Electric Machines Laboratory (EE2P001)

EXPERIMENT-9

SEQUENCE IMPEDANCE OF 3 Φ ALTERNATOR

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Aim of the Experiment:

- To determine negative sequence impedance Z2 of a 3-Φ alternator.
- To determine zero sequence impedance Z0 of a 3-Φ alternator.

Apparatus Required:

Instruments/Equipments:

Sl. No	Instruments/Equipments	Type	Specification	Quantity
1	Ammeter	MI	(0–5/10)A	2 No
2	Voltmeter	MI	(0–15/30/75) V	1 No
3	Voltmeter	MI	(0–150/300/600) V	1 No
4	Rheostat	Tubular	500Ω, 3A	1 No
			70Ω, 3A	1 No
5	1-ϕVariac	Iron core	230 V, 10 A	1 No
6	3-ϕVariac	Iron core	415 V, 10 A	1 No
7	Tachometer	Digital	(0-2000)rpm	1
8	Phase Sequence Indicator	Analog		1
9	Connecting Wires	Cu	1.5 sq. mm	As required

Machines Required:

Sl. No	Machine	Specification	Quantity
1.	D.C. Motor coupled with 3-Φ Alternator	**D.C. Shunt Motor :-**6 HP, 1500 RPM 220 V, 24 A, Excitation- 220V/ 2 A **3-Φ Alternator :-** 5 kVA, 415V,50 Hz 7A, 1500RPM, 0.8 pf, Star connected Excitation- 220 V/4 A	1 Set

Theory:

Symmetrical components are mainly used for the resolution of unsymmetrical Phase currents or voltages in to a set of components that possess certain symmetry features. The positive sequence components possess –three phase symmetry having the phase sequences $R_1Y_1B_1$ or $A_1B_1C_1$; the negative sequences components possess three phase symmetry having the phase sequences $R_2Y_2B_2$ or $A_2C_2B_2$; and the Zero sequences components ($R_0Y_0B_0$ or $A_0B_0C_0$) have equal magnitudes and phases. The Impedance offered to these sequences' components are called Positive, Negative and Zero-sequence Impedances.

