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Analysis of 33kV Overhead Cable Fault Detection and Classification Using MATLAB Software

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Abstract: Overhead transmission line protection is a crucial issue in power systems since overhead power lines are responsible for 85 to 87 percent of power system problems. Thus, fault detection techniques were created in response to this requirement to lessen the financial impact of fault situations and to make their correction simpler and more accurate. For transmission systems to operate more reliably and with fewer interruptions, accurate segment fault diagnosis is essential. By using a MATLAB-built model of a 33 kV small transmission line system, any faults in electrical overhead power lines are identified and analysed in this work. The system employs a modest transmission line system situated in a rural location. By measuring the transmission line system's phase current coefficient, the system may identify fault conditions. The designated power system model with the algorithm that calculates the precise detection and classification of transmission line faults was used for the analysis. With the implementation of four categories of faults that resulted in 11 types of faults as variables, this study examined the accuracy of data categorization and detection. The result shows the data collected as sinusoidal signals, and the threshold value is chosen to restrict the reading of the maximum coefficient for each phase's current under problematic circumstances based on the temporary overcurrent. A cutoff point of 200 A has been established for this project. As seen, the most significant coefficient for each phase current will exceed the threshold value in faulted situations. Using the data that had been collected, the system can pinpoint the different fault variables that affected the transmission line. The fault type that occurred on each phase of the current is successfully identified and classified by the system.

Keywords: Transmission Line, Faults, 3-Phase Current

1. Introduction

Transmission lines, the lifeblood of the contemporary world, are used to provide electricity to consumers at their residences, places of employment, and companies. It is essential to make sure that transmission lines are running efficiently to guarantee a minimum amount of power supply disruption. This is vital for the reliable operation of electrical power lines. In response to this demand, fault location

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detection techniques were developed to reduce the financial impact of fault situations and make it easier and more precise to rectify them. Due to their dependability and minimal environmental impact, underground and overhead wires have been widely used. Accurate segment fault identification is necessary to minimize system interruption time and increase transmission system reliability [1]. A quick and reliable fault detection method is required to speed system restoration, cut outage times, reduce financial losses, and significantly boost system reliability. When a fault develops on a transmission line, the power system needs to identify it to fix it before more harm to the system is done. It is challenging to pinpoint the source of a cable failure.

An electrical cable that is typically placed above the ground using utility poles is called an overhead cable. This electrical wire is typically useful for carrying data and electrical power. This form of electrical wire is more typical than most others, particularly in crowded residential areas. The main reason for their appeal is that they are a more affordable option than underground cables. Air offers a considerable proportion of the insulation required [2]. Overhead cable is the most inexpensive electrical cable on the market as it requires less insulation.

Voltage and current fluctuations could happen because of these unexpected circumstances, harming any equipment or devices hooked to the transmission line [3]. If the failures continue for a long time, it can cause severe disturbance and could damage the equipment attached to the transmission line. It is necessary to conduct routine inspections to identify any disturbances and quickly resolve them to preserve the system from damage.

The paper proposed an idea to solve this unexpected circumstance to preserve the functionality of the transmission line. Based on data gathered from the transmission line, which can identify the type of faults that occurred and facilitate repair, these systems can detect any instability condition on the transmission line which can be caused by the type of fault variables that occurred on the line. The system operates by identifying the instability condition on the transmission line which can be seen in the measurement of the phase current coefficient on the transmission line system.

2. Materials and Methods

A. Previous Study on Fault Detection Method

The following methods were employed in earlier studies on fault detection methods:

i. Phasor Measurement Unit (PMU) Technique
According to Researcher [4], this technique analyses transmission system events across large areas to detect and avoid grid instabilities. The PMU bus has the biggest voltage deviation, and the data collected was compared to the same bus's deviation threshold [4]. Using the two-stage fault detection approach, researchers can establish the maximum value of positive sequence and zero sequence.

ii. Artificial Neural Network Technique
Researcher [5] said this method is working depending upon a series of very simple operations. The neural network's inputs are the voltage and current ratios in each phase before and after the fault occurs. The correlation coefficient (r), which runs from 0 to 1, reflects how well the neural network's targets can track changes in outputs. The correlation coefficient in this case was 0.99982, suggesting a very strong connection [5].

iii. Support Vector Machine (SVM) Technique
Researcher [6] described a method for discovering an ideal hyperplane that maximizes the margin between two groups of samples in their work from 2016. To differentiate between fault and transient switching scenarios, an additional SVM was added to each phase's SVM. The complexity of the wavelet coefficients was decreased using principal component analysis (PCA) and the discrete wavelet transform (DWT) before they were given to the SVMs for fault-type classification [6]. The

quarter-sphere SVM (QSSVM) can map the input vectors so that the inputs from normal states are maintained inside and the inputs from faulty states are kept outside the quarter sphere.

iv. Concurrent Neuro-Fuzzy (CNF) Technique

According to Researcher [7], the power transmission line (PTL) model 1 and 2 CNF approach attained and gained the highest prediction accuracy as data volume rose. In the first PTL model (750 kV), the CNF accuracy for fault location and fault type detection is 99.2309% and 97.47%, respectively [7]. In the second PTL model (400 kV), CNF accuracy is 97.8% for fault location and 95.7% for fault type detection.

v. Wavelet Technique

According to Researcher [8], this method combines multi-resolution analysis (MRA) and discrete wavelet transform (DWT). Using the db1 wavelet, the three-phase currents are split into approximations (A) and details (D) [8]. The initial decomposition level's details (D1) are used to determine the anomalous situation in each phase current. The phase is deemed faulty if the estimated norm value exceeds the threshold value. The gearbox system is in good condition when the threshold values for the three-phase current norms are all exceeded. The proposed method yields accurate results for all fault types and is suited to high fault resistances of up to 500.

