Modelling and Analysis of Faults in a Nominal Π Model of a Medium Transmission Line Using Simulink

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Abstract
This paper describes a nominal π model of a medium transmission line using MATLAB/SIMULINK. A three-phase fault block in SIMULINK is used as a fault in the transmission line. Its Analysis is given and the effect on sending and receiving current and voltages is observed. A Nominal π Method is formed when each line's shunt capacitance i.e., phase-to-neutral is split into two equal parts. One section is bunched at the sending end while the other is bunched at receiving end. Such type of analysis is convenient, effective, and simple when done in SIMULINK. The overall understanding of the system remains intact when the schematic is viewed afterward and the problem is presented more practically. The results of SIMULINK are also fine and implicit. The results obtained after the simulation of this model coincided with the theoretical approaches developed and used in the beginning. A large amount of current along with a very small voltage can be observed at the receiving end. This current and voltage change takes place on only those phase/phases of the transmission lines on which the fault occurs. This fault in the transmission line needs to be removed to maintain a desired constant current and voltage supply to consumers.

Keywords
MATLAB; SIMULINK; modeling simulation; medium transmission line; fault

Introduction

A set of conductors that are being run from one spot to another either through underground transmission networks or above-ground transmission towers are known as transmission lines. There are mainly three distributed parameters of these lines which are series resistance, inductance, and shunt capacitance. When the series impedance of the line is converged at the midpoint with half of each capacitance placed at the centre of the line, a nominal pi model is obtained [1].

The faults in transmission lines may arise due to several factors. Some of them include extreme weather situations, equipment malfunctions, human mistakes, and smoke of fires. Weather conditions like lightning strikes, intense winds, extreme rains, snow and ice formation the transmission lines, salt deposition on overhead lines and conductors, etc. Equipment failure may arise due to malfunctioning of reactors, switching devices, generators, transformers, motors, loss of insulation of cables and windings, etc. Human errors arise due to mistakes on the human part like the improper selection of rating of the equipment, no maintenance of metallic or electrical conducting parts, etc. Smoke particles cause ionization of air around the overhead lines that in turn cause sparking between transmission lines or between insulators and conductors. This results in the loss of the insulating capacity of insulators [2].

Method

Various simulation programs can be used for the simulation of a π model a medium transmission. This paper discusses the effects of faults on a medium transmission line through the use of the SIMULINK software of MATLAB. It is given preference over other programming-oriented software as it offers construction of the circuit through basic function blocks. Thus, decreasing the programming efforts and syntax proficiency [3].

Transmission Lines having lengths more than 80 km (50 miles) and less than 250 km (150 miles) in length are termed medium-length transmission lines. A nominal π model of the medium transmission line is given in **Figure 1**

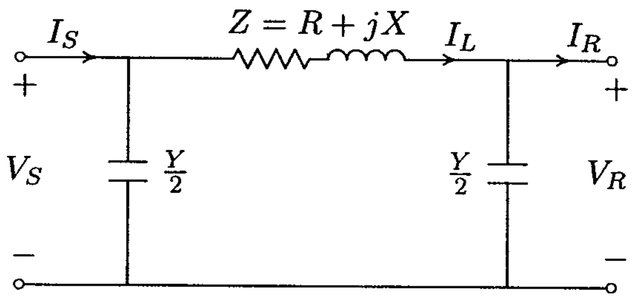

Figure 1. Nominal π model of for medium transmission line

The sending end voltage and current for the nominal π model are obtained as follow

$$V_S = \left(1 + \frac{ZY}{2}\right) V_R + Z I_R \quad (1)$$

$$I_S = Y\left(1 + \frac{ZY}{4}\right) V_R + \left(1 + \frac{ZY}{2}\right) I_R \quad (2)$$