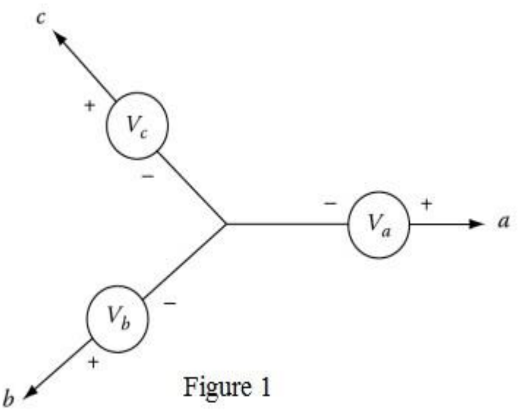


Figure 1

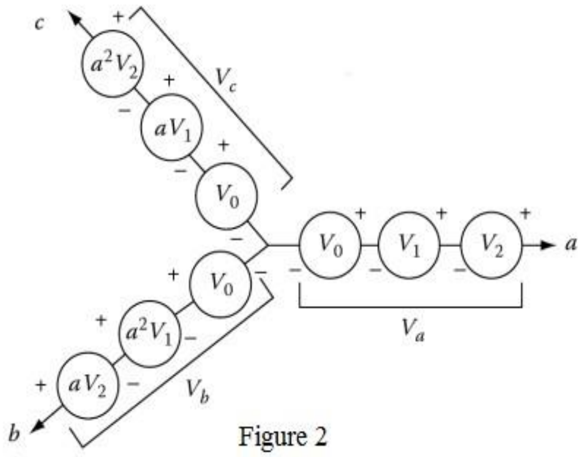


Figure 2

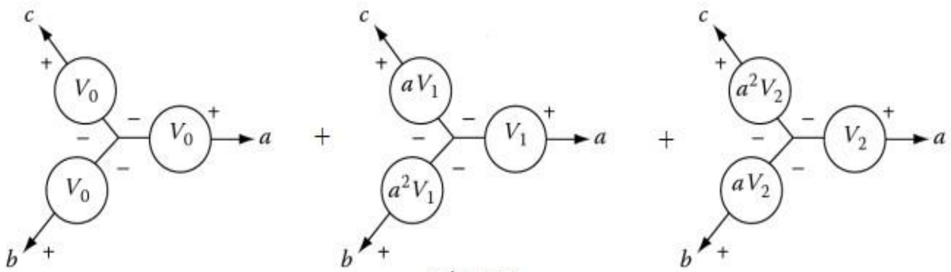


Figure 3

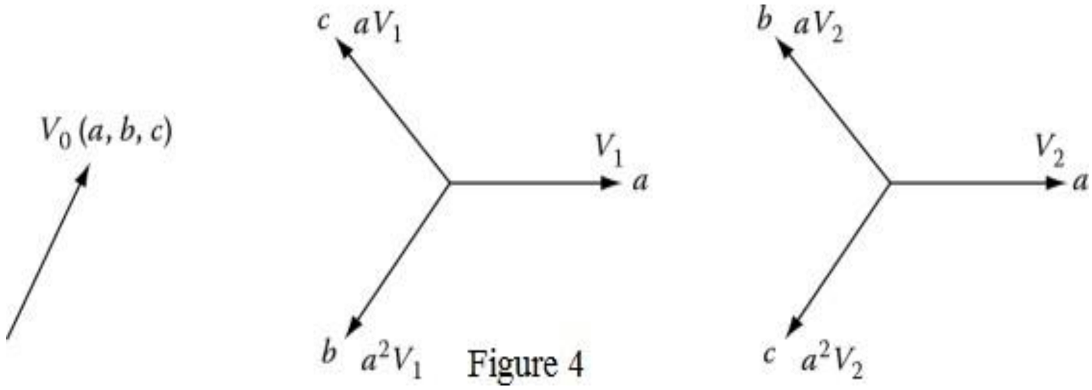
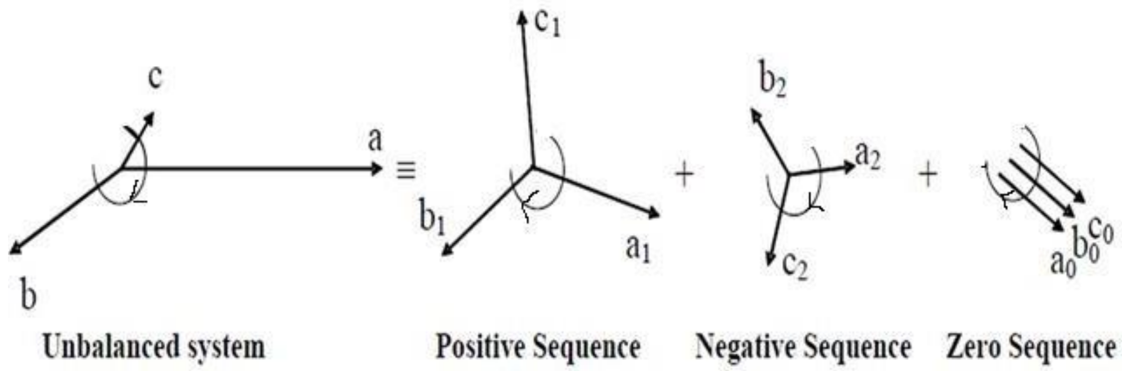


Figure 4



POSITIVE SEQUENCE COMPONENT

These are the components having equal in magnitude and having 1200 phase displacement. Its phase sequence is same as that of the original phase sequence of network.

- Direction of rotation of rotor of synchronous generator is the reference in order to decide the sequence of power system network.
- The sequence at which the system is working before fault is called as original sequence of network.

