting of high tension transmission system.
2) In this, the primary is connected in delta fashion and secondary in star fashion so that three phase 4 wire system at secondary is possible.
3) The secondary voltage to the load is √3 times the delta connected primary voltage. Also the load and secondary currents will be the same due to the same series circuit.
4) This connection provides three single phase circuits at both lower and higher voltages and one three phase circuit at higher voltage so that single and three phase loads can be supplied.
5) Dual voltages are obtained delta-star connection. Low single phase voltages are obtained by wiring between any phase and ground. Higher single phase voltages are obtained by wiring between any two phases. And by connecting all three phases to the load, three phase voltage is obtained.
6) The insulation requirement on high voltage side is lowered due to the star (less number of turns per phase) connected secondary.
7) Similar to star-delta, this connection causes to create a 30 degrees phase difference between primary and secondary line voltages.
8) By using this connection, it is not possible to connect it parallel with delta-delta and star-star transformers due to the primary and secondary voltage phase difference.

U. Delta-delta



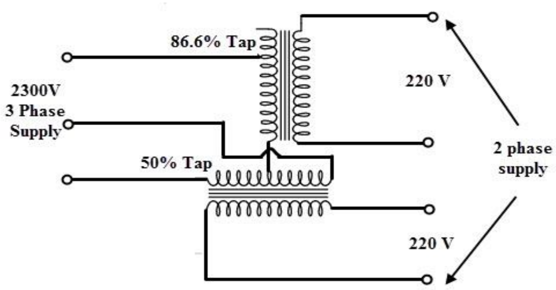
1) This type of connection is used when the supply source is delta connected and the secondary load needs single voltage with high current. This is generally employed for three phase power loads (like three phase motor).
2) In this, both primary and secondary windings are connected in delta fashion.
3) The voltage across the load is equal to the secondary voltage and voltage across the primary winding is equal to source voltage. In this, the current flow through the load will be 1.732 times the secondary current and the feeder current will equal to the 1.732 times current through the primary winding. Due to these high supply and load currents, it is recommended to place transformer much closer to both source and load circuits.
4) In this, there exists no phase difference between the primary and secondary voltages.
5) The three phase voltages remains constant even with unbalanced load, thus allows unbalanced loading.
6) The main advantage of this connection is if the one transformer is defective or removed for service (open delta connection), then remaining two transformers continue to deliver thee phase power at reduced load capacity.

V. Star – Star Connection



1) In this, both primary and secondary windings are connected in star fashion and also there exist no phase difference between the primary and secondary voltages.
2) In this, current flowing through both primary and secondary windings are equal to the currents of the lines to which they are connected (supply source and load). And voltages between line phases on either end equal to 1.732 times respective winding voltages.
3) Due to neutral availability, it is well suited for three phase four wire system.
4) This type connection satisfactorily works if the load is balanced. But if the load is unbalanced, the neutral point shift causes unequal phase voltages.
5) Large third harmonic voltages would appear in both primary and secondary windings without the neutral tie. This may lead to the insulation failures.
6) This connection considerably generates interference with communication lines and hence with this connection configuration, telephone lines cannot be run in parallel.
7) Due to these disadvantages, the star-star connection is rarely used and not employed in practice.

