**Equivalent Circuit parameters of three-phase three winding Transformer**

**INTRODUCTION**

A 3 Φ Transformer can be realized either by using a bank of 3 single phase transformers with the primaries and the secondaries connected in star or delta fashion or by directly using a 3 Φ Transformer. In this experiment we determine the equivalent circuit parameters of a 3Φ-3 winding Transformer (the third winding being the tertiary winding). Tertiary winding offers various advantages such as a voltage different from the secondary and the primary voltages, provides option for reactive power injection into the system (used for voltage control), provides reduced impedance to ‘0’ sequence currents thereby allowing a larger earth fault current to flow for proper operation of the protective equipment (Better known as stabilization by Tertiary winding), etc. For elaborate understanding of the utilities and advantages of a Tertiary winding please refer to any standard Text Book on machine theory. The basic steps in extracting the relevant circuit parameters of a 3 Φ-3 winding transformer are similar to that of a basic 1 Φ transformer only this time around we need to proceed in pairs i.e. 2 windings at a time (that gives us 3 pairs of windings, {9 windings in all})

**THEORY**

![1 Φ Equivalent circuit Diagram of a 3 winding Transformer](image)

The Subscripts 1 2 & 3 indicate primary secondary and Tertiary respectively. The individual impedances can be obtained by conducting 3 short circuit tests, one on each pair of windings. It may be recalled from the short circuit test of single phase Transformers that

\[
Z = \frac{V_{sc}}{I_{sc}} \quad (1) \\
R = \frac{P_{sc}}{I_{sc}^2} \quad (2) \\
X = \sqrt{Z^2 - R^2} \quad (3)
\]

Where \(V_{sc}\) = short circuit voltage, \(I_{sc}\) = Short circuit current, \(P_{sc}\) = Power input, \(Z\) = lumped impedance & \(R\) = lumped resistance and \(X\)=lumped reactance. Also \(Z=R + jX\).
From the three short circuit tests we obtain 3 lumped impedances namely $Z_{12}$, $Z_{23}$ & $Z_{13}$.

Where $Z_{ij} = Z_i + Z_j$

From the above we get

$$Z_1 = \frac{1}{2} \left( Z_{12} + Z_{13} - Z_{23} \right)$$

similarly we can find $Z_2$ and $Z_3$.

For the open circuit test we have

$$Y = \frac{I_0}{V_1} \quad \text{(4)}, \quad V_1^2 G_i = P_0 \quad \text{(5)}$$

&

$$B_m = \sqrt{Y_0^2 - G_i^2} \quad \text{(6)}$$

Where $Y_0 = G_i - jB_m$ is the equivalent admittance of the shunting branch in the open-circuit (in the primary side).

Based on the above equations one can obtain the values of the equivalent circuit parameters of the 3 Φ-3 winding transformer.

**PROCEDURE**

The entire task is divided into 2 parts:

(a) Open circuit test (conducted on the primary)

(b) Short circuit test (conducted in pairs)

(A) Open Circuit Test

(1) Connect the 3 Φ mains supply to the auto-transformer (The connections to the auto-transformer have been described in detail in the prelude to the manual)

(2) Output of the Auto-transformer is fed to the TPST. (Choose appropriate fuse value based on the maximum current that will flow amongst the three pairs of winding under test i.e. Primary-Secondary, Secondary-Tertiary and Primary-Tertiary)

(3) The connections of the 3 Φ-3 winding transformer are elaborately mentioned on the Transformer’s front panel. They should be strictly adhered to. Open the connections if already connected and reconnect in accordance with the directions on the panel. Connect primary and secondary in Υ and Tertiary in Δ.

(4) The Secondary and tertiary should be left open (i.e. The tertiary should be left as it is and the secondary should be left open).

(5) The Ammeter and the wattmeter should be connected as shown in Fig.2. The Voltmeter should be kept floating. Take care to use a low power factor wattmeter for open-circuit test.
(6) Increase the autotransformer voltage till the voltmeter reads the rated primary side voltage.

(7) Once this voltage is reached note down the readings of the Voltmeter, wattmeter and ammeter. Do not forget to note down the multiplication factor of the wattmeter.

(8) Slowly decrease the voltage of the autotransformer to 0 volts. Switch off the mains power supply and throw open the TPST.

B) Short-circuit test

1) Follow the steps 1, 2, and 3 of (A).

2) Make the connections as shown in figure 3. Three-phase supply is given to primary through auto-transformer, the secondary will be short circuited and the tertiary will be open-circuited.

3) Determine the rated current which would flow in the primary and secondary depending on the rated KVA.

4) Close the TPST switch and gradually increase the Autotransformer voltage till either A1 or A2, whichever reaches the rated current first.

5) Note down the readings of V, A1 and W1. Note down the multiplication factor of the Wattmeter and proceed to calculate the short circuit parameters i.e., Z_{12}.

6) Repeat the above procedure with supply given to primary, and tertiary short-circuited to get Z_{13}. (Refer Figure 4).

7) Repeat the above procedure with supply given to secondary, and tertiary short-circuited to get Z_{23}. (Refer Figure 5).

Figure 2: Open circuit-test of 3-phase 3-winding Transformer
Figure 3: Short-circuit test of 3-phase 3-winding Transformer to find $Z_{12}$

Figure 4: Short-circuit test of 3-phase 3-winding Transformer to find $Z_{13}$

Figure 5: Short-circuit test of 3-phase 3-winding Transformer to find $Z_{23}$