Analysis of Voltage Sag on Transmission System Under Fault Conditions

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EE5200: Advanced Methods in Power System Analysis

Outline

- Introduction
- Background
- Concept
- Simulink Model and Analysis
- Results
- Conclusion
- Recommendation for Future Work

Introduction

Problem Description

- Load equipment are sensitive to power quality variation.
- Voltage Sag is the most important problem in transmission and distribution systems
- Growth of devices to improve the efficiency of the power system

Motivation for the project

- Consumers not only require reliability and also power quality.
- Location of the fault plays an important role.
- Voltage variation leads to failure/disconnection of load equipment or entire plant.

Project Overview

- Determination of voltage sag, phase voltage of various types of faults.
- Key aspects of voltage sag characteristics.
- Factors affecting the characteristics of the voltage sag.

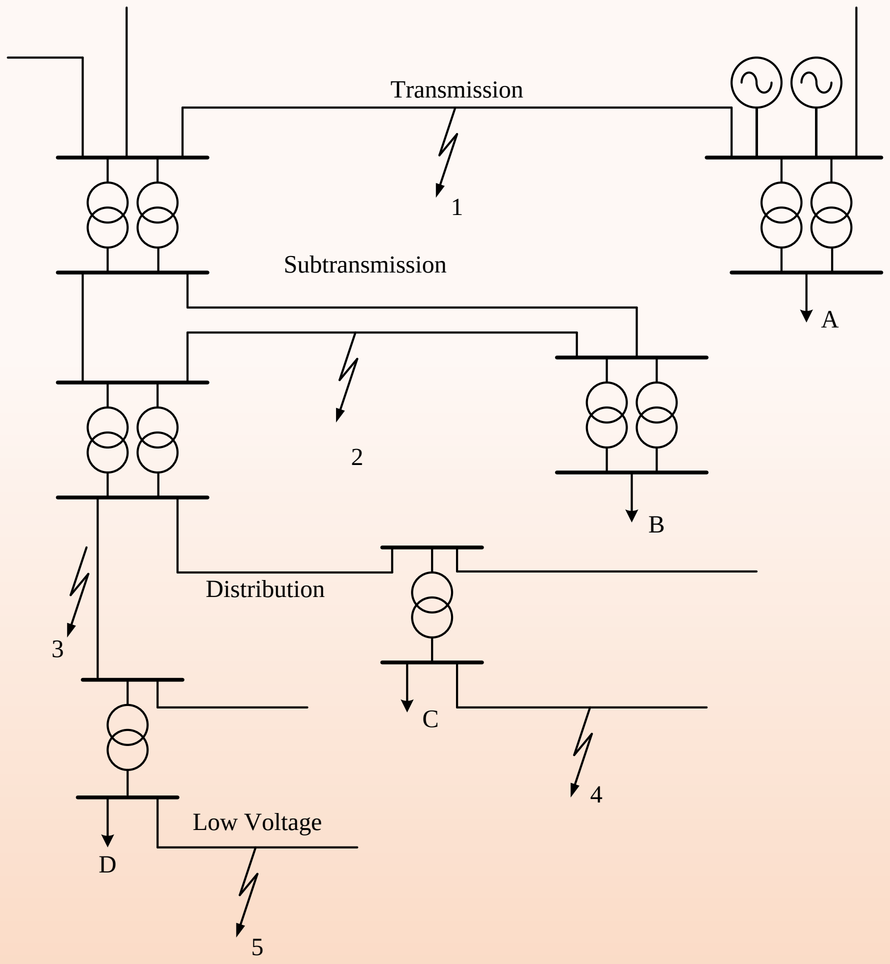
Background

- Power Quality Problems
- What is voltage sag and its importance
- Voltage sag characteristics

Power Quality problems and its causes

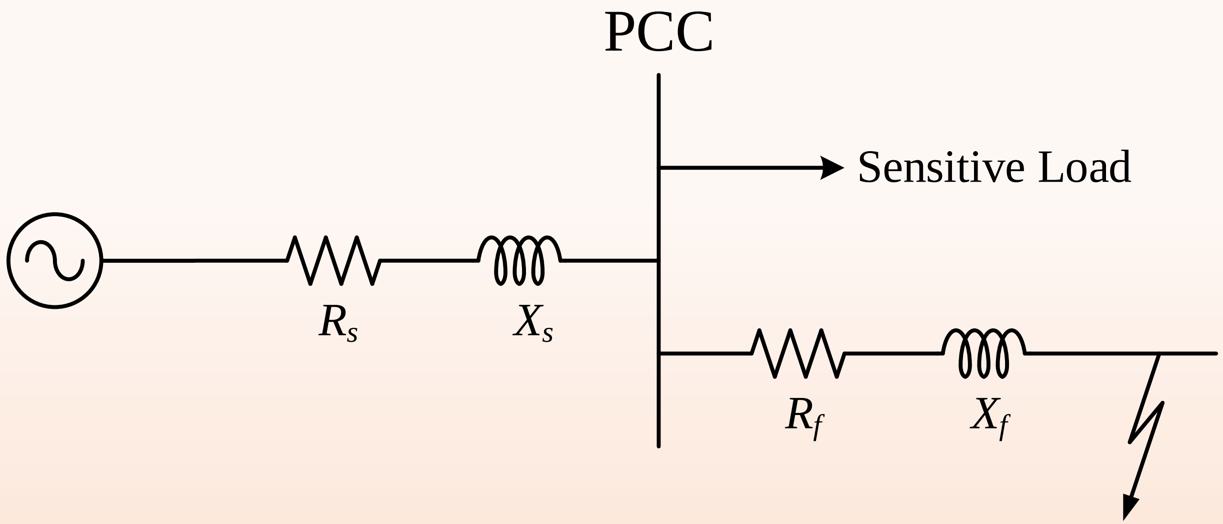
Broad Categories	Specific Categories	Methods of Characterization	Typical Causes
Transients	Impulsive	Peak magnitude, rise time and duration	Lightning strike, transformer energization, capacitor switching
	Oscillatory	Peak Magnitude, frequency components	Line or capacitor or load switching
Short duration voltage variation	Sag	Magnitude, duration	Ferro-resonant transformers, single line-to-ground faults
	Swell	Magnitude, duration	Ferro-resonant transformers, single line-to-ground faults
	Interruption	Duration	Temporary (self-clearing) faults
Long duration voltage variation	Undervoltage	Magnitude, duration	Switching on loads, capacitor de-energization
	Overvoltage	Magnitude, duration	Switching on loads, capacitor energization
	Sustained	Duration	Faults
Voltage Imbalance		Symmetrical Components	Single-phase loads, single-phasing condition
Waveform Distortion	Harmonics	THD, Harmonic spectrum	Adjustable speed drives and other non-linear loads
	Notching	THD, Harmonic spectrum	Power electronics Converter
	DC Offset	Volts, Amps	Geo-magnetic disturbance, half wave rectification
Voltage Flicker		Frequency of occurrence, modulating frequency	Arc furnace, arc lamps

