LABORATORY MANUAL

ON

POWER SYSTEMS & SIMULATION
LABORATORY

2018 – 2019

IV B. Tech I Semester (JNTUA-R15)

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(AUTONOMOUS)
Chadalawada Nagar, Renigunta Road, Tirupati – 517 506

Department of Electrical and Electronics Engineering
LIST OF EXPERIMENTS

1. Determination of sequence impedances of cylindrical Rotor synchronous machine
2. Fault Analysis-I (LG FAULT, LL FAULT)
3. Fault Analysis-II (LLG FAULT, LLLG FAULT)
4. Determination of Subtransient reactances of a salient pole synchronous machine
5. Equivalent circuit of a 3-Φ three winding transformer
6. Gauss-Seidal load flow analysis using MATLAB
7. Fast decoupled load flow analysis using MATLAB
8. \( Y_{bus} \) formation using MATLAB
9. \( Z_{bus} \) formation using MATLAB
10. Develop a Simulink model for a single area load frequency control problem
11. Newton Raphson Method of load flow analysis using MATLAB
12. Short circuit analysis for line to ground fault and line to line fault using MATLAB
Circuit diagram for positive sequence reactance $X_1$:—
1. DETERMINATION OF SEQUENCE IMPEDANCES OF CYLINDRICAL ROTOR SYNCHRONOUS MACHINE

Aim:- To determine experimentally Positive, Negative and Zero sequence reactance’s of a cylindrical rotor synchronous machine.

Name Plate Details:-

<table>
<thead>
<tr>
<th>S.No</th>
<th>Parameter</th>
<th>Alternator</th>
<th>DC Motor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rated Voltage</td>
<td>415 V</td>
<td>220 V</td>
</tr>
<tr>
<td>2</td>
<td>Rated Current</td>
<td>4.2 A</td>
<td>20 A</td>
</tr>
<tr>
<td>3</td>
<td>Speed</td>
<td>1500 RPM</td>
<td>1500 RPM</td>
</tr>
<tr>
<td>4</td>
<td>Rating</td>
<td>3 KVA</td>
<td>5 HP</td>
</tr>
<tr>
<td>5</td>
<td>Power factor</td>
<td>0.8</td>
<td>-----</td>
</tr>
<tr>
<td>6</td>
<td>Frequency</td>
<td>50 Hz</td>
<td>-----</td>
</tr>
<tr>
<td>7</td>
<td>Excitation</td>
<td>220 V, 2 A</td>
<td></td>
</tr>
</tbody>
</table>

Apparatus Required:-

<table>
<thead>
<tr>
<th>S.No</th>
<th>Apparatus</th>
<th>Type</th>
<th>Range</th>
<th>Quantity</th>
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<tr>
<td>1</td>
<td>Ammeter</td>
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<td></td>
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<td>2</td>
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<td>Wattmeter</td>
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</tr>
<tr>
<td>4</td>
<td>Rheostat</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Tachometer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Connecting Wires</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Procedure:-

(a) Determination of $X_1$ :-

(i) Open Circuit Test:-

1. Connect the circuit as per the given circuit diagram.
2. Ensure that the filed rheostat is kept in minimum resistance position.
3. Supply of 220V is given to dc motor, which is placed on the same shaft on which synchronous machine is placed and thus the synchronous machine is made to run at rated speed.
4. Voltmeter is connected across machine terminals and this meter is used to measure the voltage corresponding to the given field excitation and also the reading of the ammeter which is placed in the field winding.
5. Vary the field excitation, such that the voltmeter reads the rated voltage.
Circuit diagram for Negative sequence reactance $X_2$:

Circuit diagram for Zero sequence reactance $X_0$:
(ii) Short Circuit Test:-

1. Connect the circuit as per the given circuit diagram.
2. Ensure that the filed rheostat is kept in minimum resistance position.
3. Supply of 220V is given to dc motor, which is placed on the same shaft on which synchronous machine is placed and thus the synchronous machine is made to run at rated speed.
4. Apply low voltage across the field circuit such that the rated current in the ammeter which connect the short circuit winding of the synchronous machine.

(b) Determination of $X_2$:–

1. Connect the circuit as per the given circuit diagram.
2. Ensure that the filed rheostat is kept in minimum resistance position.
3. Supply of 220V is given to dc motor, which is placed on the same shaft on which synchronous machine is placed and thus the synchronous machine is made to run at rated speed.
4. Short circuit the two phases of an alternator through an ammeter and the current coil of the wattmeter.
5. Connect the voltage coil of the wattmeter and voltmeter between the open phase and any short circuit phase.
6. Increase the Excitation gradually in step by step such that the short circuit current should not exceed the full load value.

