# EE4170

# Power Systems and Renewable Energy Laboratory

INDIAN INSTITUTE OF TECHNOLOGY PALAKKAD

# Post Lab Report

Experiment 3 :

## Fault Analysis with Different Transformer Configurations


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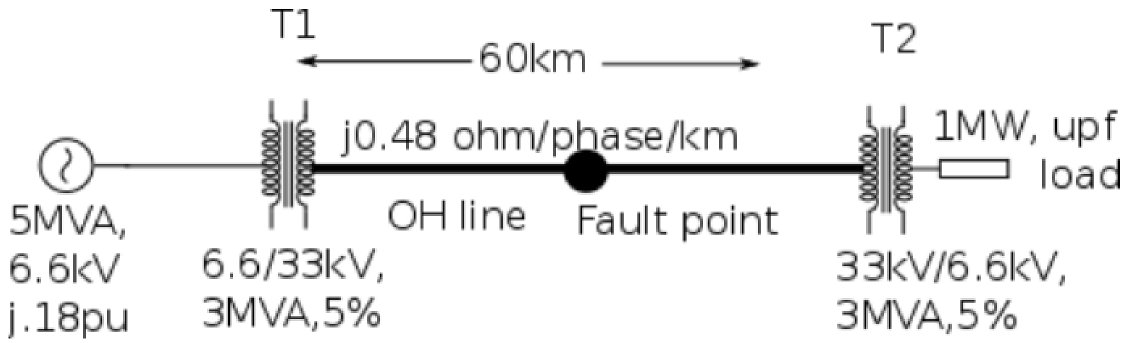
# 1 Question 1

A power system network is shown in fig. A single line to ground fault is occurred at a distance xx+10 km from transformer T1. (Where xx is sum of your roll number digits). Do a simulation study in Matlab Simulink powersystems tool, and obtain the fault current and post fault phase to neutral voltages with proper explanation. (Take 50 Hz as operating frequency).




## A) Generator is Ungrounded

1. T1 and T2 are star connected on both sides and ungrounded.
2. T1 and T2 are delta connected on both sides.
3. T1 and T2 are delta connected on the low voltage side and star connected with ungrounded neutral on the high voltage side.
4. T1 and T2 are delta connected on the low voltage side and star connected with grounded neutral on the high voltage side.
5. T1 and T2 are star connected on both sides and grounded.

## B) Generator is Grounded

1. T1 and T2 are star connected on both sides and ungrounded.
2. T1 and T2 are delta connected on both sides.
3. T1 and T2 are delta connected on the low voltage side and star connected with ungrounded neutral on the high voltage side.
4. T1 and T2 are delta connected on the low voltage side and star connected with grounded neutral on the high voltage side.
5. T1 and T2 are star connected on both sides and grounded.

## Calculations :

The fault occurs at a distance of $12 + 10 = 22\,\text{km}$ from T1 (where 12 is our group number). The distance after the fault is thus, $60 - 22 = 38\,\text{km}$.

- The Base Power is chosen as, $S_{b3\phi} = 5\,\text{MVA}$
- The Base line-to-line voltage, $V_{bLL} = 6.6\,\text{kV}$
- The Base current is: $I_b = 437.4\,\text{A}$
- The Base impedance is thus:

$$Z_b = \frac{V_{bLL}^2}{S_{b3\phi}} = 8.712\,\Omega$$

- For the transformer, we can calculate the new base value using Base-impedance transformation so that the transformer base power value is the same as the generator's MVA:

$$Z_{pu_{new}} = Z_{pu_{old}} \times \left(\frac{V_{b_{old}}}{V_{b_{new}}}\right)^2 \times \left(\frac{S_{b_{new}}}{S_{b_{old}}}\right)$$

$$Z_{pu_{new}} = 0.05 \times 1 \times \frac{5}{3} = 0.0833\,pu$$

- The transformer base impedance referred to the LV side is:

$$Z_{bLV} = \frac{(6.6)^2}{5} = 8.712\,\Omega$$

- Thus, the transformer impedance referred to the LV side can be calculated as:

$$Z_{bLV} \times Z_{pu_{new}} \Rightarrow Z_{tr_{LV}} = 0.0833 \times 8.712 = 0.7257\,\Omega$$

- The impedance of the transmission line is: $60 \times 0.48 = 28.8\,\Omega$.

  Transforming this impedance to the LV side gives:

$$Z_{transmission} = 28.8 \times \left(\frac{6.6}{33}\right)^2 = 1.152\,\Omega$$

  Here, $\left(\frac{6.6}{33}\right)$ is the turns ratio of the transformer (T1).

- The load impedance referred to the LV side is:

$$Z_{load} = \frac{V_{LL}^2}{P_{real}} = \frac{(6.6 \times 10^3)^2}{10^6} = 43.56\,\Omega$$

## 2 Simulink Model

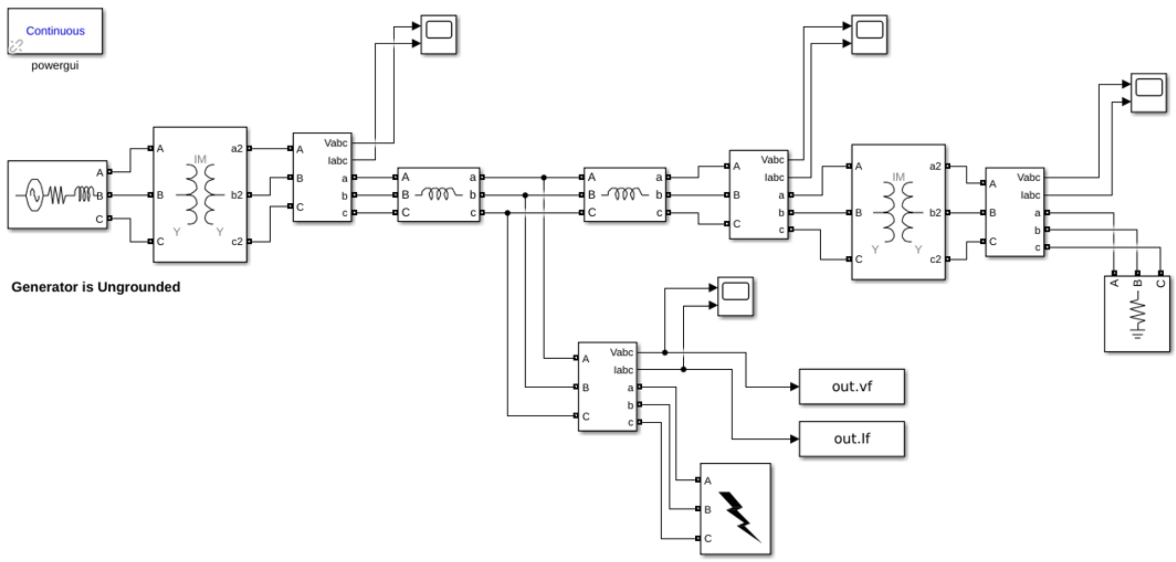



Figure 1: The required simulink model

The code associated with the Simulink model is shown below:

Listing 1: Simulink Model Code

```
Time = out.vfault.Time;
v = out.vfault.Data;
i = out.ifault.Data;

figure();
plot(Time, v, 'LineWidth', 2);
title('The Three Phase Voltage at The Fault Point');
xlabel('Time (s) \rightarrow');
ylabel('Voltage (V) \rightarrow');
grid on;
grid minor;

figure();
plot(Time, i, 'LineWidth', 2);
title('The Three Phase Current at The Fault Point');
xlabel('Time (s) \rightarrow');
ylabel('Current (A) \rightarrow');
grid on;
grid minor;
```

# 3 Sequence Networks

## 3.1 Positive and negative sequence

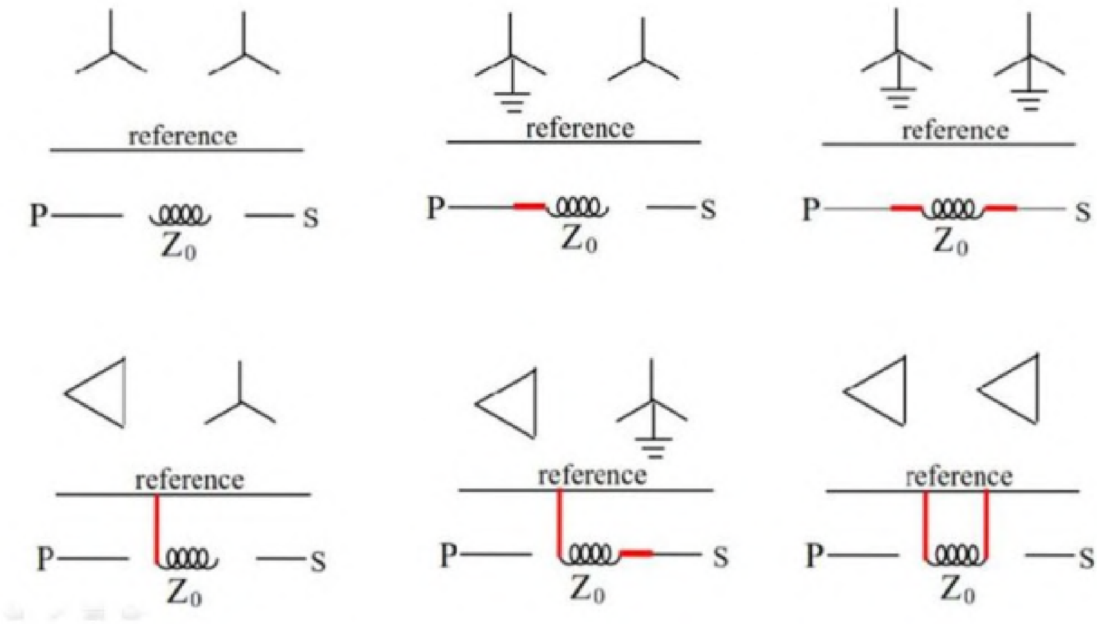



Figure 2: The three phase voltage and current at the fault point

The positive and the negative sequence are going to remain same for all the cases. Only zero sequence network changes according to different transformer configuration. From figure 1 we infer the system's zero sequence network