Theoretical Calculation for Voltage Sag



Distribution Network with load positions and fault positions

Concept



Voltage Divider Model for determination of Voltage Sag

$$\bar{V}_{sag} = \bar{E}\frac{\bar{Z}_f}{\bar{Z}_f + \bar{Z}_s} \quad (1)$$

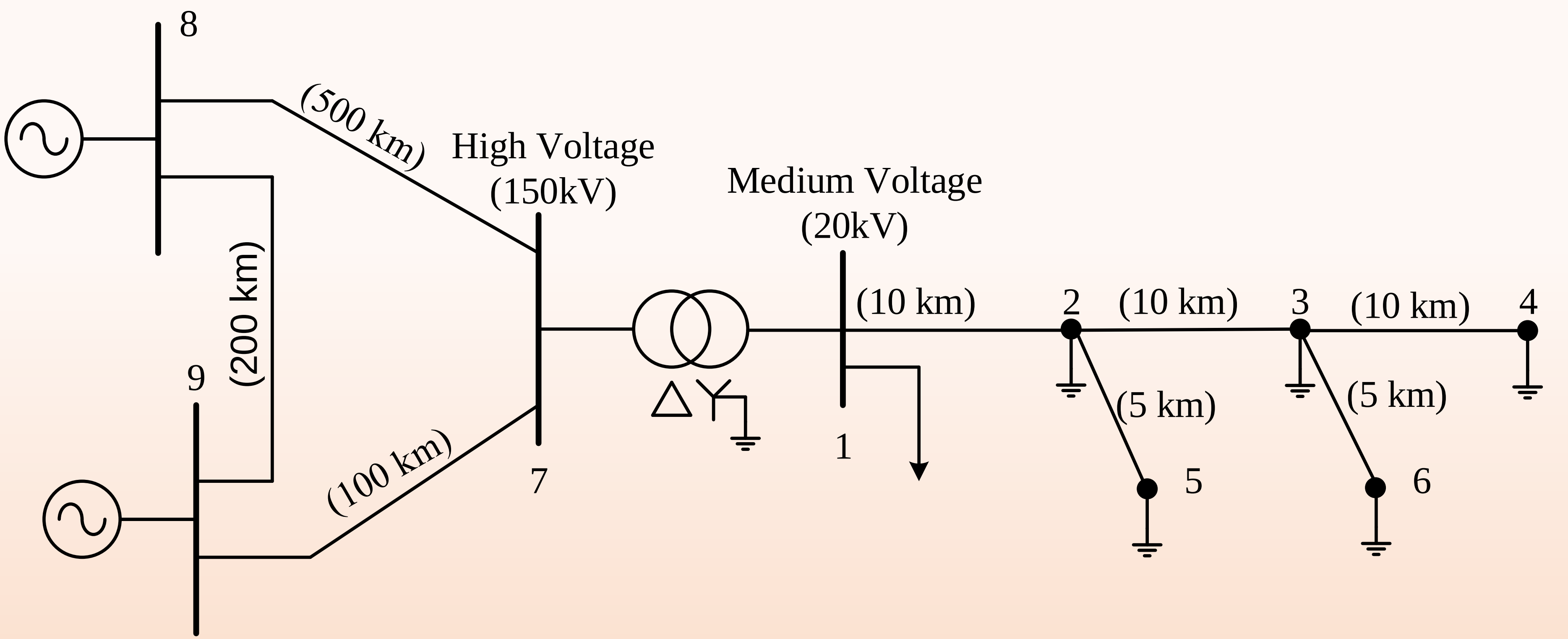
$$\bar{V}_{sag} = \frac{\bar{Z}_f}{\bar{Z}_f + \bar{Z}_s} \quad (2)$$

$$\bar{V}_{sag} = \frac{\bar{zl}}{\bar{zl} + \bar{Z}_s} \quad (3)$$

$$\left|V_{sag}\right| = \frac{|zl|}{|zl| + |Z_s|} \quad (4)$$

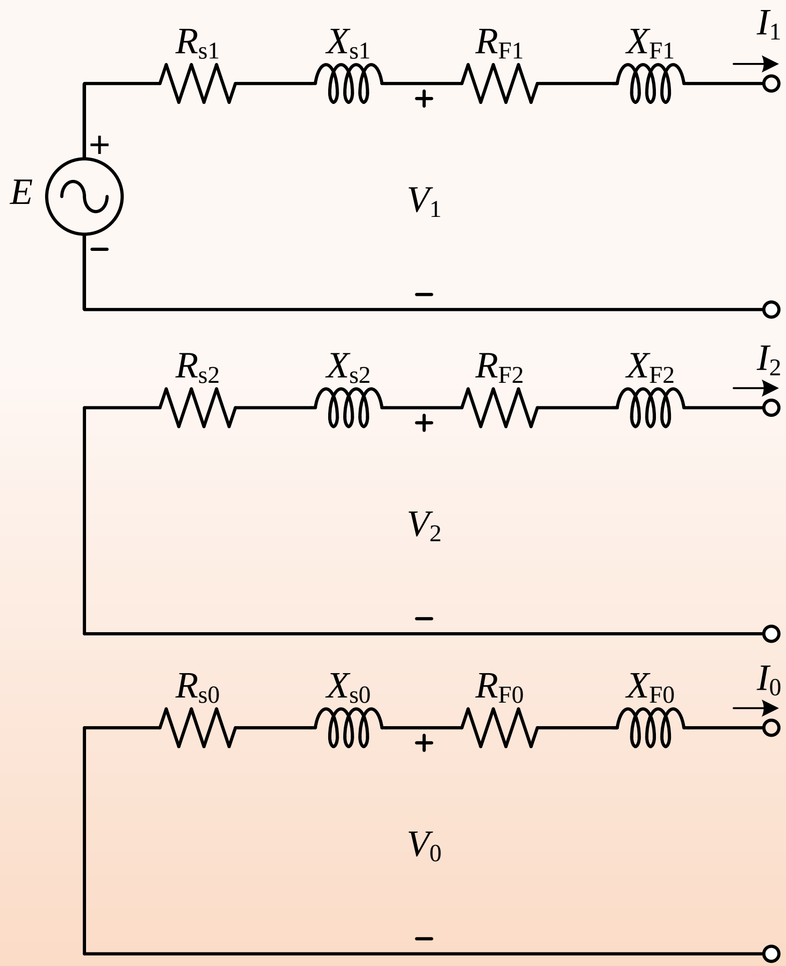
$$\Delta\emptyset = arctan\frac{X_f}{R_f} - arctan\frac{X_s + X_f}{R_s + R_f} \quad (5)$$