(c) Determination of $X_0$:–

1. Connect the circuit as per the given circuit diagram.
2. Ensure that the filed rheostat is kept in minimum resistance position.
3. Supply of 220V is given to dc motor, which is placed on the same shaft on which synchronous machine is placed and thus the synchronous machine is made to run at rated speed.
4. Connect the armature winding in parallel.
5. Short circuit the field winding of an alternator.
6. Apply a low voltage of 1-Ø auto transformer and then taken the both the values of voltmeter and ammeter of an armature winding.
Tabular Column:-

(a) Determination of $X_1$: -

(i) Open Circuit Test:-

<table>
<thead>
<tr>
<th>Excitation Current $I_f$ (A)</th>
<th>Open circuit voltage (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(ii) Short Circuit Test:-

<table>
<thead>
<tr>
<th>Excitation Current $I_f$ (A)</th>
<th>Short Circuit Current (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Positive sequence impedance $Z_1 = \frac{V_{oc}}{I_{sc}}$

Positive sequence reactance $X_1 = \sqrt{Z_1^2 - R_1^2}$

(b) Determination of $X_2$: -

<table>
<thead>
<tr>
<th>Applied voltage (V)</th>
<th>Short circuit current (A)</th>
<th>Wattmeter reading (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Negative sequence impedance $Z_2 = \frac{V_{oc}}{I_{sc}}$

Power factor $\cos\phi = \left(\frac{P}{\sqrt{3V_{sc}I_{sc}}}\right)$

Negative sequence reactance $X_2 = Z_2\sin\phi$

(c) Determination of $X_0$: -

<table>
<thead>
<tr>
<th>Short circuit voltage (V)</th>
<th>Short circuit current (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Zero sequence reactance $X_0 = \frac{V_0}{(I_0/3)}$
Precautions:-

1. Avoid the loose connections.
2. Note down the readings without parallax error.
3. Keep the field rheostat in maximum resistance position.
4. Keep the variac of the static exciter in minimum voltage output position.

Result:-

Conclusion:-
Circuit diagram for L-G Fault:
2. FAULT ANALYSIS – I

**Aim:-** To find the fault currents and fault voltages when a single line to ground (L-G) fault and line to line (L-L) faults occurred on unloaded alternator.

**Name Plate Details:-**

<table>
<thead>
<tr>
<th>S.No</th>
<th>Parameter</th>
<th>Alternator</th>
<th>DC Motor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rated Voltage</td>
<td>415 V</td>
<td>220 V</td>
</tr>
<tr>
<td>2</td>
<td>Rated Current</td>
<td>4.2 A</td>
<td>20 A</td>
</tr>
<tr>
<td>3</td>
<td>Speed</td>
<td>1500 RPM</td>
<td>1500 RPM</td>
</tr>
<tr>
<td>4</td>
<td>Rating</td>
<td>5 KVA</td>
<td>5 HP</td>
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<tr>
<td>5</td>
<td>Power factor</td>
<td>0.8</td>
<td>-----</td>
</tr>
<tr>
<td>6</td>
<td>Frequency</td>
<td>50 Hz</td>
<td>-----</td>
</tr>
<tr>
<td>7</td>
<td>Excitation</td>
<td>220V, 1A</td>
<td>220V, 1A</td>
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</tbody>
</table>

**Apparatus Required:-**

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<th>Range</th>
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<td>1</td>
<td>Ammeter</td>
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<tr>
<td>2</td>
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<td>Rheostat</td>
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<tr>
<td>4</td>
<td>Static Exciter</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>5</td>
<td>Tachometer</td>
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<td></td>
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</tr>
<tr>
<td>6</td>
<td>Connecting Wires</td>
<td></td>
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</tr>
</tbody>
</table>

**Procedure:-**

(a) **LG Fault:-**

1. Connect the circuit as per the given circuit diagram.
2. Ensure that the filed rheostat is kept in minimum resistance position and DPST switch in off position and give the supply to DC motor and then by varying field rheostat. Let, the motor runs at rated speed.
3. By varying the rheostat rated voltage in the voltmeter connected between the phase into be obtained with DPST switch in open stator.
4. At this instant note down all the voltmeter and ammeter readings.
5. Now close the DPST switch under fault condition. Note down the fault currents and fault voltages.
Circuit diagram for L-L Fault:-
(b) LL Fault:-

1. Connect the circuit as per the given circuit diagram.
2. Ensure that the filed rheostat is kept in minimum resistance position and DPST switch in off position and give the supply to DC motor and then by varying field rheostat. Let, the motor runs at rated speed.
3. Vary the rated speed up to rated voltage in the voltmeter connected between the phasor with DPST Switch in open position.
4. Now create a fault between the phasor Y and B, take readings of voltmeter and Ammeter.
5. Calculate Fault current using sequence impedance method.

**Tabular Column:-**

(a) LG Fault:-

<table>
<thead>
<tr>
<th>VRN (V)</th>
<th>VYN (V)</th>
<th>VBN (V)</th>
<th>IR (A)</th>
<th>VRY (V)</th>
<th>VYB (V)</th>
<th>VBR (V)</th>
<th>IF (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(b) LL Fault:-