## 3.2 Zero sequence

### 3.2.1 Case-A (Ungrounded Generator)

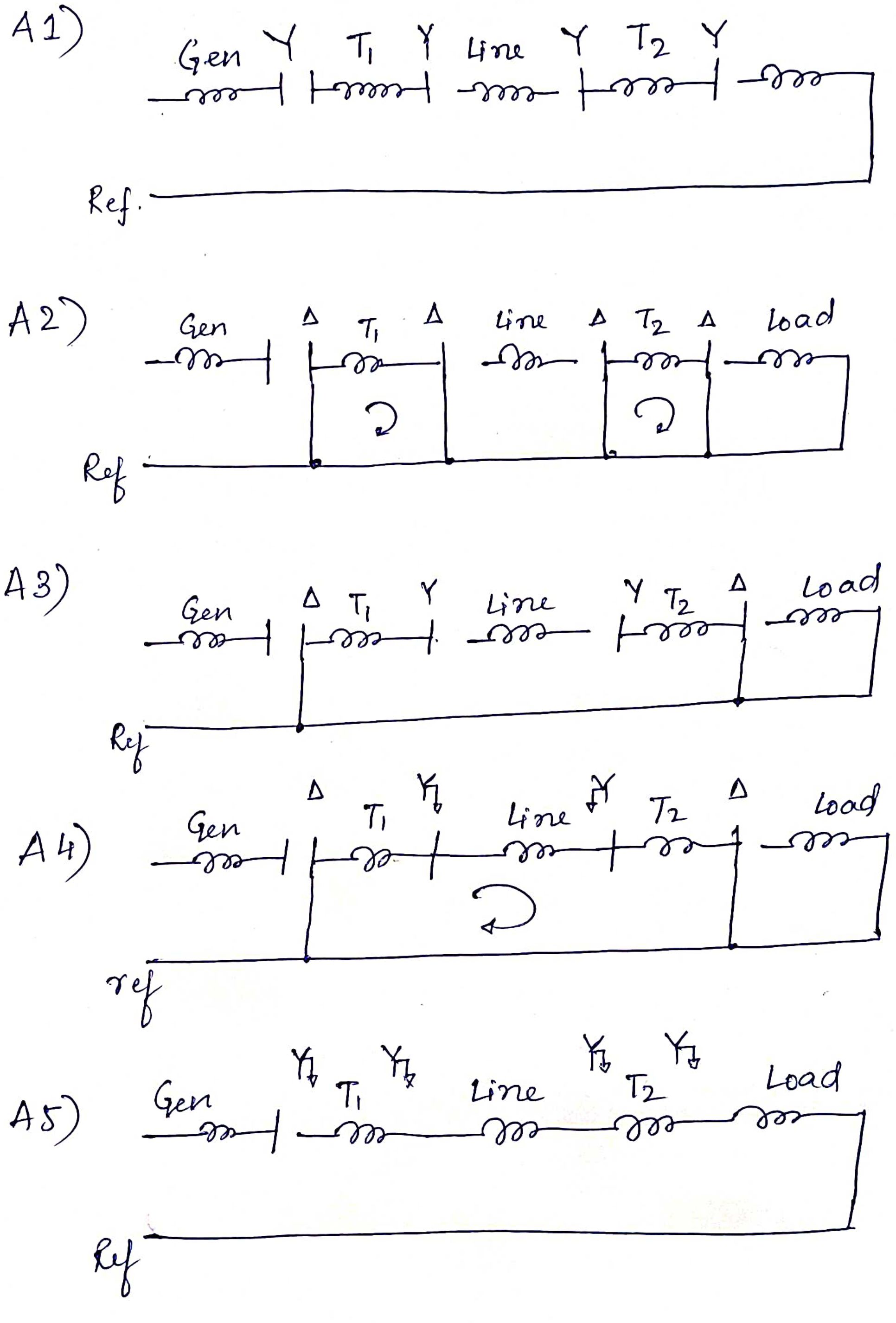



Figure 3: The three phase voltage and current at the fault point

### 3.2.2 Case-B (Grounded Generator)

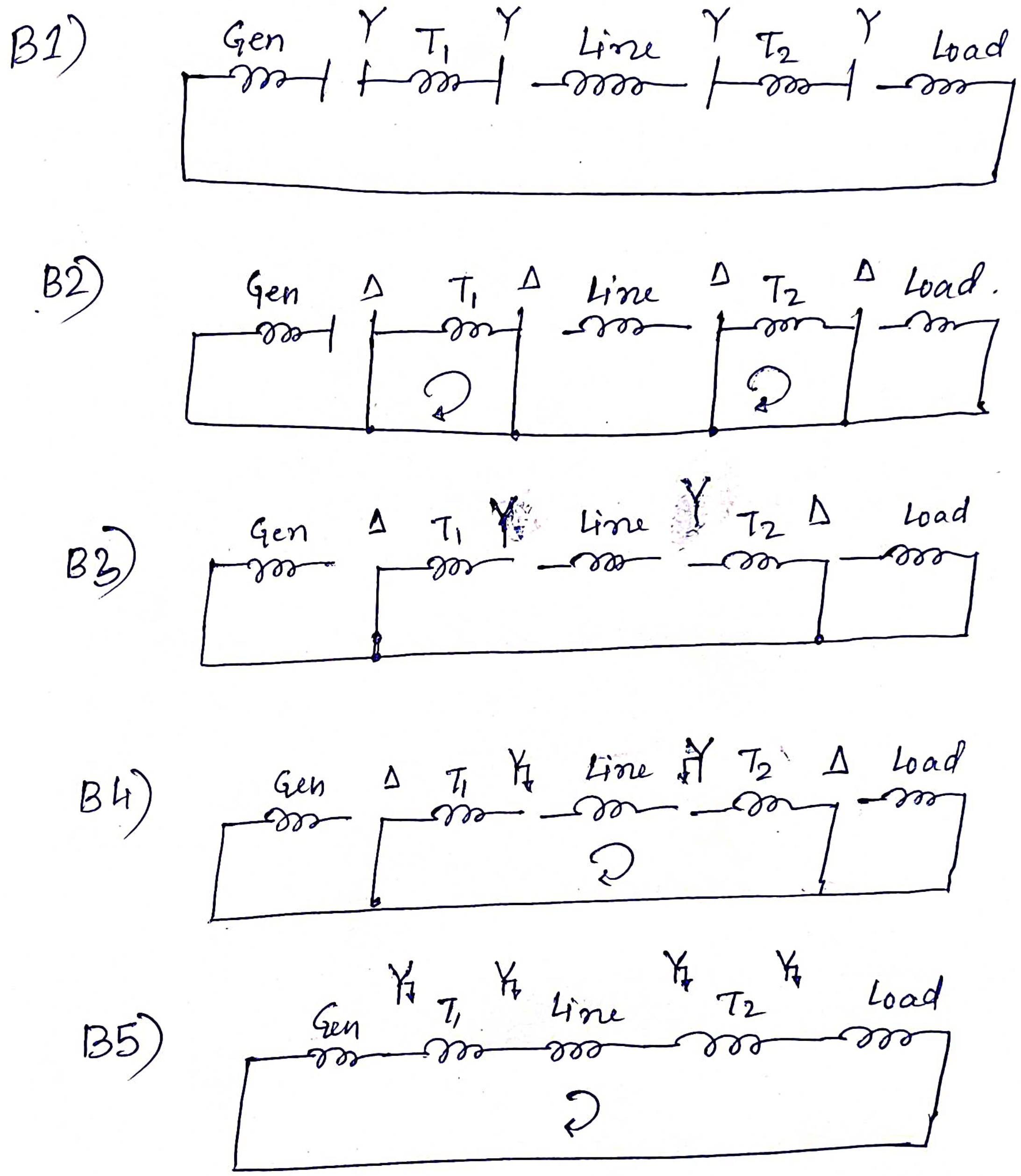



Figure 4: The three phase voltage and current at the fault point

# 4 The Fault Point Voltages and Currents (3 Phase)

## 4.1 Part A - 1

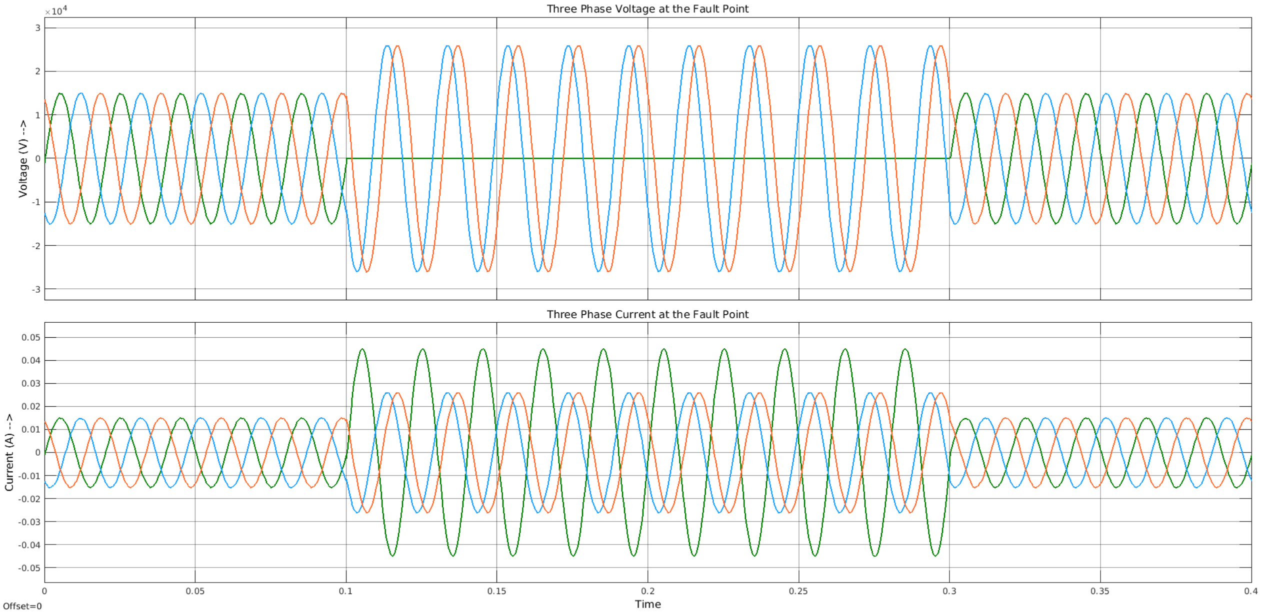



Figure 5: The three phase voltage and current at the fault point

## 4.2 Part A - 2

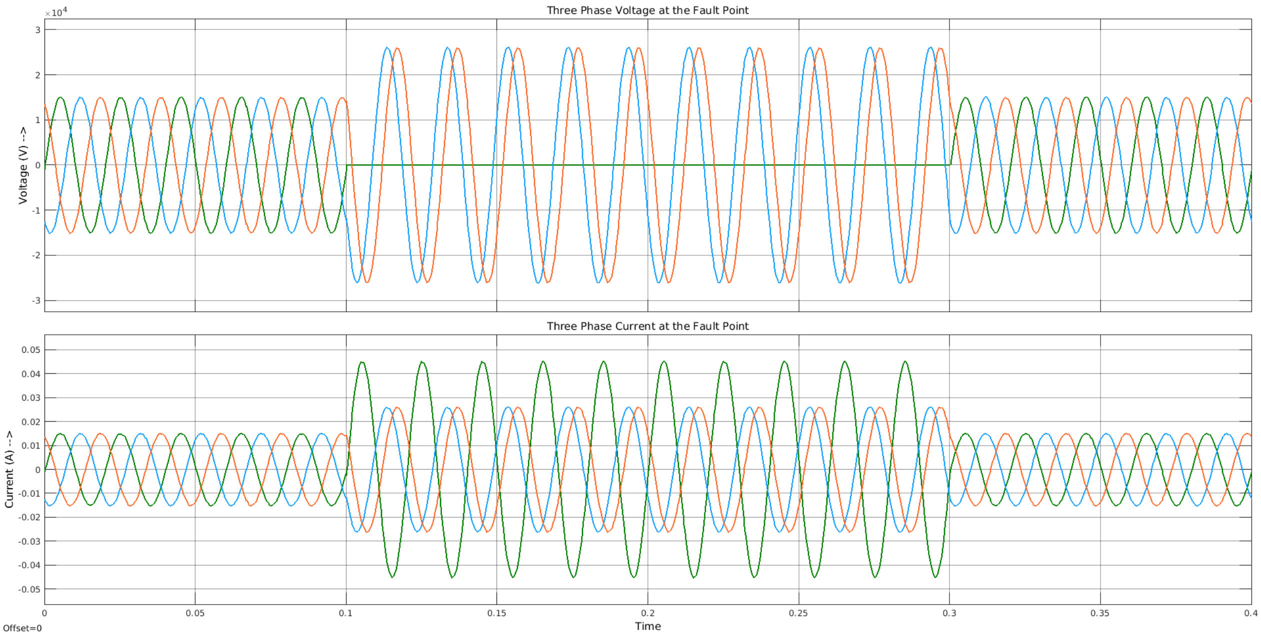



Figure 6: The three phase voltage and current at the fault point

## 4.3 Part A - 3

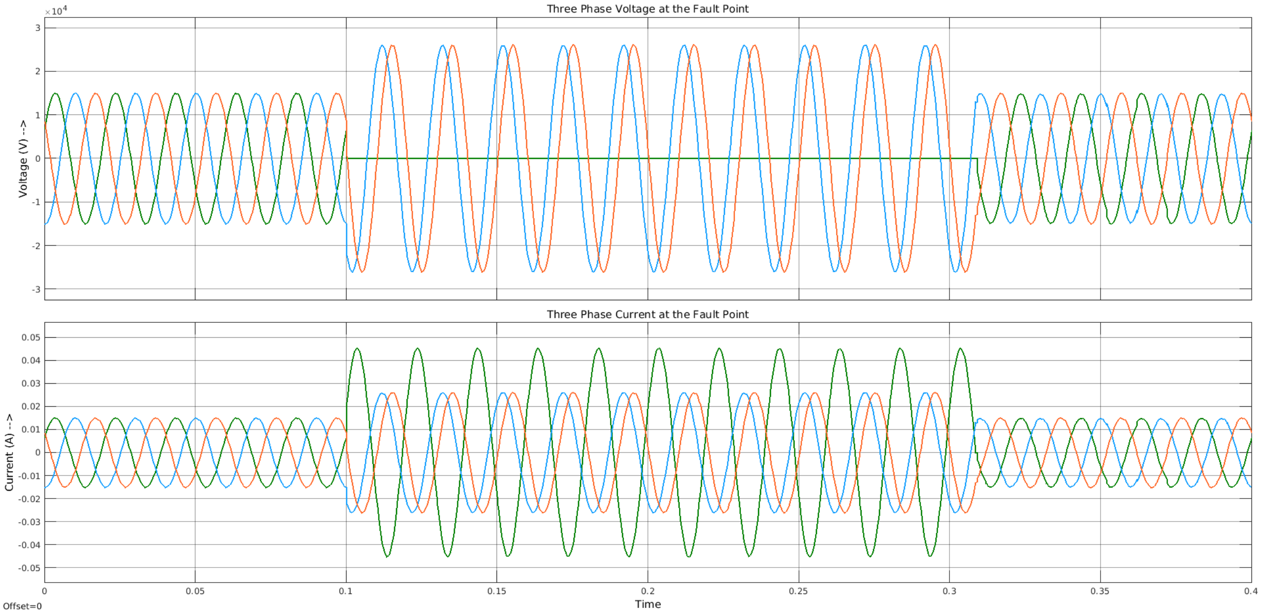



Figure 7: The three phase voltage and current at the fault point

## 4.4 Part A - 4

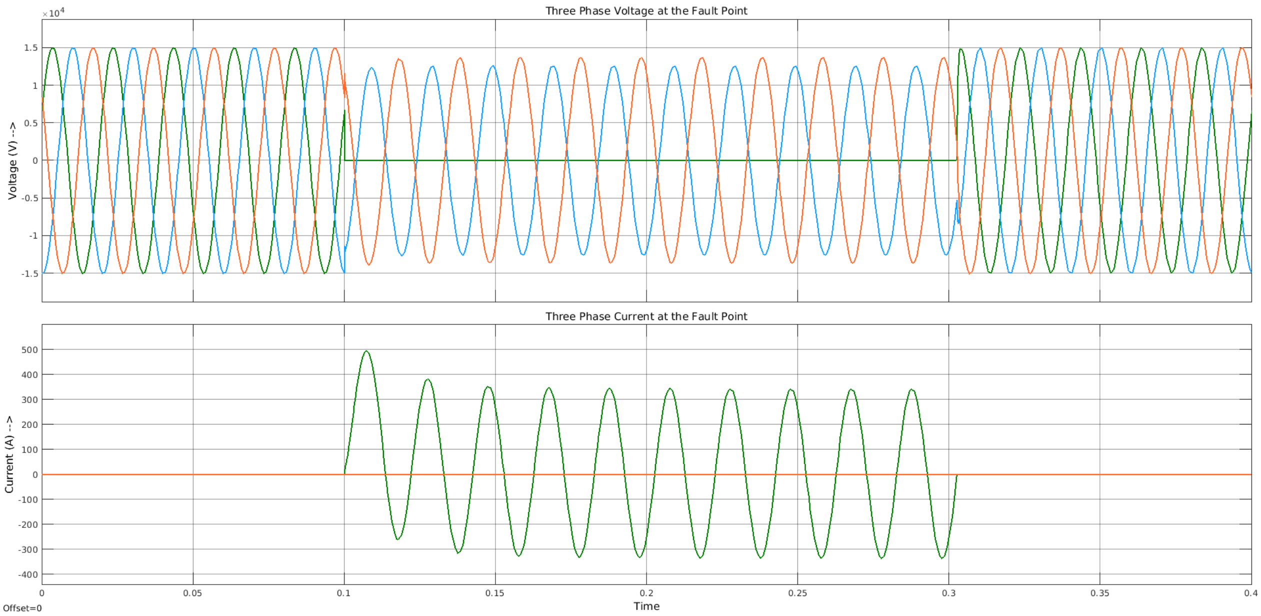



Figure 8: The three phase voltage and current at the fault point

## 4.5 Part A - 5

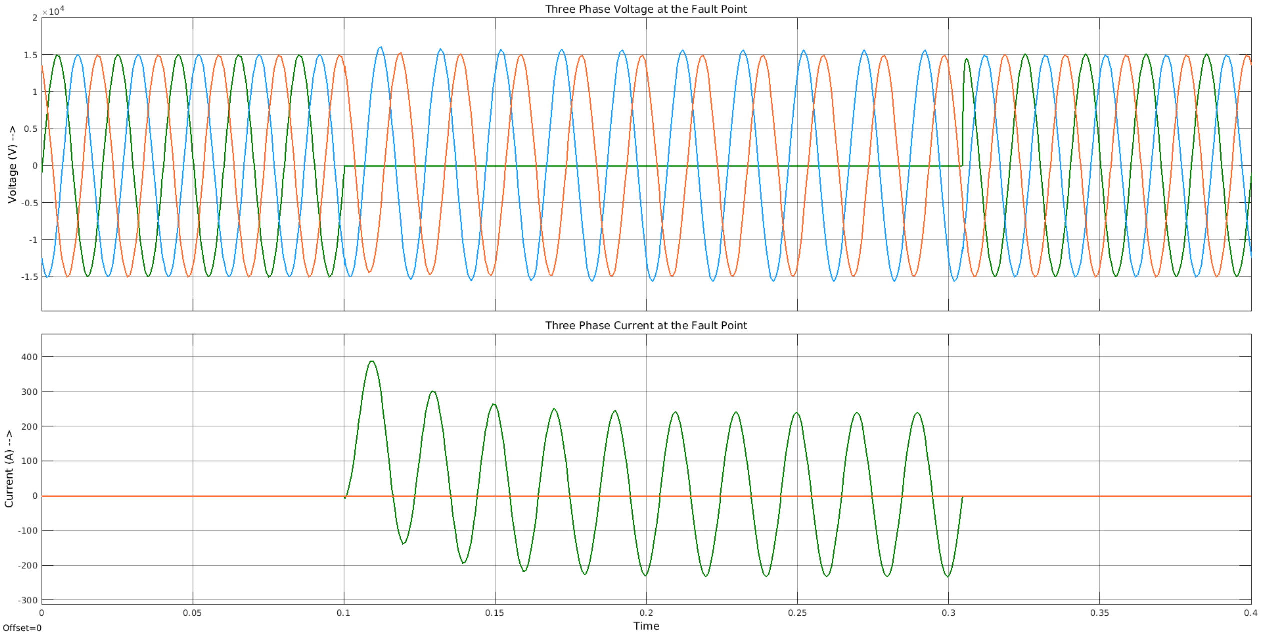