System Under Study



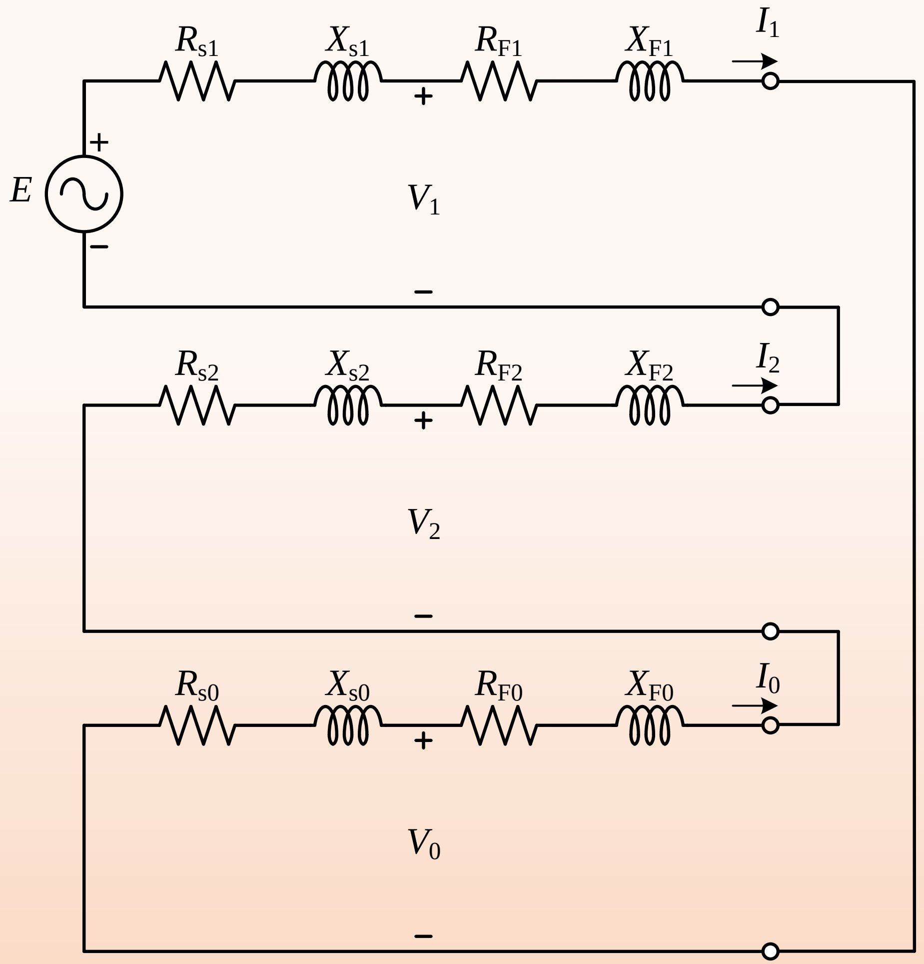
System Under Study

Voltage Sag Analysis for different Unsymmetrical Faults



Positive, negative and zero sequence networks for the voltage divider for unsymmetrical faults