<table>
<thead>
<tr>
<th>VRN (V)</th>
<th>VYN (V)</th>
<th>VBN (V)</th>
<th>IR (A)</th>
<th>VRY (V)</th>
<th>VYB (V)</th>
<th>VBR (V)</th>
<th>IF (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Calculations:-**

\[ \lambda = 1\angle 120^\circ, \lambda^2 = 1\angle 240^\circ \]

\[ I_b = I_c = 0 \text{ Amp} \]

\[
\begin{bmatrix}
V_{s0} \\
V_{s1} \\
V_{s2}
\end{bmatrix} = \frac{1}{3} \begin{bmatrix}
1 & 1 & 1 \\
1 & \lambda & \lambda^2 \\
1 & \lambda^2 & \lambda
\end{bmatrix} \begin{bmatrix}
V_a \\
V_b \\
V_c
\end{bmatrix}
\]
(i) For LG fault

\[ V_{a0} = \frac{1}{3} [V_a + V_b + V_c] = \]

\[ V_{a1} = \frac{1}{3} [V_a + V_b + \lambda V_c] = \]

\[ V_{a2} = \frac{1}{3} [V_a + \lambda^2 V_b + \lambda V_c] = \]

\[
\begin{bmatrix}
I_{a0} \\
I_{a1} \\
I_{a2}
\end{bmatrix} = \frac{1}{3}
\begin{bmatrix}
1 & 1 & 1 \\
1 & \lambda & \lambda^2 \\
1 & \lambda^2 & \lambda
\end{bmatrix}
\begin{bmatrix}
I_a \\
I_b \\
I_c
\end{bmatrix}
\]

\[ I_{a0} = I_{a1} = I_{a2} = \frac{I_a}{3} = \]

\[ Z_0 = -\frac{V_{a0}}{I_{a0}} = \]

\[ Z_1 = \frac{E_a - V_{a1}}{I_{a1}} = \]

\[ Z_2 = -\frac{V_{a2}}{I_{a2}} = \]

\[ Z_f = \frac{V_{RN}}{I_R} = \]

\[ I_{\text{fault}} = \frac{3E_a}{Z_1 + Z_2 + Z_0 + 3Z_f} = \]
(ii) For LL Fault

\[ I_a = 0 \text{ Amp}, \quad I_b + I_c = 0 \]
\[ I_c = -I_b \]
\[ V_b = V_c \]

\[
\begin{bmatrix}
I_{a0} \\
I_{a1} \\
I_{a2}
\end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & 1 & 1 \\
1 & \lambda & \lambda^2 \\
1 & \lambda^2 & \lambda
\end{bmatrix} \begin{bmatrix}
I_a \\
I_b \\
I_c
\end{bmatrix}
\]

\[ I_{a0} = 0 \]

\[ I_{a1} = \frac{1}{3} \left[ \lambda I_b - \lambda^2 I_b \right] = 0 \]

\[ I_{a2} = \frac{1}{3} \left[ \lambda^2 I_b - \lambda I_b \right] = 0 \]

\[ Z_f = 0 \]

\[ Z_1 + Z_2 = \frac{E}{I_{a1}} = \]

\[ I_{\text{fault}} = \frac{-j\sqrt{3}E}{Z_1 + Z_2} = \]

**Precautions:**

1. Avoid the loose connections.
2. Note down the readings with out parallax error.
3. Keep the field rheostat in maximum resistance position.
4. Keep the variac of the static exciter in minimum voltage output position.

**Result:**
Circuit diagram for LLG Fault:-
3. FAULT ANALYSIS – II

Aim:- To find the fault currents and fault voltages when a double line to ground (LLG) fault and Triple line to ground (LLLG) faults occurred on unloaded alternator.

Name Plate Details:-

<table>
<thead>
<tr>
<th>S.No</th>
<th>Parameter</th>
<th>Alternator</th>
<th>DC Motor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rated Voltage</td>
<td>415 V</td>
<td>220 V</td>
</tr>
<tr>
<td>2</td>
<td>Rated Current</td>
<td>4.2 A</td>
<td>20 A</td>
</tr>
<tr>
<td>3</td>
<td>Speed</td>
<td>1500 RPM</td>
<td>1500 RPM</td>
</tr>
<tr>
<td>4</td>
<td>Rating</td>
<td>3 KVA</td>
<td>5 HP</td>
</tr>
<tr>
<td>5</td>
<td>Power factor</td>
<td>0.8</td>
<td>-----</td>
</tr>
<tr>
<td>6</td>
<td>Frequency</td>
<td>50 Hz</td>
<td>-----</td>
</tr>
<tr>
<td>7</td>
<td>Excitation</td>
<td>220V 2A</td>
<td>220V 2A</td>
</tr>
</tbody>
</table>

Apparatus Required:-

<table>
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<tr>
<th>S.No</th>
<th>Apparatus</th>
<th>Type</th>
<th>Range</th>
<th>Quantity</th>
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<tbody>
<tr>
<td>1</td>
<td>Ammeter</td>
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<td></td>
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</tr>
<tr>
<td>2</td>
<td>Voltmeter</td>
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<tr>
<td>3</td>
<td>Rheostat</td>
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</tr>
<tr>
<td>4</td>
<td>Static Exciter</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Tachometer</td>
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</tr>
<tr>
<td>6</td>
<td>Connecting Wires</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Procedure:-
(a) LLG Fault:-

1. Connect the circuit as per the given circuit diagram.
2. Ensure that the filed rheostat is kept in minimum resistance position and DPST switch in off position and give the supply to DC motor and then by varying field rheostat. Let, the motor runs at rated speed.
3. By varying the static exciter across the rotor of an alternator apply the rated voltage across $V_{RN}, V_{YN}, V_{BN}$ and tabulate all readings.
4. Close the TPST switch and supply the load current and note down the readings of an voltmeter and ammeter readings.
Circuit diagram for LLLG Fault:-
(b) LLLG Fault:-

1. Connect the circuit as per the given circuit diagram.
2. Ensure that the filed rheostat is kept in minimum resistance position and DPST switch in off position and give the supply to DC motor and then by varying field rheostat. Let, the motor runs at rated speed.
3. Apply the rated voltage across each phase and note down the readings of an 3-Ø alternator and tabulate them.
4. Close the TPST switch and supply the load current and note down the readings of an voltmeter and ammeter readings.