NEGATIVE SEQUENCE COMPONENT

These are the components having equal in magnitude and having 1200 phase displacement. Its phase sequence is opposite to that of the original phase sequence of network.

ZERO SEQUENCE COMPONENTS

These are the components having equal in magnitude and having no phase displacement. There is no need to compare phase sequence.

Negative Sequence Impedance (Z2):

The negative sequence impedance of the alternator is the impedance offered by the alternator to flow of negative sequence current. A set of negative sequence currents in the armature creates in the air gap a magnetic field that rotates at synchronous speed in a direction opposite to the normal direction of rotation (i.e. normal direction of rotation is identical to the direction of rotation of field created by positive sequence currents). Thus the negative sequence magnetic field rotates with twice the normal speed with respect to the rotor.

Test for Determining Z2:

The synchronous machine is driven at synchronous speed with help of prime mover. The machine is unexcited and connected to a voltage source which is gradually increased till full load current flows. The terminals are so connected that the direction of rotating field produced by the armature current is opposite to the direction of rotation of the pole structure. It is important to keep the field winding short-circuited during the test. The negative sequence impedance Z2 = V2 /I2.

Zero sequence impedance (Z2):

If zero-sequence currents are applied to the armature, there is no space fundamental m.m.f. Hence the reactance is small and is hardly affected by the motion of the rotor. The zero sequence currents produces leakage fluxes (slot-leakage, end-winding-leakage and differential leakage). Although very little flux is set up, and the zero-sequence reactance is the lowest of the synchronous machine reactances.

Test for Determination of Z0:

The machine is driven at rated speed with field winding short-circuited. All phases are connected in series and a single phase voltage applied across them. It may be sometimes more convenient to connect the phases in parallel. The series connection is, however, preferred as the currents of the same magnitude and phase is flowing through all the three phases, a condition which must be positively fulfilled while determining X0. For series connection Z0= V0 / (3*I0)

Where, V0 = applied voltage across three phase winding in series

I0 = current flowing in three phase windings in series.

For parallel connection of armature winding Z0=V0/ (I0/3)

Where, V0 = applied voltage across three phase winding connected in parallel

I0 = current flowing in three phase windings connected in parallel. The zero-sequence impedance is the impedance offered to the flow of zero sequence current i.e. the voltage drops across any one phase (star connected) divided by the current in each of the phase.

Circuit Diagram:

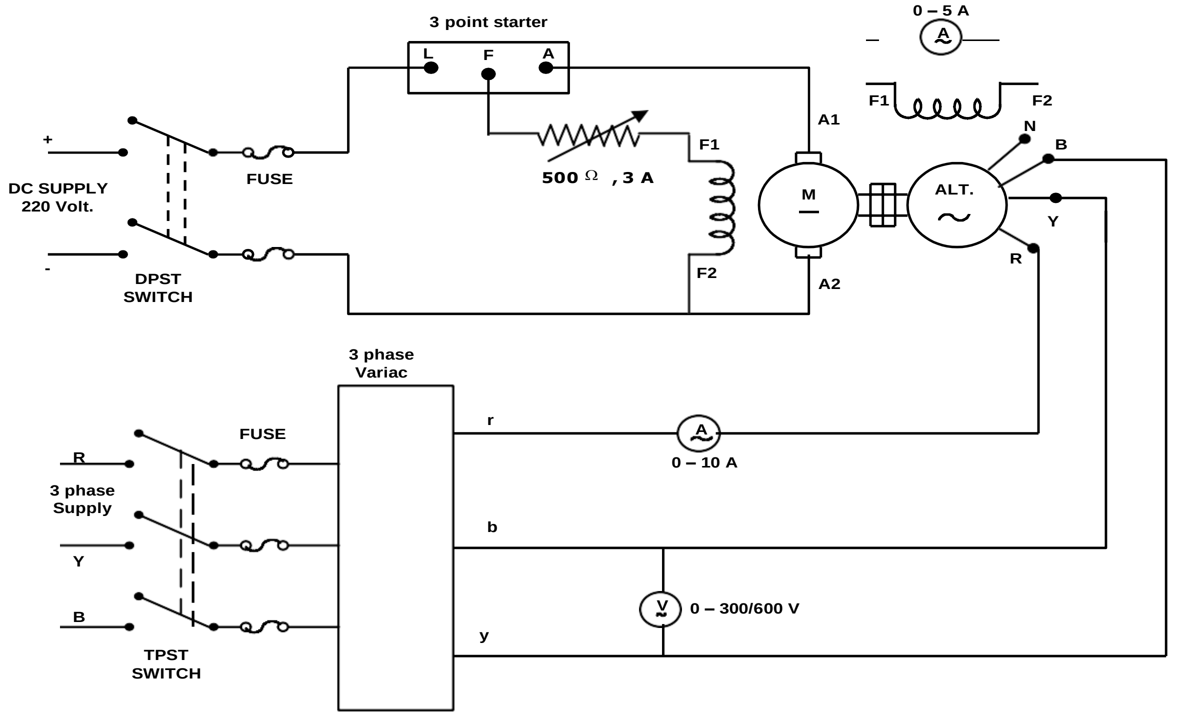


Figure 1:Circuit Diagram for Negative sequence Impedance (Z2)

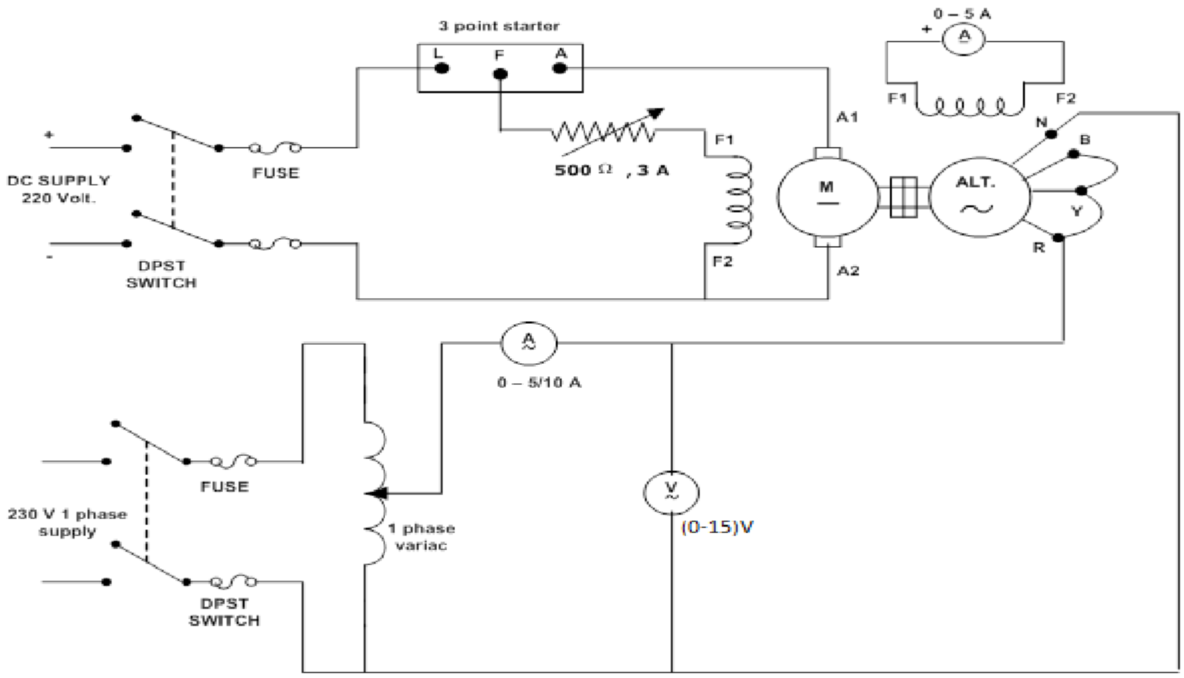


Figure 2:Circuit Diagram for zero sequence Impedance (Z0).