Figure 9: The three phase voltage and current at the fault point

## 4.6 Part B - 1

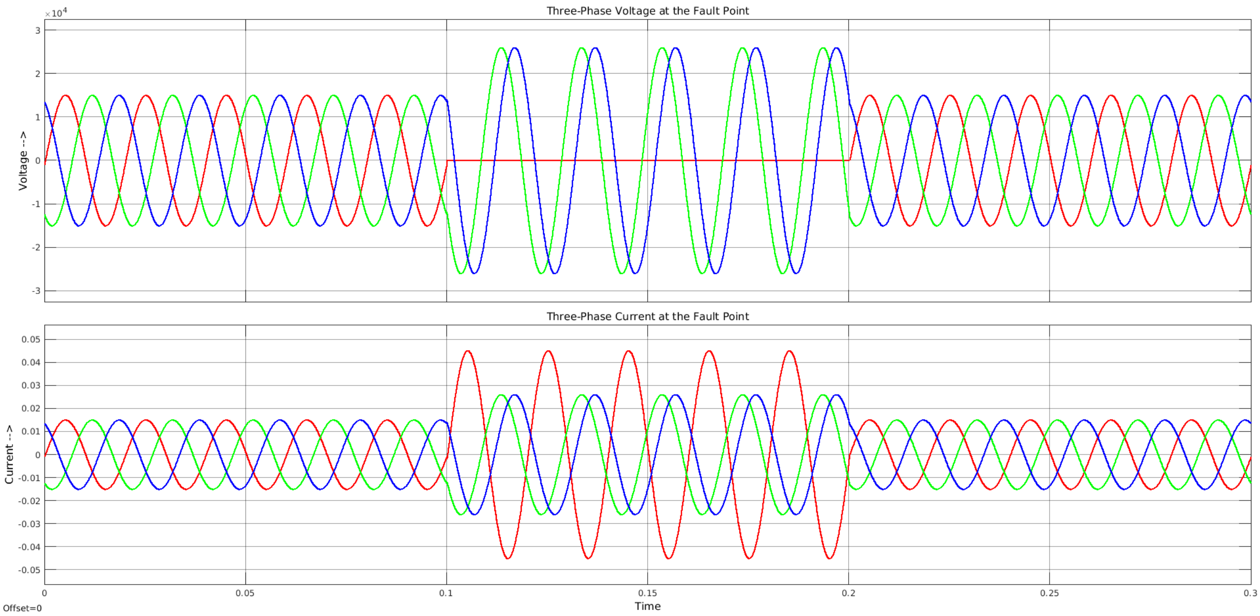



Figure 10: The three phase voltage and current at the fault point

## 4.7 Part B - 2

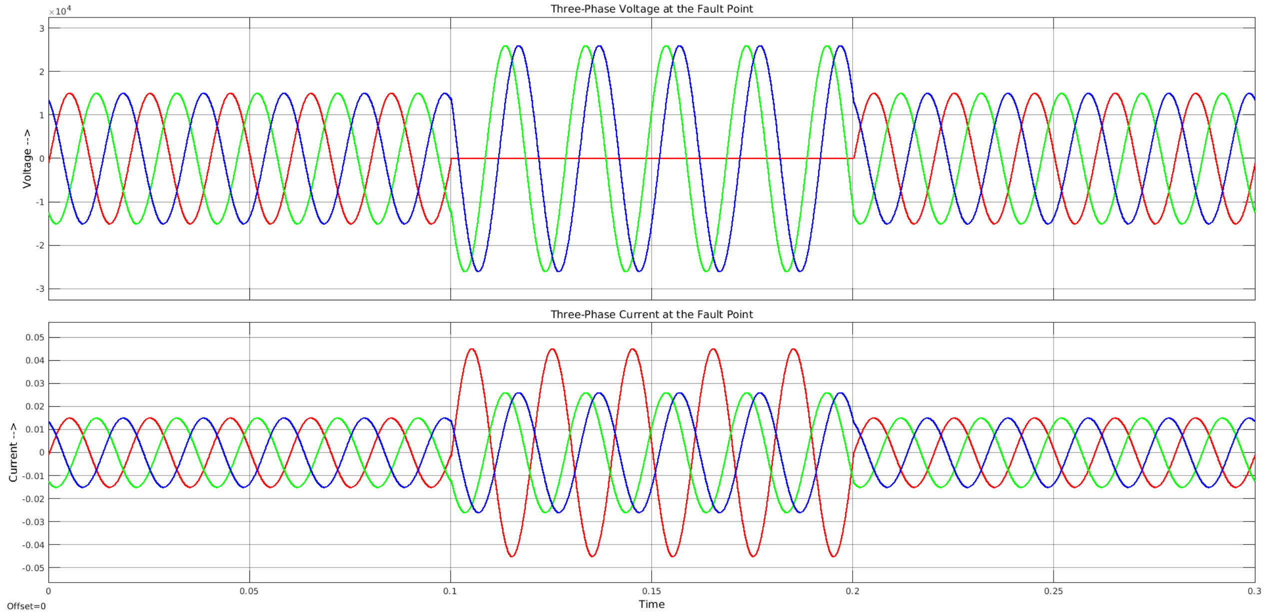



Figure 11: The three phase voltage and current at the fault point

## 4.8 Part B - 3

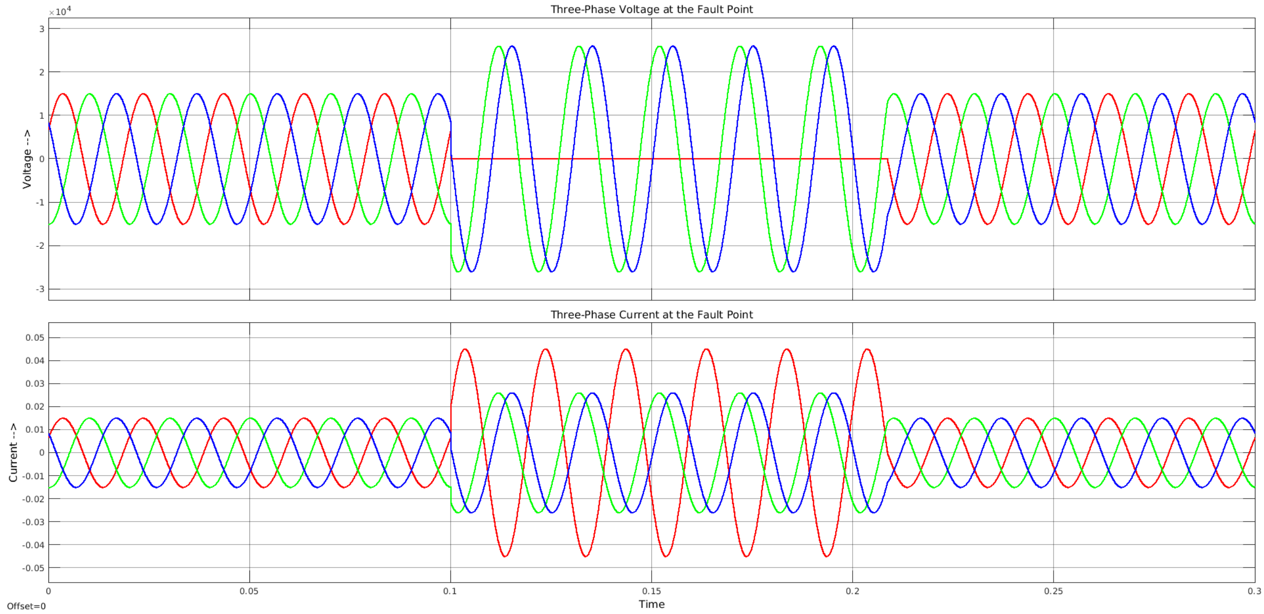



Figure 12: The three phase voltage and current at the fault point

## 4.9 Part B - 4

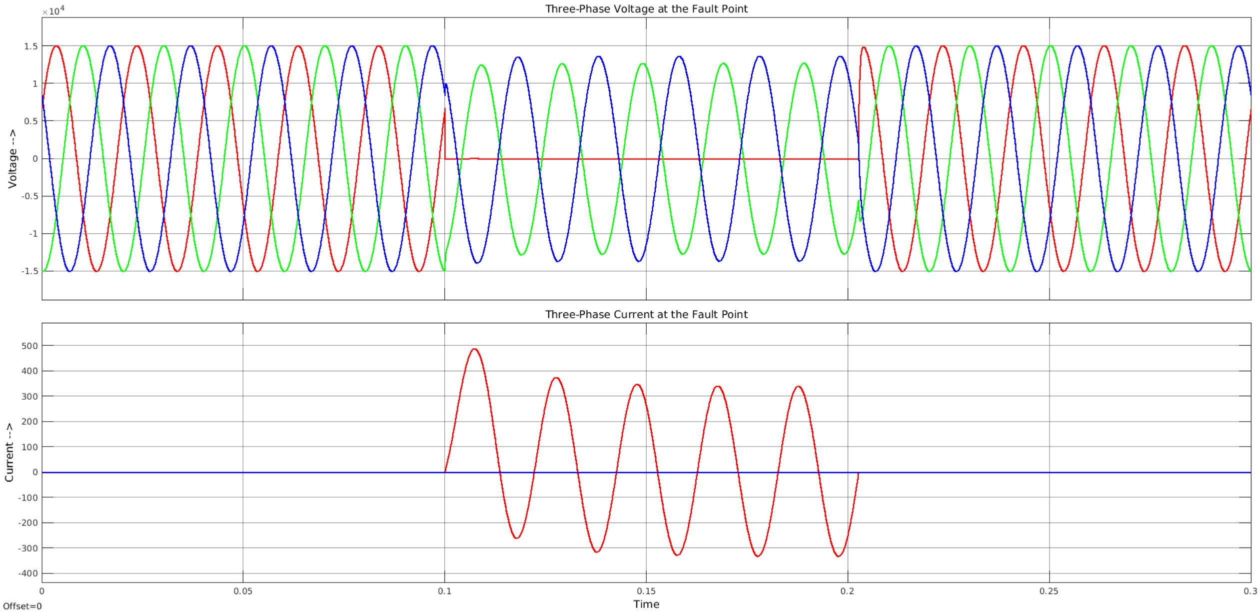



Figure 13: The three phase voltage and current at the fault point

## 4.10 Part A - 5

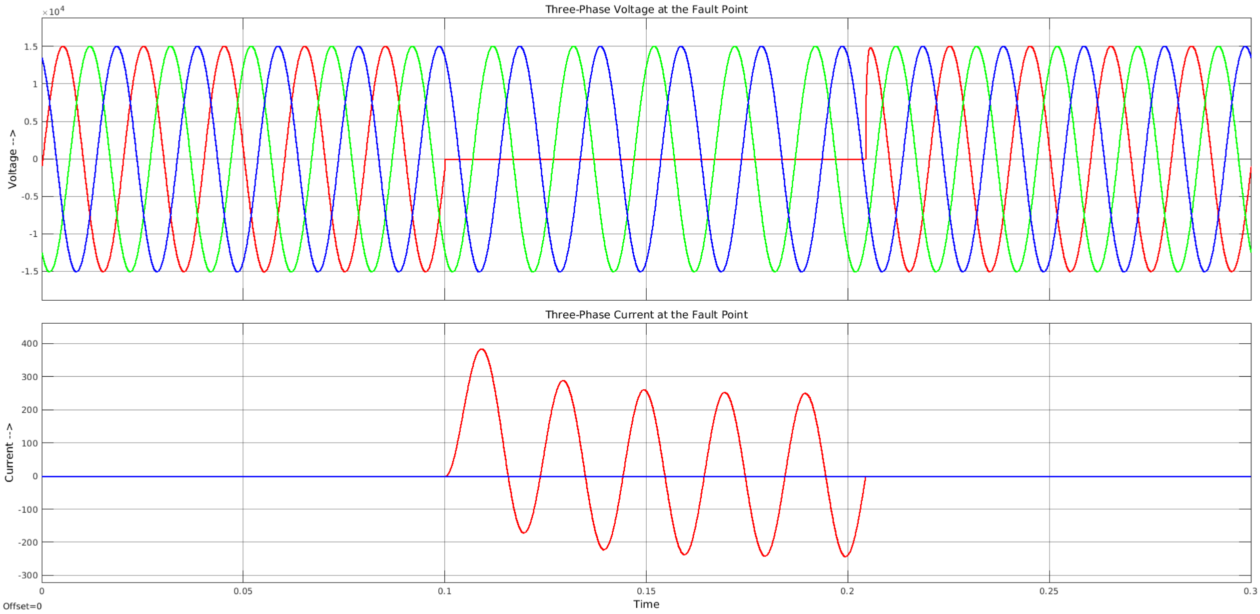



Figure 14: The three phase voltage and current at the fault point

# 5 Comparison Between Fault Currents and Fault Voltages for Various Cases

## 5.1 The Generator is Ungrounded

Table 1: Comparison of Fault Currents (Peak) in Amperes (A)

| Case | Phase A (Faulty line) | | | Phase B | | | Phase C | | |
|---|---|---|---|---|---|---|---|---|---|