**Tabular Column:-**

(a) LLG Fault:-

<table>
<thead>
<tr>
<th>$V_{RN}$ (V)</th>
<th>$V_{YN}$ (V)</th>
<th>$V_{BN}$ (V)</th>
<th>$I_{R}$ (A)</th>
<th>$V_{RY}$ (V)</th>
<th>$V_{YB}$ (V)</th>
<th>$V_{BR}$ (V)</th>
<th>$I_{F}$ (A)</th>
</tr>
</thead>
</table>

(b) LLLG Fault:-

| $V_{RN}$ (V) | $V_{YN}$ (V) | $V_{BN}$ (V) | $I_{R}$ (A) | $V_{RY}$ (V) | $V_{YB}$ (V) | $V_{BR}$ (V) | $I_{F}$ (A) |
Calculations:-
Precautions:-

1. Avoid the loose connections.
2. Note down the readings with out parallax error.
3. Keep the field rheostat in maximum resistance position.
4. Keep the variac of the static exciter in minimum voltage output position.

Result:-

Conclusion:-
Circuit Diagram for sub transient reactance

Fig. 4.1. Circuit diagram for determination of subtransient reactance of a salient pole synchronous machine
4. DETERMINATION OF SUBTRANSIENT REACTANCE OF A SALIENT POLE SYNCHRONOUS MACHINE

Aim:- To determine the subtransient direct axis reactance and quadrature axis reactance of a salient pole synchronous machine.

Name Plate Details:-

<table>
<thead>
<tr>
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<th>Alternator</th>
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<tbody>
<tr>
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<td>Rated Voltage</td>
<td>415 V</td>
<td>220 V</td>
</tr>
<tr>
<td>2</td>
<td>Rated Current</td>
<td>8A</td>
<td>27.2 A</td>
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<tr>
<td>3</td>
<td>Speed</td>
<td>1500 RPM</td>
<td>1500 RPM</td>
</tr>
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<td>4</td>
<td>Rating</td>
<td>5 KVA</td>
<td>5 HP</td>
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<tr>
<td>5</td>
<td>Power factor</td>
<td>0.8</td>
<td>-----</td>
</tr>
<tr>
<td>6</td>
<td>Frequency</td>
<td>50 Hz</td>
<td>-----</td>
</tr>
<tr>
<td>7</td>
<td>Excitation</td>
<td>220V 2A</td>
<td></td>
</tr>
</tbody>
</table>

Apparatus Required:-

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<tr>
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<td>1</td>
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<td></td>
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</tr>
<tr>
<td>2</td>
<td>Voltmeter</td>
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<td></td>
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<td>Wattmeter</td>
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<td>4</td>
<td>Auto Transformer</td>
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<td>5</td>
<td>Connecting Wires</td>
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</tr>
</tbody>
</table>

Procedure:-

1. Connect the circuit as per the given circuit diagram.
2. Initially the rotor is kept in standstill, then the auto transformer is varied and a nominal voltage is applied across the stator of the alternator. Thus the sufficient currents in the two series connected armature windings are passed.
3. The rotor position is adjusted with hand to get maximum deflection and minimum deflection values of armature.
4. The readings of ammeter, voltmeter and wattmeter are tabulated.
5. Calculate the $X_{d||}$ and $X_{q||}$ by using corresponding formulae’s.
**Tabular Column:-**

(i) For Maximum field current

<table>
<thead>
<tr>
<th>Field Current $I_F$ (A)</th>
<th>Max. Armature Current $I_a$ (A)</th>
<th>Excitation voltage (v)</th>
<th>Power (w)</th>
<th>Power factor $\cos\theta$</th>
<th>Subtransient impedance $Z_q$ (Ω)</th>
<th>Subtransient reactance $X_q$ (Ω)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Calculations:-

Power factor $\cos\theta_q = \frac{P}{V_{\text{min}} I_{\text{max}}}$

$\sin\theta_q = \sqrt{1 - (\cos\theta_q)^2}$

Subtransient impedance $Z_q (Ω) = \frac{V_{\text{min}}}{2I_{\text{max}}}$

Subtransient Reactance $X_q (Ω) = Z_q \sin\theta_q$

(ii) For Minimum field current

<table>
<thead>
<tr>
<th>Field Current $I_F$ (A)</th>
<th>Min. Armature Current $I_a$ (A)</th>
<th>Excitation voltage (v) Max.</th>
<th>Power (w)</th>
<th>Power factor $\cos\theta$</th>
<th>Subtransient impedance $Z_q$ (Ω)</th>
<th>Subtransient reactance $X_q$ (Ω)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Calculations:-

Power factor \( \cos \phi_d = \frac{P}{V_{max}I_{min}} \)

\( \sin \phi_d = \sqrt{1 - (\cos \phi_d)^2} \)