Single Line to Ground Fault



Equivalent circuit for a single line to Ground fault

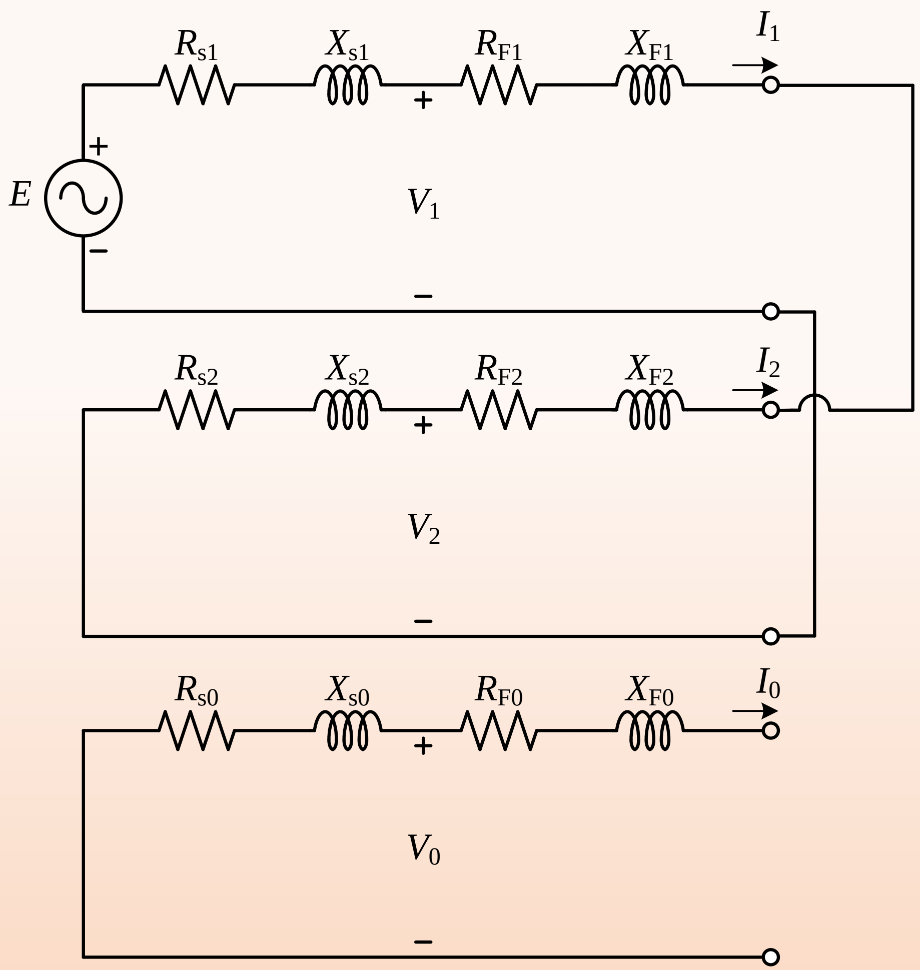
Sequence component of voltages at PCC

$$V_1 = \frac{Z_{F1} + Z_{S2} + Z_{F2} + Z_{S0} + Z_{F0}}{(Z_{F1} + Z_{F2} + Z_{F0}) + (Z_{S1} + Z_{S2} + Z_{S0})}$$

$$V_2 = \frac{Z_{S2}}{(Z_{F1} + Z_{F2} + Z_{F0}) + (Z_{S1} + Z_{S2} + Z_{S0})}$$

$$V_0 = \frac{Z_{S0}}{(Z_{F1} + Z_{F2} + Z_{F0}) + (Z_{S1} + Z_{S2} + Z_{S0})}$$

Line to Line Fault



Equivalent circuit for a line-line fault

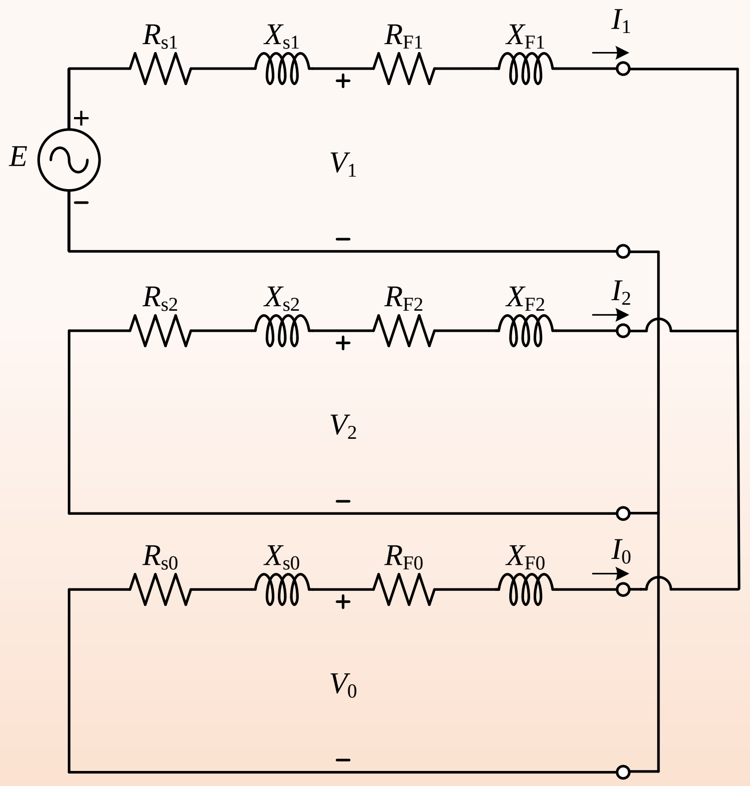
Sequence component of voltages at PCC

$$V_1 = E - E\frac{Z_{S1}}{(Z_{S1} + Z_{S2}) + (Z_{F1} + Z_{F2})}$$

$$V_2 = \frac{Z_{S2}}{(Z_{S1} + Z_{S2}) + (Z_{F1} + Z_{F2})}$$

$$V_0 = 0$$

Line to Line to Ground Fault



Equivalent circuit for a line to line to ground fault

Sequence component of voltages at PCC

$$V_1 = 1 - \frac{Z_{S1}(Z_{S0} + Z_{F0} + Z_{S2} + Z_{F2})}{D}$$

$$V_2 = \frac{Z_{S2}(Z_{S0} + Z_{F0})}{D}$$

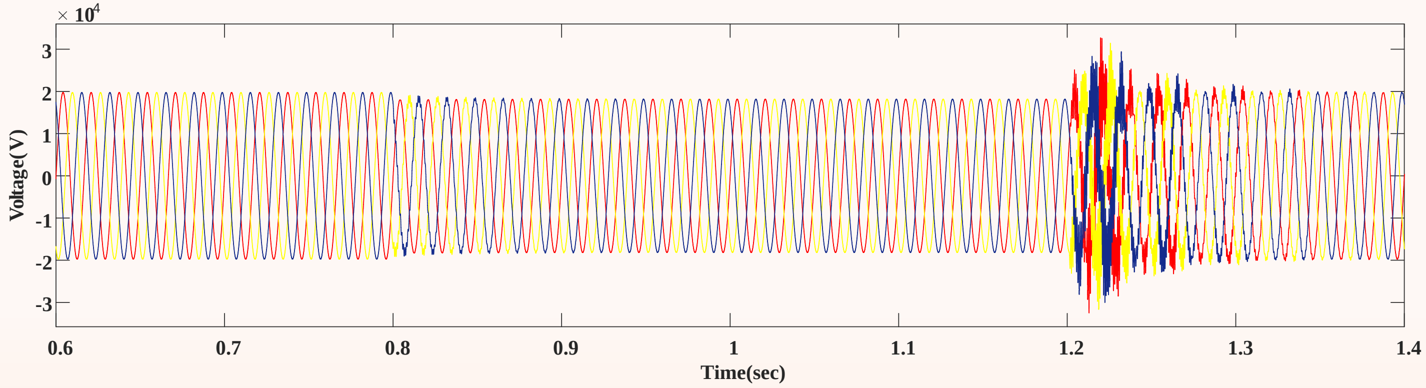
$$V_0 = \frac{Z_{S0}(Z_{S2} + Z_{F2})}{D}$$

where,

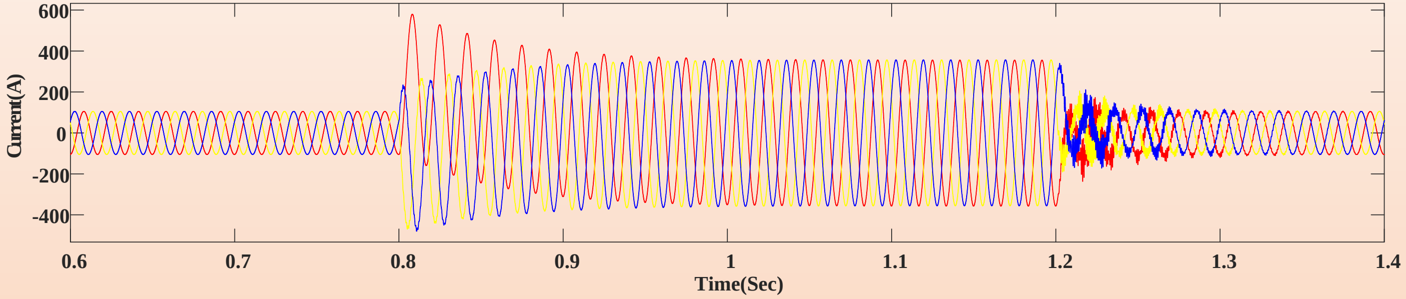
$$D = (Z_{S0}+Z_{F0})(Z_{S1} + Z_{F1} + Z_{S2} + Z_{F2}) + (Z_{S1}+Z_{F1})(Z_{S2} + Z_{F2})$$