Modeling In Simulink

The circuit is designed as shown in **Figure 2**

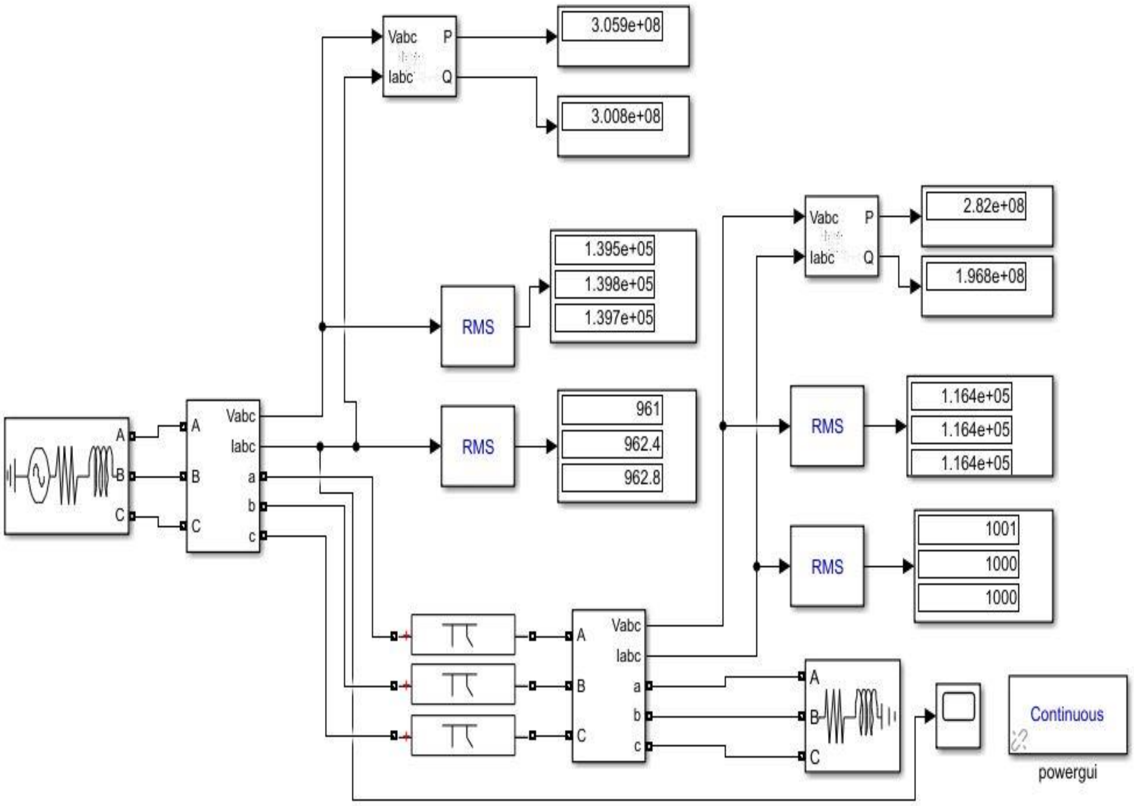

Figure 2 Simulink Model

Block Parameters

The parameters in Three-Phase Source Block are set as follows. The phase-to-phase voltage is set to $250\text{x}10^3$. The frequency is taken as 50Hz. Source resistance is 0.8929 ohms while inductance of the source is $16.58\text{x}10^{-3}$ H. Base voltage (Vrms ph-ph) is set to $25\text{x}10^3$. In load flow, the generator type is toggled to swing.

Three Pi section lines are introduced after a Three-Phase V-I Measurement Block. For each Pi section line, the frequency utilized for rlc specification (Hz) is set to 60 Hz. Resistance per unit length is set to 0.01273 Ohms/km. The Per unit length Inductance is set to $0.9337\text{x}10^{-3}$ H/km. The per unit length Capacitance is set to $12.74\text{x}10^{-9}$ F/km. Line length is taken as 100 km.

A Three-Phase Fault is added just after 3 Pi Section lines. Its switching time is set to [1/60 2] s. Fault resistance Ron to 0.001 Ohm. Ground resistance to 0.01 Ohm. Snubber resistance to $1\text{x}10^6$ Ohm

The Three-Phase Series RLC Load is attached as a load at the termination of the transmission line. Its configuration is toggled to Y Grounded. The Nominal phase-to-phase voltage (Vrms) is set to $220\text{x}10^3$. The nominal frequency is set to 60 (Hz). Active power is set to $340\text{x}10^6$ W. The value of Inductive reactive power is marked at $260\text{x}10^6$ positive vars. 0 is given as a value for capacitive reactive power. The load flow is toggled to constant Z.