Subtransient impedance \( Z_d(\Omega) = \frac{V_{max}}{2I_{min}} \)

Subtransient Reactance \( X_d(\Omega) = Z_d(\Omega) \sin \phi_d \)

Precautions:-

1. Avoid the loose connections.
2. Note down the readings with out parallax error.

Result:-

Conclusion:-
Fig. 5.1. Circuit diagram for Open Circuit Test

Fig. 5.2. Circuit diagram for Short Circuit Test (For Z_{12})
5. Equivalent Circuit of a 3-Ø Three Winding Transformer

**Aim:** To determine the equivalent circuit parameters of a 3-Ø three winding transformer.

**Name Plate Details:**

<table>
<thead>
<tr>
<th>S.No</th>
<th>Parameter</th>
<th>Primary</th>
<th>Secondary</th>
<th>Tertiary</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rated Voltage</td>
<td>400 V</td>
<td>200 V</td>
<td>80 V</td>
</tr>
<tr>
<td>2</td>
<td>Rated Current</td>
<td>1.83A</td>
<td>3.6 A</td>
<td>9.1 A</td>
</tr>
<tr>
<td>3</td>
<td>Rated Power</td>
<td>2.2 KVA</td>
<td>2.2 KVA</td>
<td>2.2 KVA</td>
</tr>
<tr>
<td>4</td>
<td>Phase</td>
<td>3-Ø</td>
<td>3-Ø</td>
<td>3-Ø</td>
</tr>
</tbody>
</table>

**Apparatus Required:**

<table>
<thead>
<tr>
<th>S.No</th>
<th>Apparatus</th>
<th>Type</th>
<th>Range</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ammeter</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Voltmeter</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Wattmeter</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Auto Transformer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>3-Ø, 3 Winding Transformer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Connecting Wires</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Procedure:**

(i) Open circuit test:

1. Connect the circuit as per the given circuit diagram.
2. The auto transformer is kept in zero output voltage position.
3. Varying the auto transformer of variable knob and the rated voltage is applied across the low voltage winding of 3-Ø transformer.
4. The values of no-load current, no-load voltage and input power are noted.
5. The auto transformer is brought to zero output voltage position and the DPST switch is opened to disconnect the circuit.
Fig. 5.3. Circuit diagram for Short Circuit Test (For $Z_{13}$)

Fig. 5.4. Circuit diagram for Short Circuit Test (For $Z_{23}$)
(ii) Short circuit test:
1. Connect the circuit as per the given circuit diagram.
2. The auto transformer is kept in zero output voltage position.
3. Varying the auto transformer of variable knob and allow the rated currents through the HV winding of 3-Ø transformer.
4. Note down the values of Short circuit voltage and input power.
5. The auto transformer is brought to zero output voltage position and the DPST switch is opened to disconnect the circuit.

**Tabular Column:-**

(i) Open circuit test:-

<table>
<thead>
<tr>
<th>No-load voltage (V)</th>
<th>No-load current (A)</th>
<th>Power $W_0$ (w)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(ii) Short circuit test:-

<table>
<thead>
<tr>
<th>For $Z_{12}$</th>
<th>Short circuit current $I_{sc}$ (A)</th>
<th>Short Circuit Voltage $V_{sc}$ (V)</th>
<th>Input Power $W_{sc}$ (w)</th>
</tr>
</thead>
<tbody>
<tr>
<td>For $Z_{13}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>For $Z_{23}$</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Calculations:-

\[ Z_{12} = \frac{V_{sc}}{I_{sc}}, \quad Z_{13} = \frac{V_{sc}}{I_{sc}}, \quad Z_{23} = \frac{V_{sc}}{I_{sc}} \]

\[ Z_1 = \frac{1}{2}[Z_{12} + Z_{13} - Z_{23}] \]
\[ Z_2 = \frac{1}{2}[Z_{23} + Z_{12} - Z_{13}] \]
\[ Z_3 = \frac{1}{2}[Z_{23} + Z_{13} - Z_{12}] \]

Precautions:-

1. Avoid the loose connections.
2. Note down the readings with out parallax error.
3. Initially the auto transformer is kept in zero output voltage position.
4. Only one phase of the transformer is used to conduct the experiment.

Result:-

Conclusion:-
6. GAUSS-SEIDEL LOAD FLOW ANALYSIS USING MATLAB

**Aim:-** To solve power flow problems by the method of Gauss-Seidel using MATLAB.

**Apparatus Required:-**

<table>
<thead>
<tr>
<th>S.No</th>
<th>Apparatus</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Personal Computer</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Keyboard</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Mouse</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>MATLAB Software</td>
<td>1</td>
</tr>
</tbody>
</table>

**Procedure:-**
1. Turn on your personal computer.
2. Click on the MATLAB icon of your personal computer.
3. Click the file button and select the new Blank M-file.
4. Type the program on the new M-file for corresponding bus system.
5. After completion of the program, save and run.
6. Note down the line flow and losses.
7. Close the MATLAB tool and turnoff your pc.
PROBLEM ON LOAD FLOW STUDIES:

For a sample power system which contains four buses, obtain the load flow analysis using Gauss Siedal method. Treat base MVA of the system as 100MVA and the acceleration factor as 1.6.

Bus data of the system is as follows.