Results

Three Phase to Ground Fault

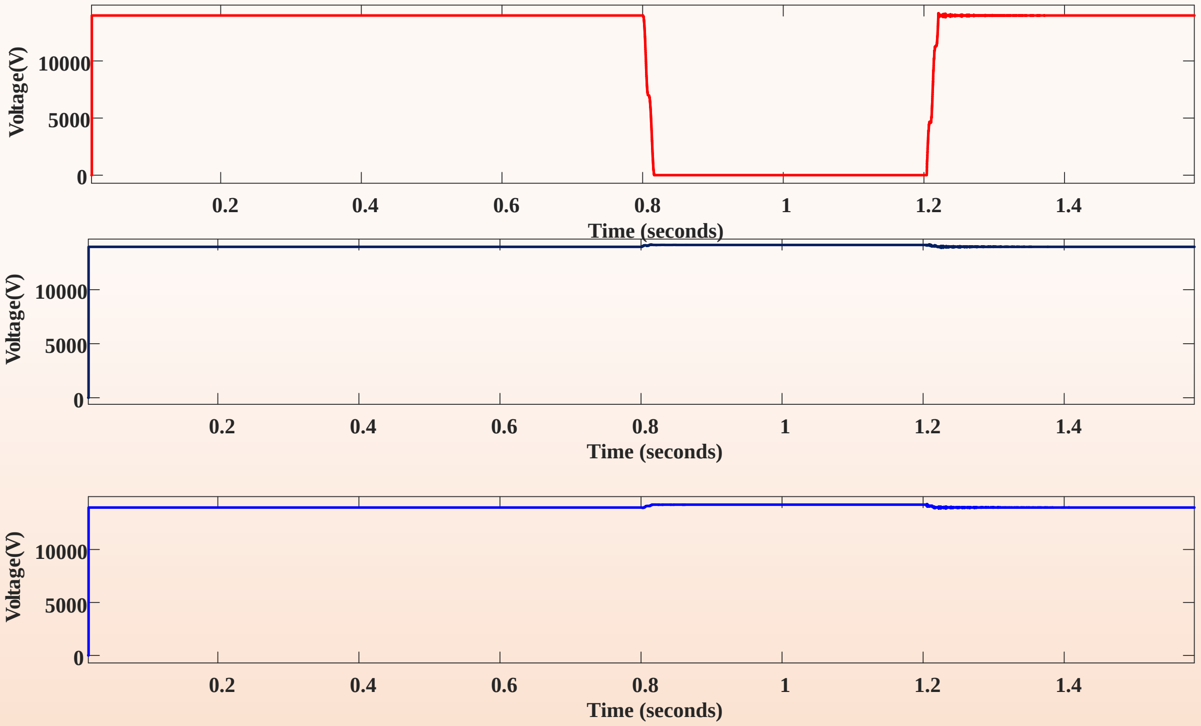


Voltages at node 9 for ABC-G fault in line 8-9

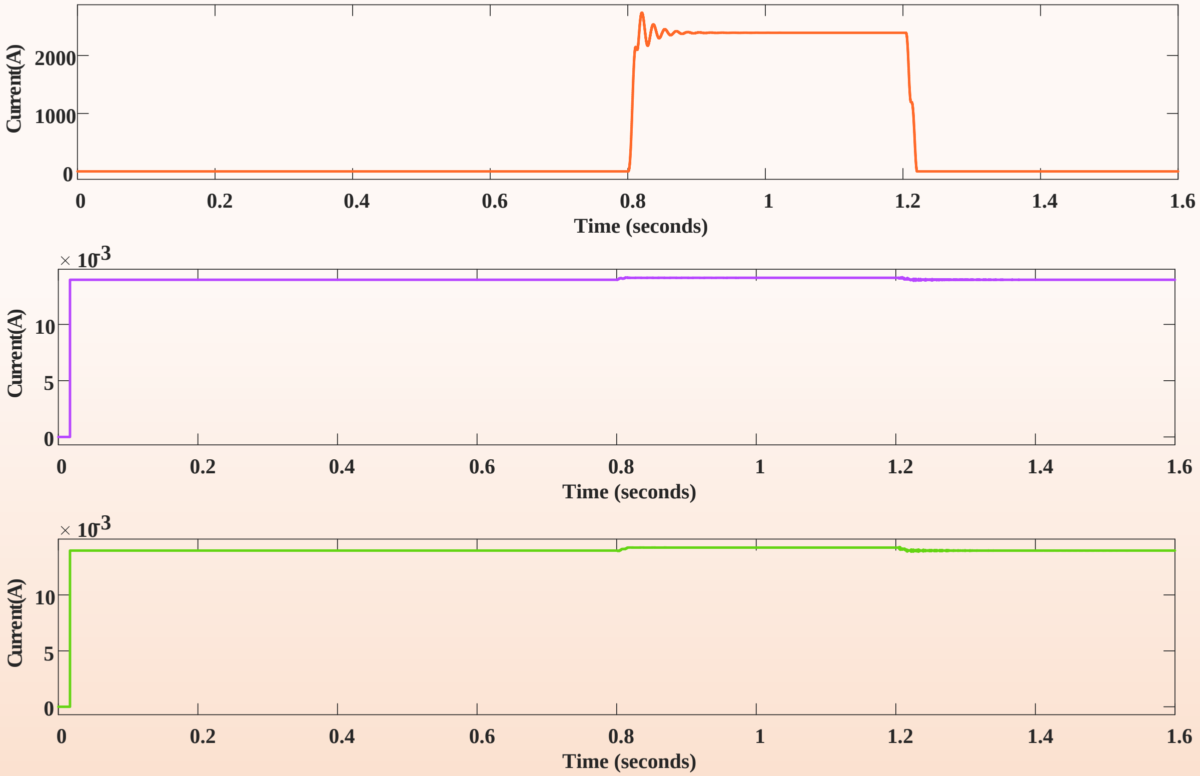


Current at node 9 for ABC-G fault in line 8-9.

