EEL3060

Power Engineering Lab

Determination of the Sequence Reactances of an Alternator

Professor: Dr. Ravi Yadav

By:

Name	**Roll Number**
Dhyey Findoriya	B22EE024

I. Objective

To determine sequence reactances of a three-phase alternator.

II. Apparatus

- 3-phase Alternator (3kVA)
- Ammeter
- Aramture Rheostat (15A, 50 Ω)
- Field Rheostat (2.8A, 290 Ω)
- DC Motor
  - 1500 rpm
  - Armature Voltage - 220 V
  - Armature Current - 20 A
  - Field Voltage - 220 V
  - Field Current - 1.65 A
- Multimeter
- Connecting Wires
- 3-phase Power Supply (Auto Transformer/Variac)

III. Theory

1. Positive Sequence Impedance (Z_1)

- The positive sequence reactance of a three-phase alternator is equal to the synchronous reactance (X_s) determined by open-circuit and short-circuit tests.
- Formula: $X_1 = X_s$.

2. Negative Sequence Impedance (Z_2)

- It is found by applying a balanced negative sequence voltage to the armature terminals while the machine runs at synchronous speed with the field winding short-circuited.
- The ratio of phase voltage (V_{ph}) to phase current (I_{ph}) gives the negative sequence impedance (Z_2):
$$Z_2 = \frac{V}{I}$$

$$X_2 = \sqrt{Z_2^2 - R_a^2}$$

where R_a (Armature resistance) is given by:

$$R_a = 1.2 \times R_m$$

(R_m = measured phase resistance)

3. Zero Sequence Impedance (Z_0)

- Determined by connecting the three-phase armature windings in parallel to a single-phase source while keeping the machine at synchronous speed with field winding shorted.
- The zero sequence impedance (Z0) is given by:

$$Z_0 = \frac{3V}{I}$$

$$X_0 = \sqrt{Z_0^2 - R_a^2}$$

IV. Experimental Procedure

a) Negative Sequence Impedance Measurement

Steps:

1. **Circuit Setup:**
   - Connect the ciruit as shown in Figure 1. (Circuit Diagram for Negative Sequence Impedance Measurement.)
2. **Applying Voltage:**
   - Run the DC motor to maintain synchronous speed.
   - Apply voltage to the stator windings while keeping the speed constant.
3. **Measurement:**
   - $R_m = 1.6\Omega$
   - Record the readings of the voltmeter and ammeter.
   - Take 3-4 readings for different applied voltages.
   - Ensure that the armature current does not exceed its rated value at any voltage.
4. **Calculations:**

- For each reading, calculate the negative sequence impedance using the following formula:

$$Z_2 = \frac{V}{I}$$

$$X_2 = \sqrt{Z_2^2 - R_a^2}$$

- Finally, calculate the average of the three Z_2 values to determine the final negative sequence impedance.

Ciruit Diagram

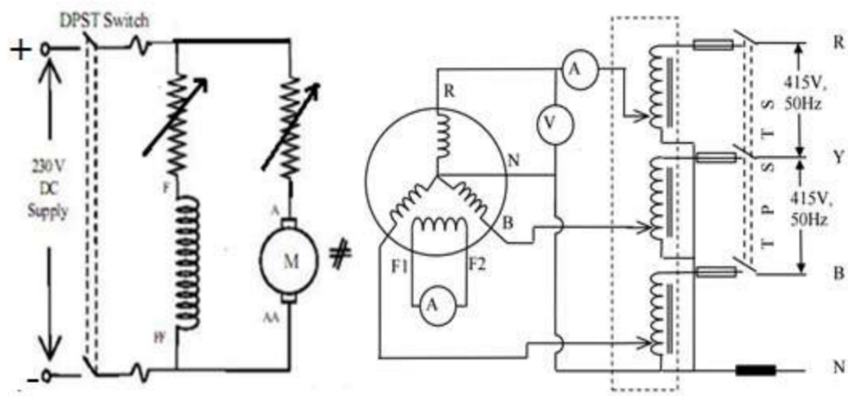

Figure 1: Circuit Diagram for Negative Sequence Impedance(Z_2) Measurement

Observation Table

S. No.	$V(V)$	$I(A)$	$Z_2(\Omega)$
1	5.23	1.00	5.23
2	10.41	1.80	5.78
3	15.92	3.00	5.31
4	23.19	4.26	5.32

Table 1: Observation Table for Negative Sequence Impedance

Calculations

1. For the first measurement:

$$Z_2 = \frac{V}{I} = \frac{5.23}{1.00} = 5.23\,\Omega$$

2. For the second measurement:

$$Z_2 = \frac{V}{I} = \frac{10.41}{1.80} = 5.78\,\Omega$$

3. For the third measurement:

$$Z_2 = \frac{V}{I} = \frac{15.92}{3.00} = 5.31\,\Omega$$

4. For the fourth measurement:

$$Z_2 = \frac{V}{I} = \frac{23.19}{4.26} = 5.32\,\Omega$$

Now, to calculate the average Z_2:

$$\text{Average } Z_2 = \frac{Z_2(1) + Z_2(2) + Z_2(3) + Z_2(4)}{4} = \frac{5.23 + 5.78 + 5.31 + 5.32}{4} = 5.41\,\Omega$$

$$R_m = 1.2 * R_m = 1.2 * 1.6 = 1.92\Omega$$

$$X_2 = \sqrt{Z_2^2 - R_a^2} = \sqrt{5.41^2 - 1.92^2} = 5.058\Omega$$

b) Zero Sequence Impedance Measurement

Steps:

1. **Circuit Setup:**
   - Connect the ciruit as shown in Figure 2. (Circuit Diagram for Zero Sequence Impedance Measurement.)
2. **Applying Voltage:**
   - Keep the synchronous machine at a standstill.
   - Switch on the power supply.
3. **Measurement:**
   - $R_m = 1.6\Omega$
   - Gradually increase the input voltage and record the voltmeter and ammeter readings.
   - Repeat for different voltages (below rated voltage and below rated current).
4. **Calculations:**

- For each reading, calculate the negative sequence impedance using the following formula:

$$Z_0 = \frac{3V}{I}$$

$$X_0 = \sqrt{Z_0^2 - R_a^2}$$

- Finally, calculate the average of the three Z_0 values to determine the final negative sequence impedance.

Ciruit Diagram

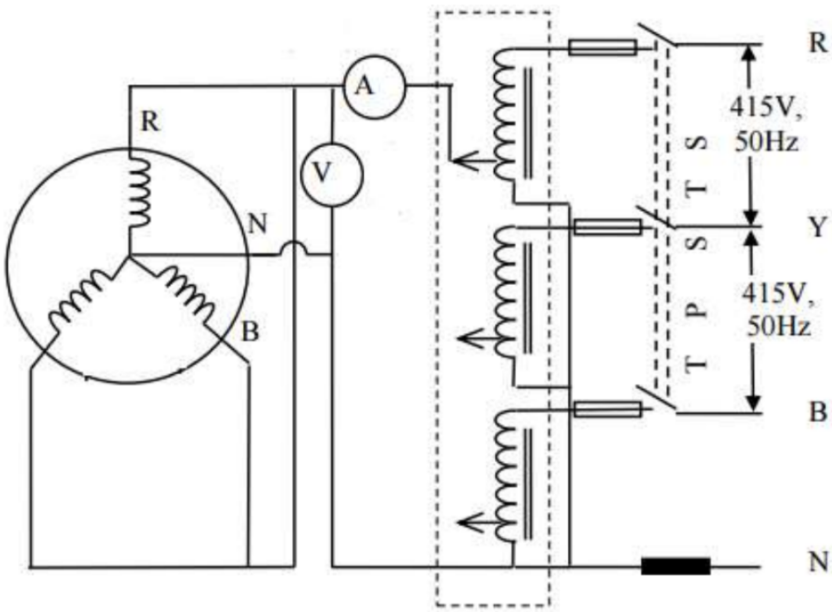

Figure 2: Circuit Diagram for Zero Sequence Impedance(Z_0) Measurement

Observation Table

S. No.	$V(V)$	$I(A)$	$Z_0(\Omega)$
1	3.46	2.56	4.05
2	4.36	3.24	4.04
3	5.80	4.24	4.10

Table 2: Observation Table for Zero Sequence Impedance

Calculations

1. For the first measurement:

$$Z_0 = \frac{3V}{I} = \frac{3 * 3.46}{2.56} = 4.05\,\Omega$$

2. For the second measurement:

$$Z_0 = \frac{3V}{I} = \frac{3 * 4.36}{3.24} = 4.04\,\Omega$$

3. For the third measurement:

$$Z_0 = \frac{3V}{I} = \frac{3 * 5.80}{4.24} = 4.10\,\Omega$$

Now, to calculate the average Z_0:

$$\text{Average } Z_0 = \frac{Z_0(1) + Z_0(2) + Z_0(3)}{3} = \frac{4.04 + 4.05 + 4.10}{3} = 4.06\,\Omega$$

$$R_a = 1.2 * R_m = 1.2 * 1.6 = 1.92\Omega$$

$$X_0 = \sqrt{Z_0^2 - R_a^2} = \sqrt{4.06^2 - 1.92^2} = 3.577\Omega$$

V. Results & Conclusion

- The positive sequence reactance of a three-phase alternator is equal to the synchronous reactance (X_s) determined by open-circuit and short-circuit tests.
- The negative sequence reactance (X_2) was calculated by applying a balanced negative sequence voltage to the alternator, and its impedance was found using the measured voltage and current.
- The zero sequence reactance (X_0) was determined by connecting all armature windings in parallel and measuring the response to a single-phase supply.
- These values are crucial for understanding how an alternator behaves under unbalanced and fault conditions, which helps in designing protective measures and ensuring system stability.
- The experiment successfully demonstrated the measurement techniques for sequence reactances, reinforcing their importance in power system analysis and fault diagnosis.