<table>
<thead>
<tr>
<th>Bus Number</th>
<th>P₀ (MW)</th>
<th>Q₀ (MVAr)</th>
<th>V∟α</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>---</td>
<td>---</td>
<td>1.04∟0</td>
<td>Slack Bus</td>
</tr>
<tr>
<td>2</td>
<td>50</td>
<td>-20</td>
<td>---</td>
<td>PQ Bus</td>
</tr>
<tr>
<td>3</td>
<td>-100</td>
<td>50</td>
<td>---</td>
<td>PQ Bus</td>
</tr>
<tr>
<td>4</td>
<td>30</td>
<td>-10</td>
<td>---</td>
<td>PQ Bus</td>
</tr>
</tbody>
</table>

Line data of the system is as follows.

<table>
<thead>
<tr>
<th>Sending end</th>
<th>Receiving end</th>
<th>Reactance values in ohms</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>0.05+j0.15</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>0.10+j0.30</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>0.05+j0.15</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>0.10+j0.30</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>0.15+j0.45</td>
</tr>
</tbody>
</table>

PROGRAM ON LOAD FLOW STUDIES:

```matlab
clc;
clear all;
basemva= 100;
acceleration=1.6;
accuracy=0.00001;
maxiter=50;
busdata=[1 1 1.04 0 0 0 0 0 0 0 0 0; 2 0 1 0 50 -20 0 0 0 0 0; 3 0 1 0 -100 50 0 0 0 0 0];
```
% IEEE BUS TEST SYSTEM
% BUS BUS VOLTAGE ANGLE ---Load---     -------Geneartor-------  static Mvar
% No  Code  Mag.  Degree  MW  Mvar  MW Mvar Qmin Qmax  +Qc/-Ql
Busdata=[
    4  0  1  0  30  -10  0  0  0  0];

load

% No   Code  Mag.  Degree  MW  Mvar  MW Mvar Qmin Qmax +Qc/-Ql
% 0     30     0     0     0     0     0     0     0     0
% 0     0     0     0     0     0     0     0     0     0

load

lineflow

commands used in the program:

busdata matrix consists of 11 columns in which

1st column represents bus number

2nd column represents bus code i.e., 1 for slack bus, 2 for PV bus and 3 for PQ bus

3rd column represents voltage magnitude

4th column represents voltage angle

5th column represents real power demand in MW

6th column represents reactive power demand in MVAr

7th column represents real power generation in MW

8th column represents reactive power generation in MVAr

9th column represents minimum limit of reactive power in MVAr

10th column represents maximum limit of reactive power in MVAr

lineflow
11\textsuperscript{th} column represents reactive power injection in MVAr

\textit{linnedata} matrix consists of six columns in which

1\textsuperscript{st} column represent sending end

2\textsuperscript{nd} column represents receiving end

3\textsuperscript{rd} column represents resistance between the sending and receiving end in ohms

4\textsuperscript{th} column represents reactance between the sending and receiving end in ohms

5\textsuperscript{th} column represents half of the susceptance in mhos

6\textsuperscript{th} column represents the line or transformer tap setting i.e., 1 for line and tap setting value for transformer

\textbf{Ifybus} is the command used to calculate admittance matrix

\textbf{Ifgauss} is the command which gives power flow solution using Gauss Siedal method

\textbf{Busout} is the command used to print the complete information about the buses

\textbf{Lineflow} is the command used to print the line flow and line losses

\textbf{Calculations:-}
Precautions:-
1. Check and write the program without errors.
2. Properly turn on and turn off your pc

Result:-

Conclusion:-
7. FAST DECOUPLED LOAD FLOW ANALYSIS USING MATLAB

**Aim:** To solve power flow problems by the method of fast decoupled using MATLAB.

**Apparatus Required:**

<table>
<thead>
<tr>
<th>S.No</th>
<th>Apparatus</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Personal Computer</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Keyboard</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Mouse</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>MATLAB Software</td>
<td>1</td>
</tr>
</tbody>
</table>

**Procedure:**

1. Turn on your personal computer.
2. Click on the MATLAB icon of your personal computer.
3. Click the file button and select the new Blank M-file.
4. Type the program on the new M-file for corresponding bus system.
5. After completion of the program, save and run.
6. Note down the line flow and losses.
7. Close the MATLAB tool and turn off your pc.
Program:-

Clear
basemva=100;
accuracy=0.001;
accel=1.8;
maxiter=100;

busdata=[1 1 1.04 0 0 0 0 0 0 0 0;
         2 0 1 0 50 -20 0 0 0 0 0;
         3 0 1 0 100 50 0 0 0 0 0;
         4 0 1 0 30 -10 0 0 0 0 0];

% IEEE BUS TEST SYSTEM
% BUS BUS VOLTAGE ANGLE ---Load--- ------Genearator-------- static Mvar
% No Code Mag. Degree MW Mvar MW Mvar Qmin Qmax +Qc/-Ql
Busdata=[

linedata=[1 2 0.05 0.15 0 1;
         1 3 0.1 0.3 0 1;
         2 3 0.15 0.45 0 1;
         2 4 0.1 0.3 0 1;
         3 4 0.05 0.15 0 1];

% Line code
% Bus Bus R X ½ B =1 for lines
% nl nr p.u. p.u. p.u. >1 or <1 tr.tap at bus nl
Linedata=[

lfybus % form the bus admittance matrix
decouple % Load flow solution by fast decoupled method
busout % Prints the power flow solution on the screen
lineflow % Computes and displays the line flow and losses
Calculations:-

Precautions:-
1. Check and write the program without errors.
2. Properly turn on and turn off your pc

Result:-
8. **Y bus FORMATION USING MATLAB**

**AIM:** To obtain the $Z_{bus}$ matrix for the given power system using $Z_{bus}$ building algorithm and to verify the same using MATLAB.