Single Phase to Ground Fault

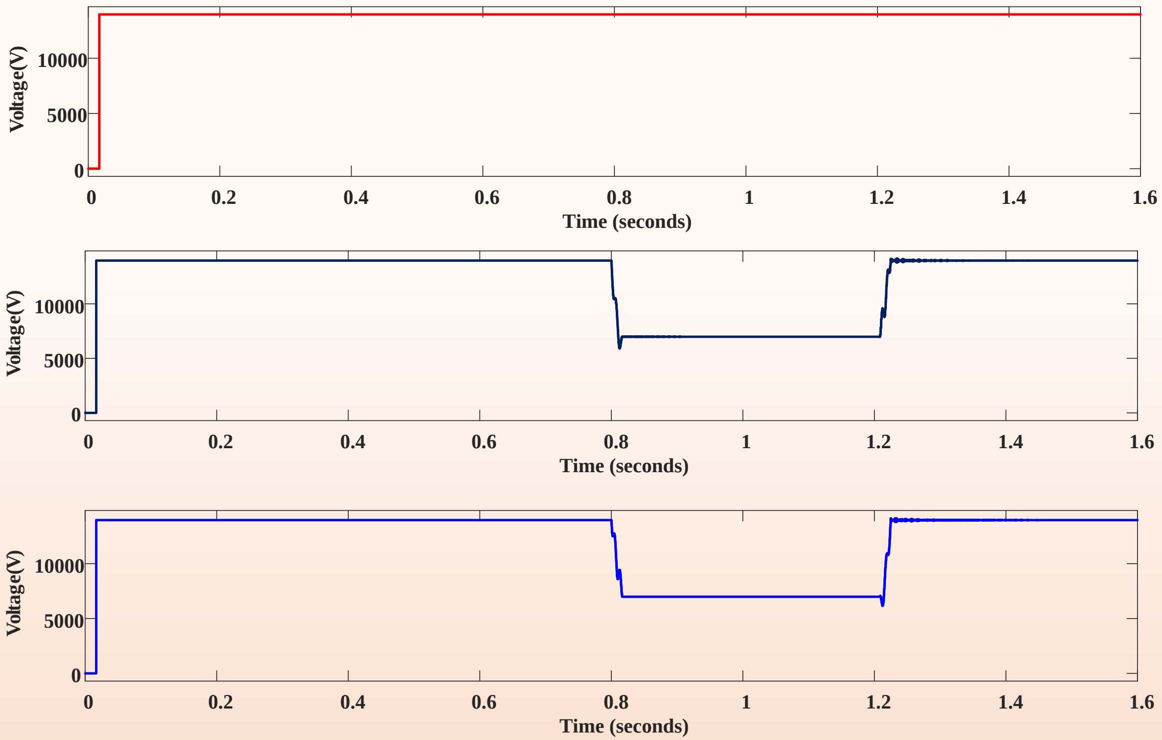


Fault voltages for a, b and c for A-G fault

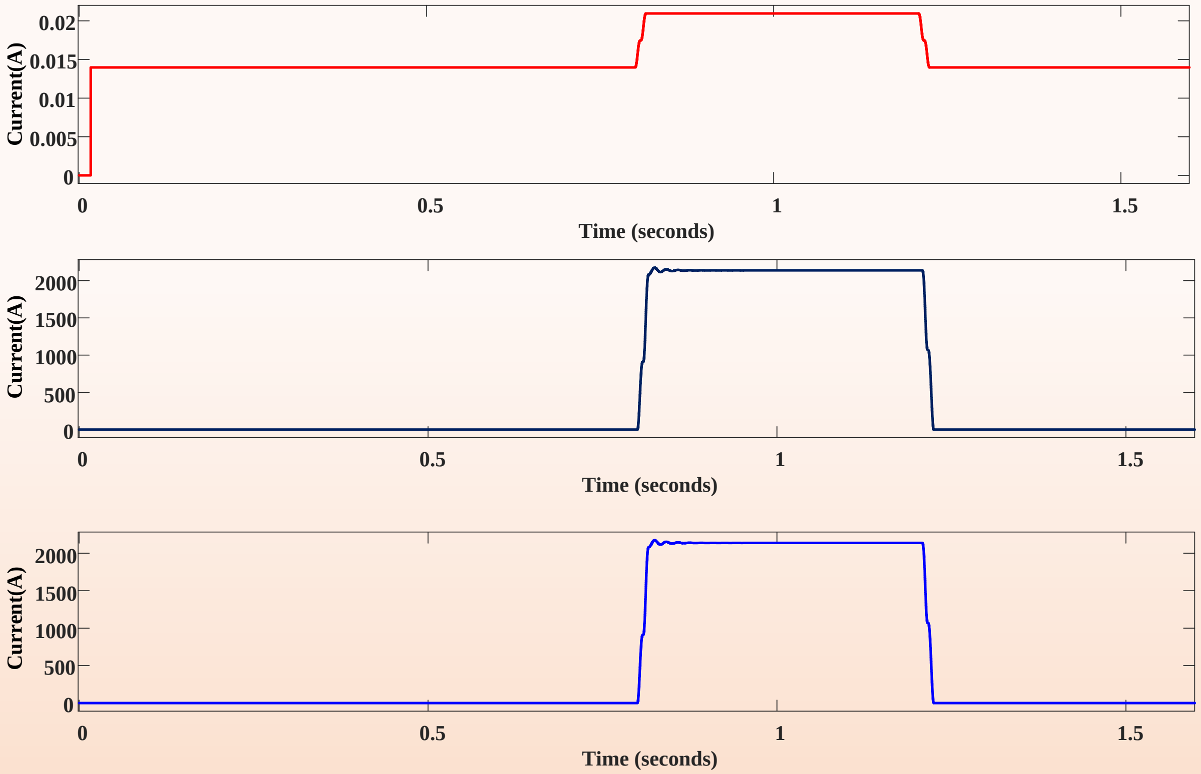


Fault current for a, b and c for A-G fault

Line to Line Fault

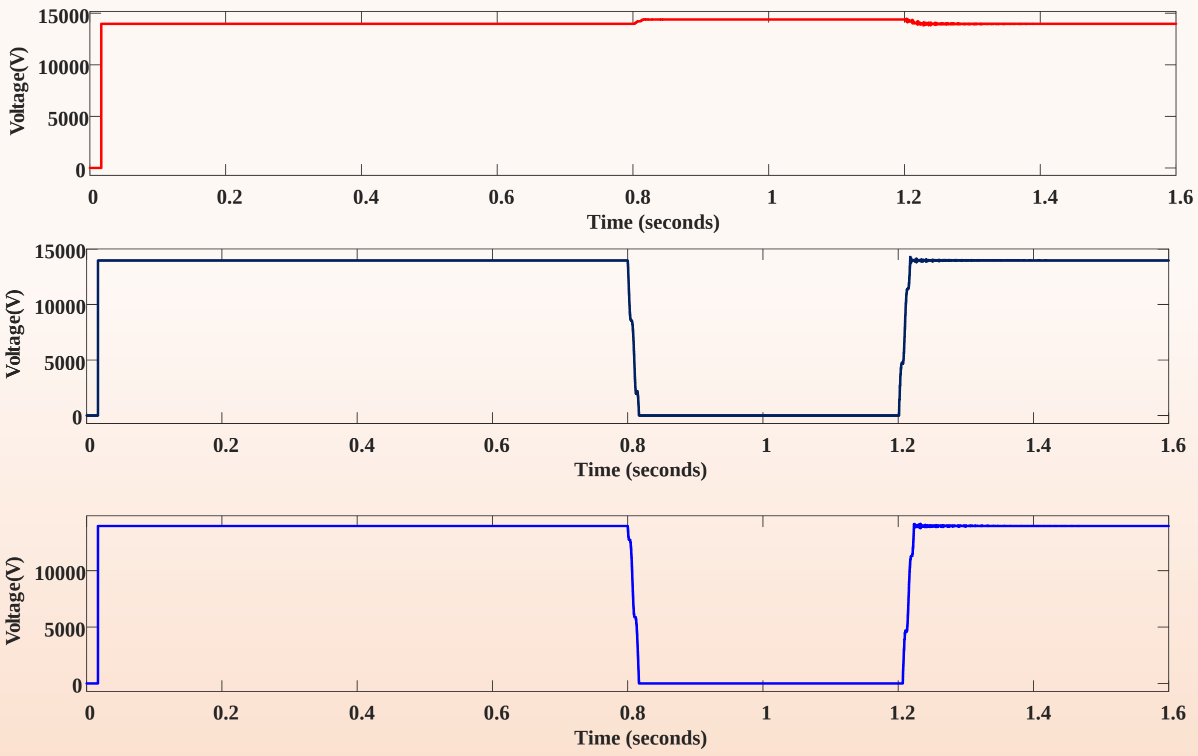


Fault voltages for a, b and c for B-C fault

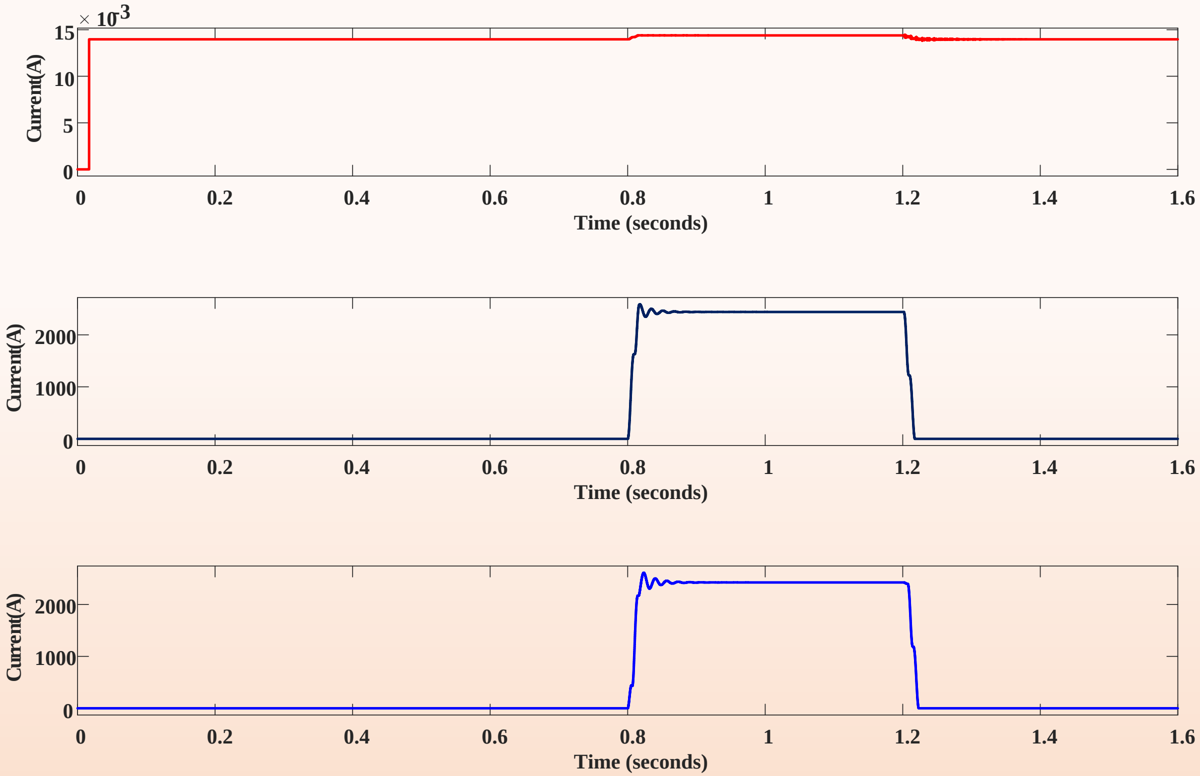


Fault current for a, b and c for B-C fault

Line to Line to Ground Fault

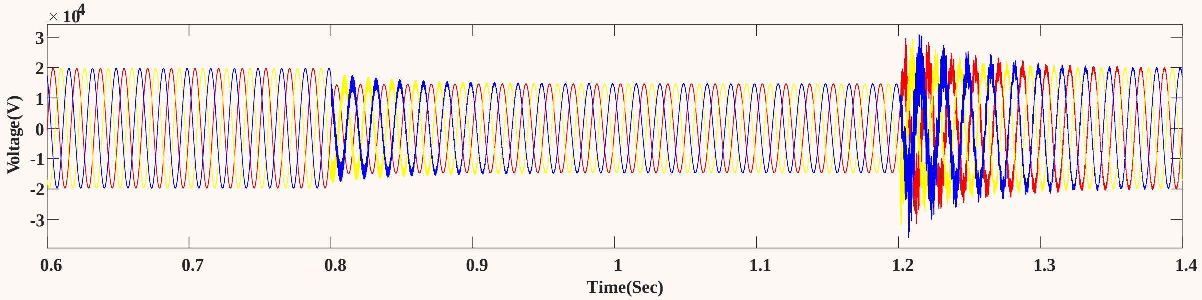


Fault voltages for a, b and c for BC-G fault

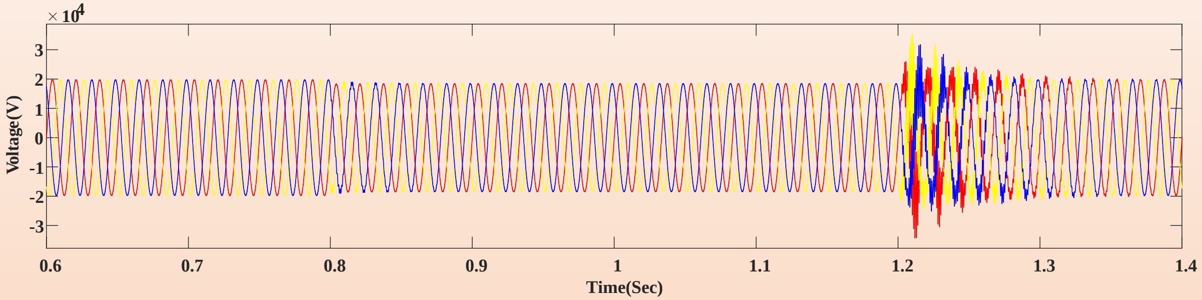


Fault currents for a, b and c for BC-G fault