| | Before Fault | During Fault | After Fault | Before Fault | During Fault | After Fault | Before Fault | During Fault | After Fault |
| A-1 | 0.0119 | 0.0451 | 0.0119 | 0.0119 | 0.0259 | 0.0119 | 0.0119 | 0.0259 | 0.0119 |
| A-2 | 0.0149 | 0.0451 | 0.0149 | 0.0149 | 0.0261 | 0.0149 | 0.0149 | 0.0259 | 0.0149 |
| A-3 | 0.0149 | 0.0451 | 0.0149 | 0.0149 | 0.0261 | 0.0149 | 0.0149 | 0.0259 | 0.0149 |
| A-4 | 0.0149 | 343 | 0.0149 | 0.0149 | 0 | 0.0149 | 0.0149 | 0 | 0.0149 |
| A-5 | 0.015 | 239 | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 |

Table 2: Comparison of Fault Voltages (Peak) in Volts (V)

| Case | Phase A (Faulty line) | | | Phase B | | | Phase C | | |
|---|---|---|---|---|---|---|---|---|---|
| | Before Fault | During Fault | After Fault | Before Fault | During Fault | After Fault | Before Fault | During Fault | After Fault |
| A-1 | 15.04k | 0 | 15.04k | 15.04k | 25.89k | 15.04k | 15.04k | 25.95k | 15.04k |
| A-2 | 15.04k | 0 | 15.04k | 15.04k | 26.10k | 15.04k | 15.04k | 25.96k | 15.04k |