**APPARATUS REQUIRED:** Personal Computer with MATLAB software.

**PROBLEM ON FORMATION OF $Z_{bus}:**

Find the bus impedance matrix using $Z_{bus}$ building algorithm for the given power system whose reactance values are as follows.

<table>
<thead>
<tr>
<th>Sending end</th>
<th>Receiving end</th>
<th>Reactance values in ohms</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>j1.0</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>j0.25</td>
</tr>
<tr>
<td>0</td>
<td>2</td>
<td>j1.25</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>j0.05</td>
</tr>
<tr>
<td>0</td>
<td>3</td>
<td>j1.50</td>
</tr>
</tbody>
</table>

**PROGRAM FOR FORMATION OF $Z_{BUS}$ USING THE GIVEN DATA:**

```matlab
linedata=[0 1 0 1.0; 1 2 0 0.25; 0 2 0 1.25; 2 3 0 0.05; 0 3 0 1.5];
ZBUS=zbuild(linedata)
```
COMMANDS USED IN THE PROGRAM:

*zbuild* is the command used to obtain the impedance matrix for the given system data using Zbus building algorithm.

linedata matrix consists of four columns in which

1\textsuperscript{st} column represent sending end
2\textsuperscript{nd} column represents receiving end
3\textsuperscript{rd} column represents resistance between the sending and receiving end in ohms
4\textsuperscript{th} column represents reactance between the sending and receiving end in ohms

Result:
AIM: To obtain the $Y_{bus}$ matrix for the given power system using Direct inspection method and to verify the same using MATLAB.

APPARATUS REQUIRED: Personal Computer with MATLAB software.

PROBLEM ON FORMATION OF $Y_{bus}$:
Find the $Y_{bus}$ matrix for the given power system data using Direct inspection method

<table>
<thead>
<tr>
<th>Sending end</th>
<th>Receiving end</th>
<th>Reactance values in ohms</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>$j0.15$</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>$j0.10$</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>$j0.20$</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>$j0.10$</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>$j0.15$</td>
</tr>
</tbody>
</table>

PROGRAM FOR YBUS FORMATION USING THE GIVEN DATA:

```matlab
zdata=[1 2 0 0.15; 1 3 0 0.2; 1 4 0 0.1; 2 3 0 0.1; 3 4 0 0.15];
YBUS=Ybus(zdata)
```
OUTPUT:

COMMANDS USED IN THE PROGRAM:

`ybus` is the command used to obtain the admittance matrix for the given system data using direct inspection method.

`zdata` matrix consists of four columns in which

1\textsuperscript{st} column represents sending end
2\textsuperscript{nd} column represents receiving end
3\textsuperscript{rd} column represents resistance between the sending and receiving end
4\textsuperscript{th} column represents reactance between the sending and receiving end

**Result:**
10. DEVELOP A SIMULINK MODEL FOR A SINGLE AREA LOAD FREQUENCY CONTROL PROBLEM

**Aim:** Develop a Simulink model for a single area load frequency problem and Simulate the same by using MATLAB.

**Apparatus Required:**

<table>
<thead>
<tr>
<th>S.No</th>
<th>Apparatus</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Personal Computer</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Keyboard</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Mouse</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>MATLAB Software</td>
<td>1</td>
</tr>
</tbody>
</table>

**Procedure:**

1. Turn on your personal computer.
2. Click on the MATLAB icon of your personal computer.
3. Click the Simulink button and select the new model file.
4. Connect the blocks as shown in fig 9.1 and fig 9.3.
5. After completion of the process, save and simulate.
6. Observe and draw the graph of frequency deviation step response.
7. Close the MATLAB tool and turnoff your pc.
Simulation Diagram

Fig.10.1: Simulink model for a single area power system without controller

Fig.10.2: Simulink model for a single area power system with controller
Model Graphs:

Fig.10.3: Frequency deviation step response without controller

Fig.10.4: Frequency deviation step response with controller
Precautions:-

1. Connect the blocks properly.
2. Properly turn on and turn off your pc

Result:-

Conclusion:-
11. NEWTON RAPHSON METHOD OF LOAD FLOW ANALYSIS USING MATLAB

AIM: To obtain load flow studies using Newton Raphson method for the given power system data and to verify the same using MATLAB.

APPARATUS REQUIRED: Personal Computer with MATLAB Software.

PROBLEM ON LOAD FLOW STUDIES:

For a sample power system which contains four buses, obtain the load flow analysis using Newton Raphson method. Treat base MVA of the system as 100MVA and the acceleration factor as 1.6.

Bus data of the system is as follows.