Analysis of Voltage Sag with Respect to line Length(L)



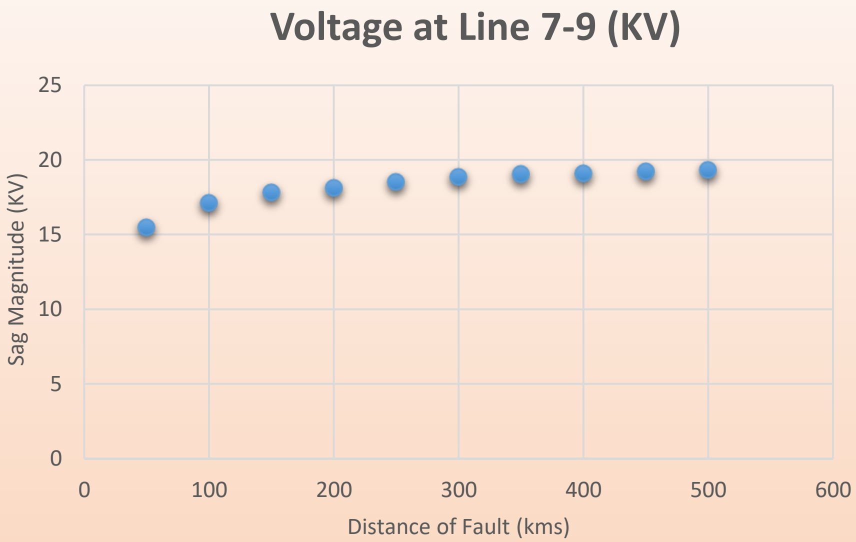
Voltage at node 9 when distance is 50 Kms



Voltage at node 9 when distance is 250 Kms

Sag Magnitude with respect to Line Length

Distance in Kms(L)	Sag Magnitude(kV)
50	15.473
100	17.118
150	17.823
200	18.119
250	18.528
300	18.857
350	19.045
400	19.092
450	19.233
500	19.327



Sag magnitude versus variation in line length

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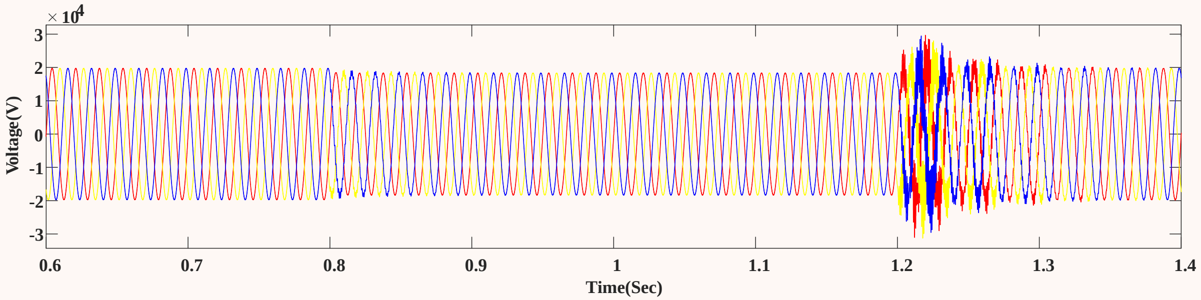
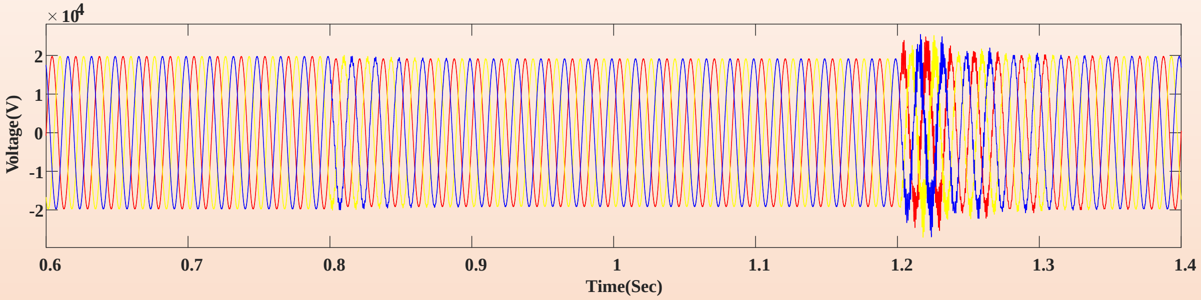
Analysis of Voltage Sag with Respect to Fault Impedance (Z_F)