| A-3 | 15.04k | 0 | 15.04k | 15.04k | 26.10k | 15.04k | 15.04k | 25.96k | 15.04k |
| A-4 | 15.03k | 5.34 | 15.03k | 15.03k | 12.49k | 15.03k | 15.03k | 13.51k | 15.03k |
| A-5 | 15.03k | 2.72 | 15.03k | 15.03k | 16.07k | 15.03k | 15.03k | 15.24k | 15.03k |

## 5.2 The Generator is Grounded

Table 3: Comparison of Fault Currents (Peak) in Amperes (A)

| Case | Phase A (Faulty line) | | | Phase B | | | Phase C | | |
|---|---|---|---|---|---|---|---|---|---|
| | Before Fault | During Fault | After Fault | Before Fault | During Fault | After Fault | Before Fault | During Fault | After Fault |
| B-1 | 0.015 | 0.0451 | 0.015 | 0.015 | 0.026 | 0.015 | 0.015 | 0.026 | 0.015 |
| B-2 | 0.015 | 0.0451 | 0.015 | 0.015 | 0.026 | 0.015 | 0.015 | 0.026 | 0.015 |
| B-3 | 0.015 | 0.0451 | 0.015 | 0.015 | 0.026 | 0.015 | 0.015 | 0.026 | 0.015 |
| B-4 | 0.015 | 338.6 | 0.015 | 0.015 | 0.013 | 0.015 | 0.015 | 0.013 | 0.015 |