ANALYSIS

Before attaching the Three Phase fault, the sending current output on the scope is seen as in **figures 3,4 & 5**

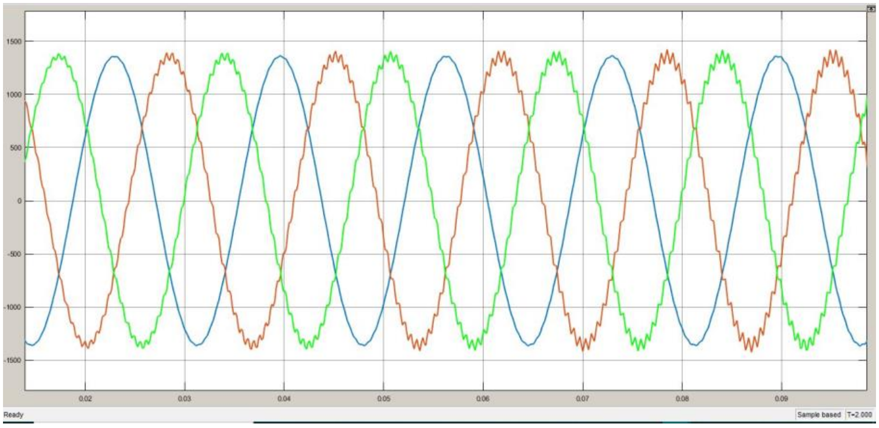

Figure 3 Sending Current before adding fault

The Sending RMS Values of current and voltages before placement of fault are as follows:

Voltages:
Phase A: 1.395×10^5 V
Phase B: 1.398×10^5 V
Phase C: 1.397×10^5 V
Currents:
Phase A: 961.0 A
Phase B: 962.4 A
Phase C: 962.8 A

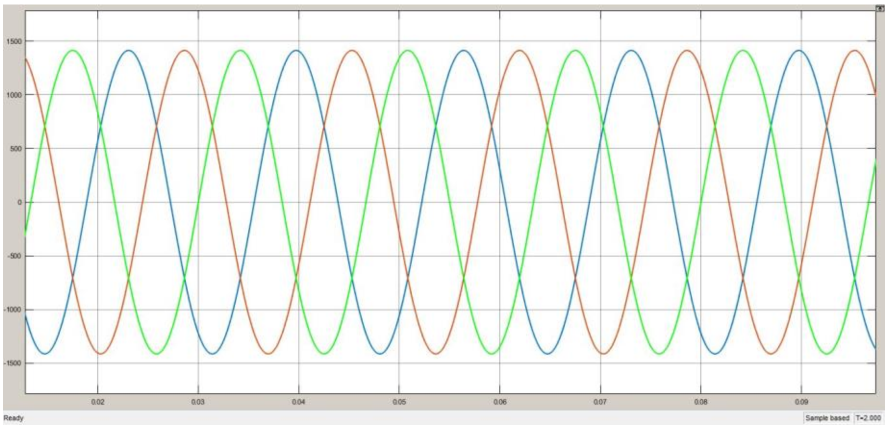

Figure 4 Receiving Current before adding fault

The Receiving RMS Values of current and voltages before placement of fault are as follows:

Voltages:
Phase A: 1.164×10^5 V
Phase B: 1.164×10^5 V
Phase C: 1.164×10^5 V
Currents:
Phase A: 1001 A
Phase B: 1000 A

Phase C: 1000 A

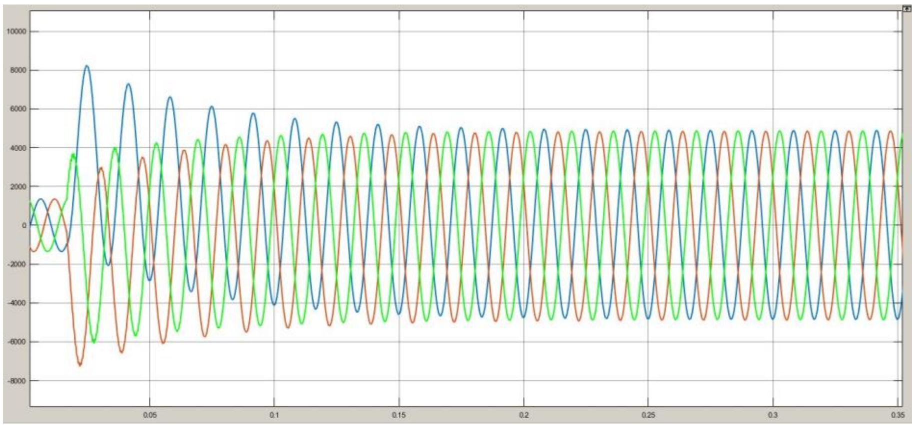

Figure 5 Sending Current after adding Three Phase Fault

The Sending RMS Values of current and voltages after placement of fault are as follows:

Voltages:
Phase A: 1.228×10^5 V
Phase B: 1.228×10^5 V
Phase C: 1.23×10^5 V
Currents:
Phase A: 3463 A
Phase B: 3465 A
Phase C: 3460 A

After attaching the Three Phase fault, the receiving current output on the scope is seen as in **Figure 6**

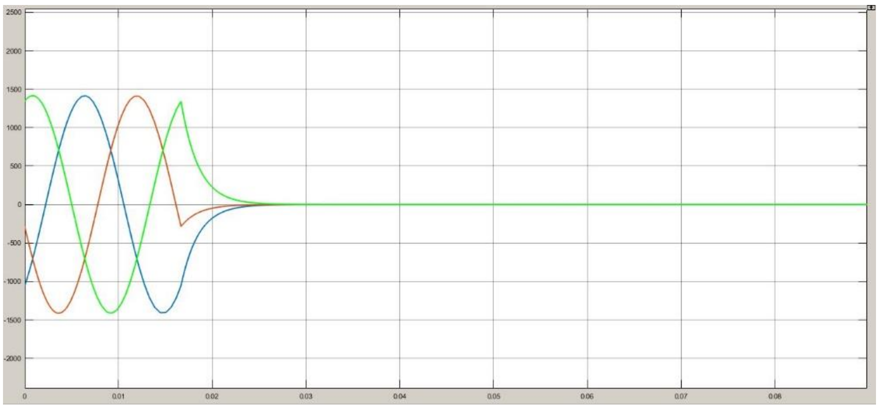

Figure 6 Receiving current after adding Three Phase Fault

The Receiving RMS Values of current and voltages after placement of fault are as follows:
Voltages:
Phase A: 7.704 V
Phase B: 115.8 V

Phase C: 229.8 V
Currents:
Phase A: 0.1694 A
Phase B: 0 A
Phase C: 0.1573 A

Now selecting individual phase and ground in the Three-Phase Fault.

1) Phase A and Ground:

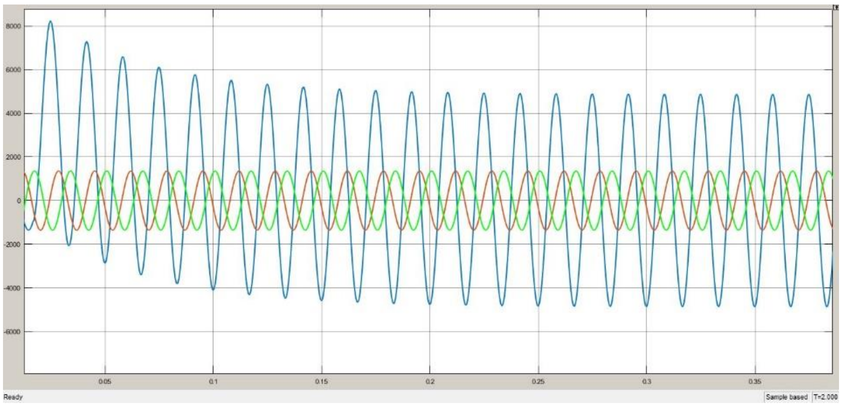

Figure 7 Sending Current when Fault applied on Phase A

After Application of Fault on Phase A

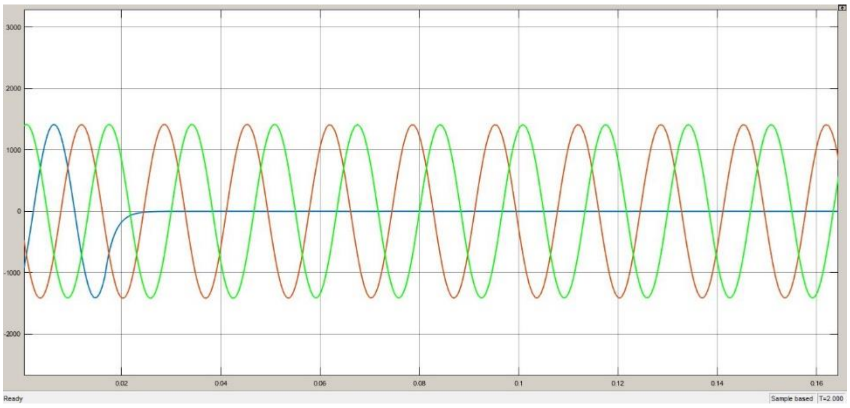

Figure 8 Receiving Current when fault applied on Phase A

Sending current = 3463 A
Sending Voltage = 1.229×10^5 V
Receiving current = 0.4163 A
Receiving Voltage = 42.52 V