<table>
<thead>
<tr>
<th>Bus Number</th>
<th>P_G (MW)</th>
<th>Q_G (MVAr)</th>
<th>P_D (MW)</th>
<th>Q_D (MVAr)</th>
<th>V∠α</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>1.025∠0</td>
<td>Slack Bus</td>
</tr>
<tr>
<td>2</td>
<td>---</td>
<td>---</td>
<td>400</td>
<td>200</td>
<td>1.0∠0</td>
<td>PQ Bus</td>
</tr>
<tr>
<td>3</td>
<td>300</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>1.03∠0</td>
<td>PV Bus</td>
</tr>
</tbody>
</table>

Line data of the system is as follows.

<table>
<thead>
<tr>
<th>Sending end</th>
<th>Receiving end</th>
<th>Reactance values in ohms</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>j0.025</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>j0.05</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>j0.025</td>
</tr>
</tbody>
</table>
PROGRAM ON LOAD FLOW STUDIES:
clc;
clear all;
busdata=[1 1 1.025 0 0 0 0 0 0 0 0;
        2 0 1 0 400 200 0 0 0 0 0;
        3 2 1.03 0 0 0 300 0 0 0 0];
linedata=[1 2 0 0.025 0 1;
        3 2 0 0.025 0 1;
        1 3 0 0.05 0 1];
basemva=100;
accel=1.6;
maxiter=50;
accuracy=0.000001;
lfybus
lfnewton
busout
lineflow

COMMANDS USED IN THE PROGRAM:
busdata matrix consists of 11 columns in which
1st column represents bus number
2nd column represents bus code i.e., 1 for slack bus, 2 for PV bus and 3 for PQ bus
3rd column represents voltage magnitude
4th column represents voltage angle
5th column represents real power demand in MW
6th column represents reactive power demand in MVAr
7th column represents real power generation in MW
8th column represents reactive power generation in MVAr
9th column represents minimum limit of reactive power in MVAr
10th column represents maximum limit of reactive power in MVAr
11th column represents reactive power injection in MVAr
linedata matrix consists of six columns in which
1st column represent sending end
2nd column represents receiving end
3rd column represents resistance between the sending and receiving end in ohms
4th column represents reactance between the sending and receiving end in ohms
5th column represents half of the susceptance in mhos
6th column represents the line or transformer tap setting i.e., 1 for line and tap setting value for transformer

Ifybus is the command used to calculate admittance matrix
Ifnewton is the command which gives power flow solution using Newton Raphson method
busout is the command used to print the complete information about the buses
lineflow is the command used to print the line flow and line losses

Result:
12. SHORT CIRCUIT ANALYSIS FOR LINE TO GROUND FAULT AND LINE TO LINE FAULT USING MATLAB

AIM: To obtain the short circuit analysis for line to ground fault and line to line fault in the given power system and to verify the same using MATLAB.

APPARATUS REQUIRED: Personal Computer with MATLAB Software.

PROBLEM ON SHORT CIRCUIT ANALYSIS:

The reactance data for the power system in p.u is given in the table below on a common base as follows.

<table>
<thead>
<tr>
<th>Item</th>
<th>Positive sequence reactance</th>
<th>Negative sequence reactance</th>
<th>Zero sequence reactance</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1</td>
<td>0.20</td>
<td>0.20</td>
<td>0.05</td>
</tr>
<tr>
<td>G2</td>
<td>0.10</td>
<td>0.10</td>
<td>0.25</td>
</tr>
<tr>
<td>T1</td>
<td>0.30</td>
<td>0.30</td>
<td>0.25</td>
</tr>
<tr>
<td>T2</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>L12</td>
<td>0.30</td>
<td>0.30</td>
<td>0.15</td>
</tr>
</tbody>
</table>

Obtain Positive, Negative and Zero sequence bus impedance matrices and compute the fault current for the fault location at bus 1 in p.u for the following type of faults

a) Bolted single line to ground fault at bus 1
b) A bolted line to line fault

PROGRAM FOR SHORT CIRCUIT STUDIES:

```matlab
zdata1=[0  3  0  0.2;
       3  1  0  0.3;
       1  2  0  0.3;
       2  4  0  0.25;
       4  0  0  0.1];
zdata2=zdata1;
zdata0=[0  1  0  0.25;
       1  2  0  0.15;
       2  0  0  0.25;
       0  3  0  0.05;
       0  4  0  0.25;
       3  1  inf  inf;
       2  4  inf  inf];
zbus1=zbuild(zdata1)
```
zbus0=zbuild(zdata0)
zbus2=zbus1
lgfault(zdata0,zbus0,zdata1,zbus1,zdata2,zbus2)
llfault(zdata1,zbus1,zdata2,zbus2)

**COMMANDS USED IN THE PROGRAM:**

zdata0, zdata1 and zdata2 represents Zero sequence, Positive sequence and Negative sequence matrices which consists of four columns in which

1\textsuperscript{st} column represent sending end

2\textsuperscript{nd} column represents receiving end

3\textsuperscript{rd} column represents resistance between the sending and receiving end

4\textsuperscript{th} column represents reactance between the sending and receiving end

\textit{zbuild} is the command used to obtain the impedance matrix for the given system data using Zbus building algorithm.

\textit{lgfault} is the command used to calculate the total fault current of Line to ground fault

\textit{llfault} is the command used to calculate the total fault current of Line to line fault

\textbf{Result:}