| B-5 | 0.015 | 250 | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 |

Table 4: Comparison of Fault Voltages (Peak) in Volts(V)

| Case | Phase A (Faulty line) | | | Phase B | | | Phase C | | |
|---|---|---|---|---|---|---|---|---|---|
| | Before Fault | During Fault | After Fault | Before Fault | During Fault | After Fault | Before Fault | During Fault | After Fault |
| B-1 | 15.04k | 0 | 15.04k | 15.04k | 26.01k | 15.04k | 15.04k | 26.01k | 15.04k |
| B-2 | 15.04k | 0 | 15.04k | 15.04k | 26.01k | 15.04k | 15.04k | 26.01k | 15.04k |
| B-3 | 15.04k | 0 | 15.04k | 15.04k | 26.01k | 15.04k | 15.04k | 26.01k | 15.04k |
| B-4 | 15.04k | 4.12 | 15.04k | 15.04k | 12.64k | 15.04k | 15.04k | 13.61 | 15.04k |
| B-5 | 15.04k | 2.74 | 15.04k | 15.04k | 15.04k | 15.04k | 15.04k | 15.04k | 15.04k |

# 6 Inference

1. In Cases A-1, A-2, and A-3, the absence of a closed-loop path within the zero-sequence network prevents the flow of zero-sequence current. As a result, both the fault current and the fault voltage are significantly low in these cases.
2. In Case A-4, a closed-loop path is present, allowing the zero-sequence current to flow. Consequently, the fault current reaches a value of 343 A, while the fault voltage remains low due to the occurrence of the fault.
3. In Case A-5, a path exists that permits the flow of zero-sequence current. Thus, the fault current measures 239 A, and the fault voltage is non-zero, indicating some level of voltage present during the fault condition.
4. In Cases B-1, B-2, and B-3, there is no closed-loop path available for the zero-sequence current to circulate. Therefore, both the fault current and the fault voltage remain very low, similar to Cases A-1, A-2, and A-3.
5. In Cases B-4 and B-5, a closed-loop path is established, enabling the zero-sequence current to flow effectively. As a result, the fault current is extremely high, while the fault voltage remains low due to the short-circuiting effect caused by the fault.