2) Phase B and Ground:

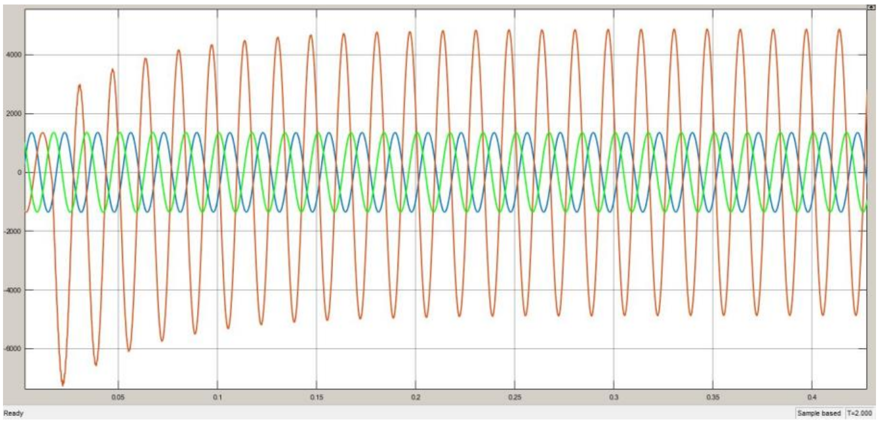

Figure 9 Sending Current when fault applied on Phase B

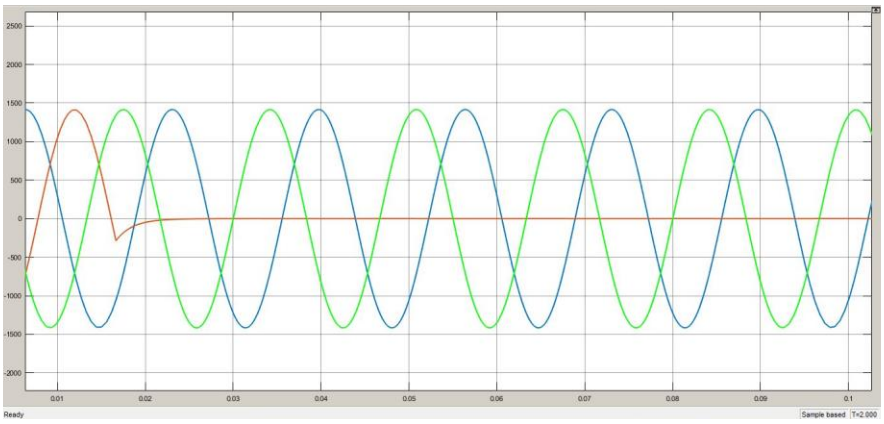

Figure 10. Receiving current when fault applied on Phase B

After Application of Fault on Phase B
Sending current = 3464 A
Sending Voltage = 1.229×10^5 V
Receiving current = 0.3275 A
Receiving Voltage = 37.9 V

3) Phase C and Ground:

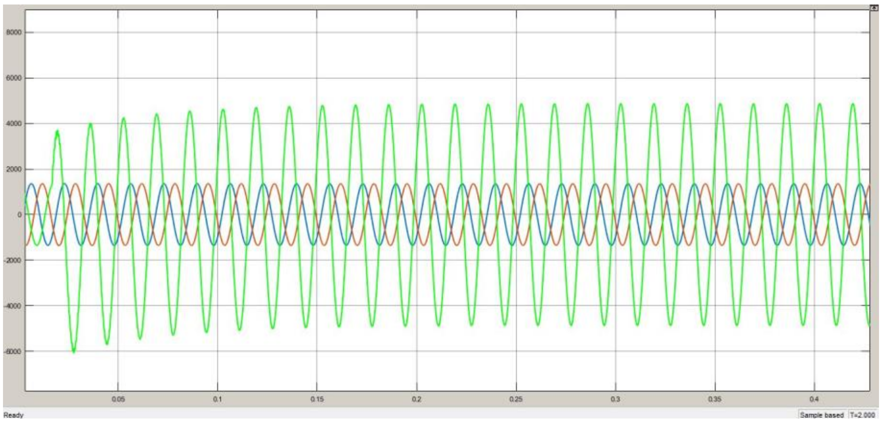

Figure 11. Sending Current when Phase Applied on Phase C

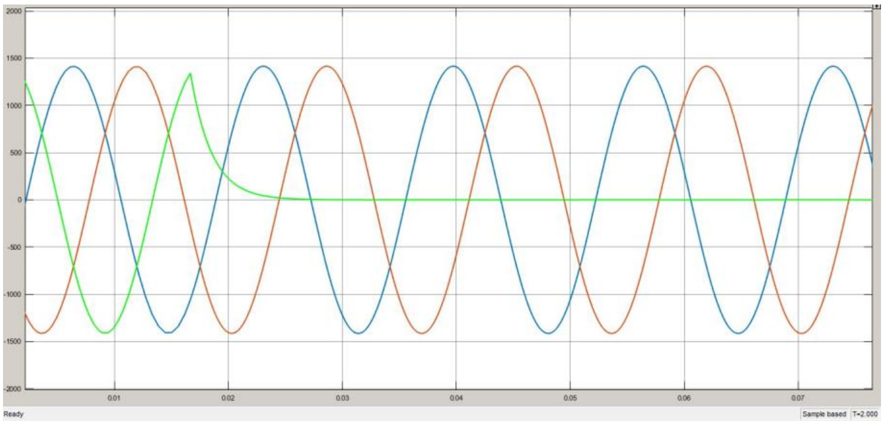

Figure 12 Receiving Current when fault applied on Phase C

After Application of Fault on Phase C
Sending current = 3462 A
Sending Voltage = 1.23×10^5 V
Receiving current = 0.313 A
Receiving Voltage = 44.86 V

DISCUSSION

So, we see that before the addition of a Three-Phase Fault in the medium transmission's line nominal pi model, the voltages and currents in all three phases were almost equal. The sending and receiving values of these parameters were also comparable. After the addition of a three-phase fault, we see nearly 3.5 times an increase in the sending current while the voltages remain almost the same as before. The interesting thing which is observed after the placement of a Three-Phase Fault is that the receiving currents reduce to zero and receiving voltages also decreased drastically. This whole phenomenon is visible if the graphs of scope attached at sending and receiving ends are analyzed.

Moreover, if we provide fault to each phase, we observe the same effect. The sending current witnesses a sharp increase with nearly no change in sending voltage. The receiving voltage and current in that particular phase approached zero.

CONCLUSION

So, we see that when a three-phase fault occurs, it introduces very high currents which cause devastation to equipment and devices. A fault provides a low resistance path to the current flow hence a very large current is drawn. An efficient transmission network detects and separates the part containing fault from the remaining system. This allows the other parts of the circuit network to behave normally.

Nomenclature

V_S	sending end voltage [V]
Z	total series impedance [ohm]
Y	total shunt admittance [ohm]
V_R	receiving end voltage [V]
I_R	receiving end current [A]
I_S	sending end current [A]

References

[1] Adil Abdul Hameed, Ankush Gupta, AS Kiranraj, Ashwini Devendran G, ‘Modeling and Implementation of Impedance based Fault Locator for Medium Transmission Line’, International Conference on Condition Assessment Techniques in Electrical Systems (CATCON), 2015

[2] Faults and Effects in Electrical Power System, https://madhavuniversity.edu.in/faults-and-effects-in-electrical-power-system.html

[3] K. L. SHI, T. F. CHAN, Y. K. WONG, S. L. HO, Modelling and Simulation Of The Three-Phase Induction Motor Using Simulink, International Journal Of Electrical Engineering, Manchester U.P, Vol. 36,163-164, 1999.

[4] Hadi Saadat, Power System Analysis, 1st Edition, 1998

[5] Transmission Line Faults in Power System and the Different Algorithms for Identification, Classification, and Localization: A Brief Review of Methods, https://link.springer.com/article/10.1007/s40031-020-00530-0#:~:text=Four%20major%20classes%20of%20faults,i.e.%2C%20LLL%20or%203L%20fault.

[6] Increase of Accuracy of the Fault Location Methods for Overhead Electrical Power Lines, https://www.hindawi.com/journals/amse/2018/3098107/

[7] John J. Grainger, William D. Stevenson, JR., Stevenson Power System Analysis, 1st Edition, 1994.

[8] J. Duncan Glover, Mulukutla S Sarma, Power System Analysis and Design, 6th edition, 2017.

[9] Leonard L Grigsby, Power Systems, 1st edition, 2012