SEQUENCE IMPEDANCES OF TRANSFORMERS

Objective:

To determine the positive, negative and zero sequence impedances for the following transformer connections:
1. Star-star, both neutrals solidly earthed
2. Star-delta, neutral solidly earthed
3. Star-star, one neutral earthed

Theory:

The positive sequence impedance of a transformer equals the leakage impedance. It may be obtained by the usual short-circuit test. Since the transformer is a static device, the leakage impedance does not change, if the phase sequence is altered from RYB to RBY. Therefore the negative sequence impedance of transformer is the same as the positive sequence impedance.

The zero sequence impedance of the transformer depends on the winding type (star or delta) and also on the type of earth connection.

The positive & negative sequence per unit impedances are independent of whether the sequence currents are injected into the primary or the secondary. However the zero sequence impedances will have different values, depending upon whether the sequence currents are injected into the primary or the secondary.

Pre-experimental quiz

1. Define symmetrical components.
2. What is the importance of sequence impedances?
3. The impedances of rotating machines to currents of the three sequences will generally be (a) same for each sequence (b) different for each sequence.
4. What is the utility of three-phase three-winding transformer?
5. Why is tertiary winding connected in delta?
6. What are the representative pu values for the sequence impedances for three-phase two-winding and three-phase three-winding transformers?

Procedure:

1. Connect the three-phase transformer in star-star with both neutrals solidly earthed as shown in FIG.1. In this case, only the leakage impedance per phase impedes the current. The zero sequence impedance Z_o equals the leakage impedance. The pu zero sequence impedance has the same value, if measured from both sides (Note that the ohmic values on the two sides would be in the ratio, a2 where 'a' is the turns ratio). Measure E, I_o, and I_o/a and calculate Z_o.
2. Connect the transformer in star -delta with the neutral solidly earthed as shown in FIG.2. Measure E and I_o and calculate the zero sequence impedance which when measured from the star side equals the leakage impedance. Note that the zero-sequence currents cannot be injected into the delta terminals.

3. Connect the transformer in star-star, with one neutral earthed, as shown in FIG.3.Measure E and Io and calculate the zero sequence impedance, which in this case is equal to the magnetising impedance. From a zero sequence point of view, the secondary acts as an open-circuit, and therefore from the primary side we measure the magnetising impedance. From the secondary side, the zero sequence current faces a total interruption. Note that the magnetising impedance is very large.

Post-experimental quiz

1. Do the positive & negative sequence impedances depend on the transformer winding connections?
2. Why is the magnetising impedance not considered while determining the sequence impedances?
3. Draw the zero-sequence networks for the following transformer connections (i) star-grounded /star (ii) star-grounded/star-grounded (iii)star-grounded/delta (iv)star/delta (v) delta/delta (vi) star/delta/delta
4. A transformer is star/star connected with neutrals grounded through Zl. Draw the zero sequence network.
5. For a transformer with star-grounded/delta connection, are the zero sequence impedances as viewed from the primary and secondary sides the same?
6. Compare for different connections the zero sequence impedance values with the positive & negative sequence impedance values respectively.

FIG.1   Primary   Secondary

Io/a

Io/a

Io/a

A

3 Io/a

Io

I o

Io

A

3 Io

E

3 Io

FIG.2   Primary   Secondary

Io   Io

Io

3 Io

E

FIG.3   Primary   Secondary

3 Io   Io

A

E

3Io