Precautions:

- Connection should be right and tight.
- Check the circuit connection thoroughly before switching on the supply.
- Instruments should be connected in proper polarity and range.
- Do not touch any non-insulated part of any instrument or equipment.
- Be ensured the zero setting of instrument is on right position. Avoid parallax error.
- While applying voltage the armature current should not exceed 7 A.
- The short circuit current should be kept low in order to avoid undue heating of the field winding.

Procedure:

For Negative Sequence Synchronous Impedance (Z2)

- Connect the circuit as shown in Fig-1.
- Rotate the rotor at synchronous speed with field winding unexcited & short circuited.
- Apply the balanced 3-ϕ voltage.
- Note down the instrument readings in observation table-1.
- Switch off the 3-ϕ supply & stop the machine.

For Zero Sequence Synchronous Impedance (Z0)

- Connect the circuit as shown in Fig-2.
- Rotate the rotor at synchronous speed with field winding unexcited & short circuited.
- Apply the 1-ϕ voltage.
- Note down the instrument readings in observation table-2.
- Switch off the1-ϕ supply & stop the machine.

Observation:

Table-1 for Z_2

Sl. No	V	I	Z_2
1	55	3.1	10.244
2	96	5.1	10.868
3	139	7	11.464

Table-2 for Z_0

Sl. No	V	I	Z_0
1	6.3	3.4	5.558
2	9.8	5.1	5.765
3	14.4	7	6.171

Calculation:

Calculation of Z_2

$Z_2 = V_t / I_0$ (negative sequence)

$V_t = V / 1.732$

1. $Z_2 = 55 / 1.732 * 3.1 = 10.244$
2. $Z_2 = 96 / 1.732 * 5.1 = 10.868$
3. $Z_2 = 139 / 1.732 * 7 = 11.464$

Calculation of Z_0

$Z_0 = V_0 * 3 / I_0$ (zero sequence)

1. $Z_0 = 6.3 * 3 / 3.4 = 5.558$
2. $Z_0 = 9.8 * 3 / 5.1 = 5.765$
3. $Z_0 = 14.4 * 3 / 7 = 6.171$

Conclusion:

The experiment was successfully conducted and the negative sequence impedance and zero sequence impedance was calculated.

Discussion:

1. **Define positive, negative and zero sequence components for unbalanced power system.**

- **Positive Sequence:** A balanced three-phase system with the same phase sequence as the original sequence.
- **Negative sequence:** A balanced three-phase system with the opposite phase sequence as the original sequence.
- **Zero Sequence:** Three phasors that are equal in magnitude and phase.

2. **Can zero sequence currents produce rotating field? Justify your answer.**

No zero sequence can't produce as they are in same phase in order to produce a rotating magnetic field, we need 3 coils to be 120. In space as well as time instead the field due to zero sequence will be zero as around the periphery.

3. **Explain how double frequency current is produced in the rotor field when negative sequence currents are impressed on armature.**

The negative sequence current which is produced by the unbalanced current produces a reverse rotating field in the air gap. The magnetic field rotates at synchronous speed but in a reverse direction to the rotor. In rotor's reference, the field appears to rotate at twice the synchronous speed. As the field sweeps across the rotor it induces double frequency currents into the rotor.

4. **Explain why X1 & X2are different in synchronous machine whereas they are equal in Transformer.**

A synchronous machine has an armature reaction and the air gap too which creates an armature reactance and leakage reactance where as a transformer does not have any armature reaction and only it has leakage flux so it has only leakage impedance X1 & X2which are equal due to same air gap.

5. **Explain how X_2 is arithmetic sum of "X_d" and "X_q".**

The negative sequence mmf is alternatively presented with reluctances of direct and quadrature axes. Thus, the negative sequence reactance X2 is found to oscillate between Xd and Xq and the value taken is usually the average.