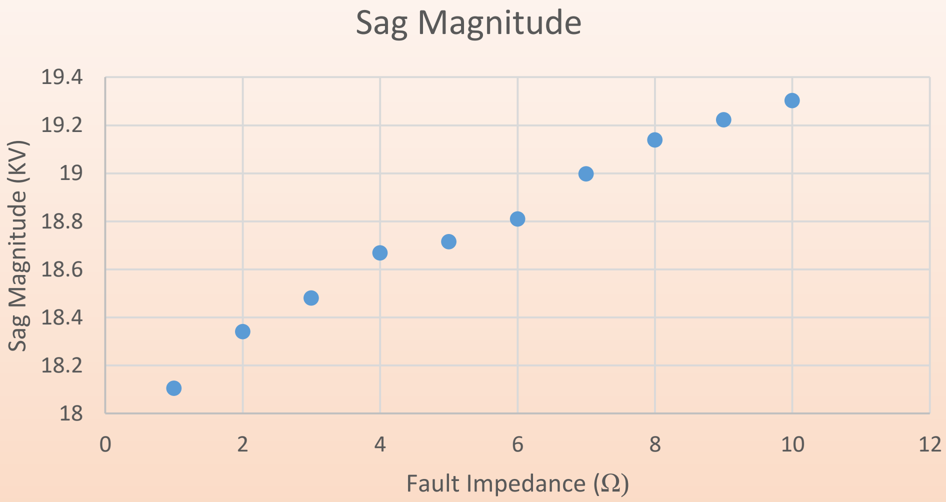
Voltage at node 9 when the fault resistance is 2Ω



Voltage at node 9 when the fault resistance is 8Ω

Sag Magnitude with respect to Fault Impedance

Fault Impedance Z_F(Ω)	Sag Magnitude(kV)
1	18.105
2	18.341
3	18.481
4	18.669
5	18.716
6	18.811
7	18.998
8	19.139
9	19.223
10	19.303



Sag magnitude versus time for variation in fault impedance

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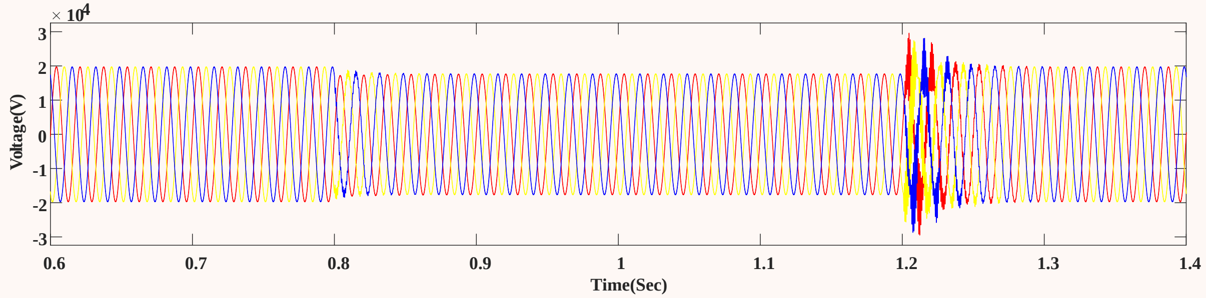
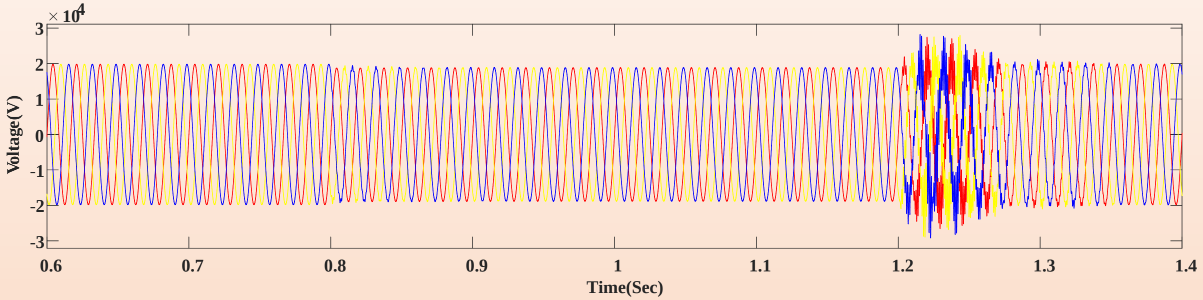
Analysis of Voltage Sag with Respect to X/R Ratio



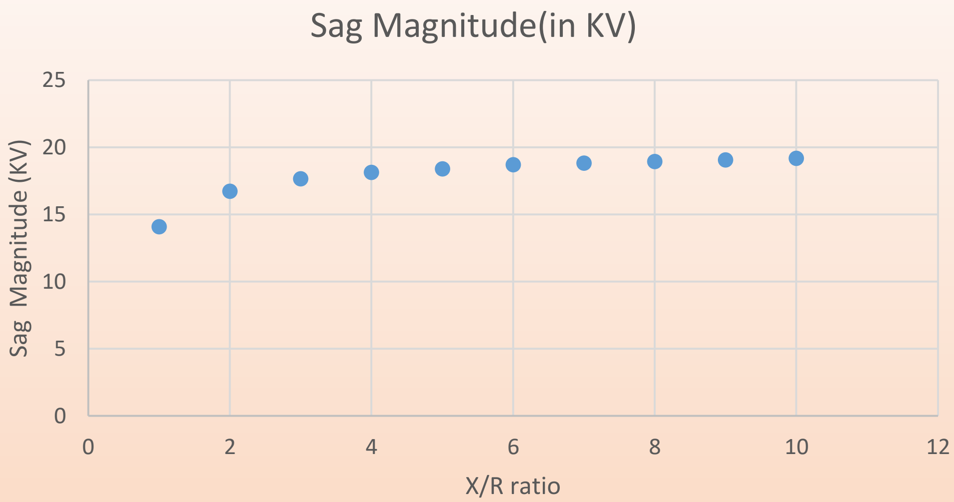
Voltage at node 9 when the X/R ratio is 3



Voltage at node 9 when the X/R ratio is 7

Sag Magnitude with respect to X/R ratio

X/R ratio	Sag Magnitude(kV)
1	14.063
2	16.718
3	17.635
4	18.105
5	18.387
6	18.692
7	18.810
8	18.927
9	19.045
10	19.162



Sag magnitude versus time for variation in X/R ratio

Conclusion

- Different power quality problems arising in distribution system is discussed.
- Analysis of voltage sag in terms of power system parameters are analyzed.
- The effect of symmetrical and unsymmetrical on double circuit transmission line is been evaluated mathematically.
- All the above proposals are verified through an extensive digital simulation in MATLAB/ Simulink

Recommendation for Future Work

- This work successfully demonstrates the analysis of voltage sag in terms of different power system parameters using symmetrical and unsymmetrical faults. However, further it also creates some space for future investigations using new and modified algorithms.
- The work analyses the effect of unsymmetrical faults in terms of sequence components. Since, the different types of voltage sag are already proposed, further investigations can be extended towards the unbalance sag analysis for these various types of voltage sag.
- Also, a critical analysis can be done in terms of different sag indices and few more parameters like phase angle jump, conductor area with overhead and underground cables.
- Moreover, the mitigation techniques can also be implemented, and new proposal can be put forward to improve the dynamic performance of the system.

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Thank You