W. Scott Connection



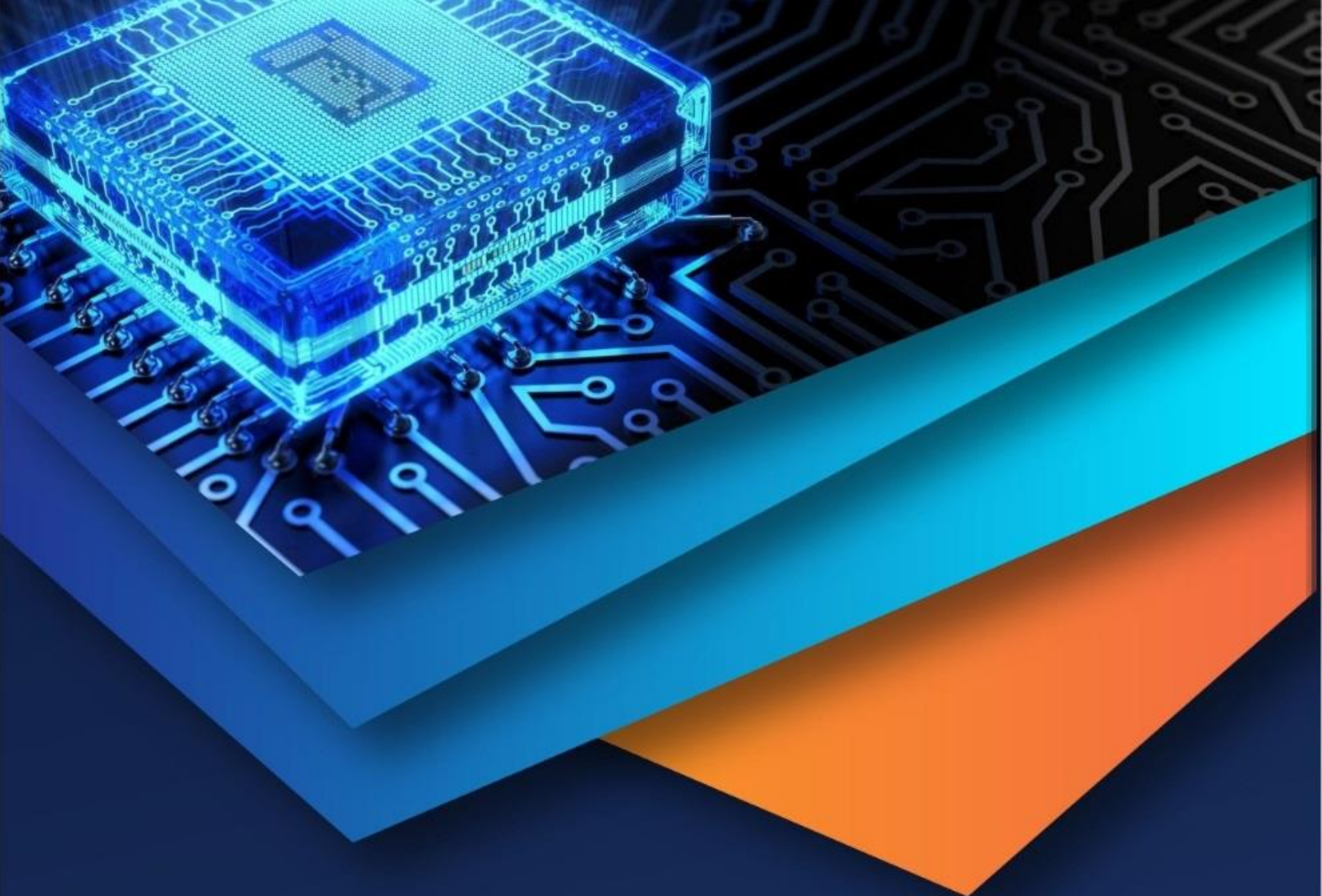
1) This connection is used to convert the three phase power into two phase power using two single phase transformers.
2) One transformer called as main transformer having center or 50 percent tap and is connected between the two lines of the three phase wires. The other transformer called as teaser transformer having 86.6 tap and is connected between the third phase wire and 50 percent tap of the main transformer.
3) The secondary winding of each transformer provides the phases of two phase systems.
4) The secondary voltages in the two transformers will be equal in magnitude if both transformers are wound for equal number of turns on secondary. And produced voltages are 90 degrees out of phase with each other.
5) This connection is mainly used to supply the power to the two phase motor.

III. CONCLUSION

The impedance of the positive, negative and zero sequence components are given by the ratio of the phase sequence voltage to the phase sequence current of the system. There is no mutual impedance between various symmetrical components. The each sequence impedance considered separately, which simplifies the calculation of asymmetrical fault calculations.

REFERENCES

[1] Electric Power Transformer Engineering - edited by James H. Harlow, Page no.15.3
[2] Symmetrical Components for Power Systems Engineering - By J. Lewis Blackburn, Page No. 227
[3] Short-circuit Currents - By Jürgen Schlabbach, J. Schlabbach Page No. 19
[4] Transformer Engineering: Design and Practice - By S.V. Kulkarni, S.A. Khaparde, Page No.74
[5] Allis-Chalmers Manufacturing Company, 1941, Page No.6
[6] Principles of Power Engineering Analysis- By Robert C. Degeneff, M. Harry Hesse, Page No. 189
[7] Electrical Power System Analysis - By S. Sivanagaraju, B. V. Rami Reddy,Page No. 137
[8] Electrical Power Engineering by Henslay William Kabisama Mcgraw-Hill Companies, 01-Jan-1993, Page No. 245
[9] https://web.ecs.baylor.edu/faculty/grady/_07A_ELC4340_Spring13_Transformers.doc



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