B. Simulation and Analysis Works

Utilizing the SimPowerSystems toolbox found in Simulink within the MATLAB environment, this power system model is being simulated [5]. Figure 1 shows the full model of the transmission line for testing and training.

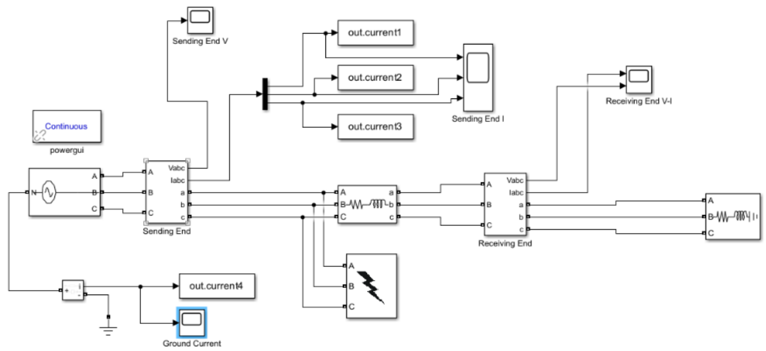


Figure 1: The model of the transmission line for testing and training

The power system model consists of four parts of the block diagram which are the sending end, the busbar, the signal data recoding point and the receiving end. The function of every part of the transmission line is as follows:

i. The Sending End

The sending end of the transmission line is the main power source of the simulation. The phase-to-phase voltage (Vs ph-ph) at the block diagram is set up to 21.32∠3.93° kV with the frequency of 50 Hz which is the general frequency that is in Malaysia. The line voltage (Vs line) of the simulation is set to 36.93 kV as it was used to simulate the HV transmission line for this project [9]. Next, the three-phase source is connected to the three-phase V-I measurement block which will measure the input voltage and input current of the simulation.

ii. The Busbar

The block used for the busbar is a three-phase series RLC branch which needs to set up the value of resistance and the inductance used per length of the transmission line in unit kilometer (km). The length used for the simulation power system model busbar is 40 km. The block for the three-phase fault is placed between the V-I measurement block for the sending end and the busbar to generate the fault condition for the transmission line in the simulation.

iii. Signal Data Recording Point
The collected data can be seen in the Scope. In the sending end signal data recording point, there are two types of data that will be collected which are the current for each line and the voltage value of the sending end. The data collected from the current for each line are used to analyse the maximum coefficient value of each phase current and ground current. The process occurred to determine the threshold value used for fault detection and classification on the transmission line. The data of the input voltage and input current will be gathered and shown in the scope to see if there are increments or deduction of current that indicates that there are faults happening.

iv. The Receiving End
The receiving end which has a three-phase series load is attached to the three-phase V-I measurement block. The V-I measurement will measure the output voltage and output current flows through the transmission line. The three-phase series load has set up the parameter used which the active power is set to 45.72 MW and the inductive reactive power (QL) is set to 34.29 MVAR.

The analysis process incorporated the Wavelet Technique to get the desired result on the signal data produced by the simulation system. Figure 2 shows the workflow used by the Wavelet Transform to analyze and compose the sinusoidal signal data to get the desirable value in this simulation [10].

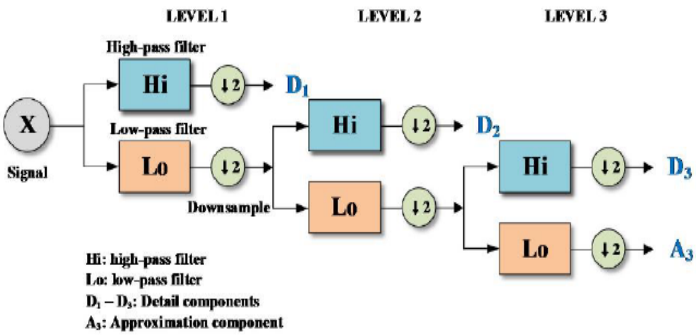


Figure 2: The Wavelet Transform technique to analyse signal data

Based on the coding of the system, it used the Wavelet Transform syntax to apply on signal.

$$[c, 1] = wavedec(x, n, wname); \quad \text{Eq. 1}$$

where,

wavedec = function which decomposes the signal.
x = signal
n = wavelet layer (default =1)
wname = name of the wavelet type (such as haar, Daubechies etc)
c = output wavelet decomposition vector
1 = number of coefficients by level

Next, the system used different syntax for detailed coefficients of the signal of every phase current and ground current. The data will be collected to determine the threshold value for each fault that occurred in the simulation.

$$D = detcoef(C, L, N); \qquad \text{Eq. 2}$$

Where,

detcoef = function which obtains the detailed coefficients of the signal
c = output wavelet decomposition vector
l = number of coefficients by level
n = wavelet layer (default = 1)
D = extracts the detail coefficients at the coarsest scale from the wavelet decomposition structure [C, L]

The system shows the value of maximum coefficient value for each phase current and ground current. The system also will show the result if there is a fault occurs and classify the type of fault based on the threshold value setup. The result will show the type of fault that the system detected. The flow process of the simulation work of the transmission line can be seen in Figure 3.

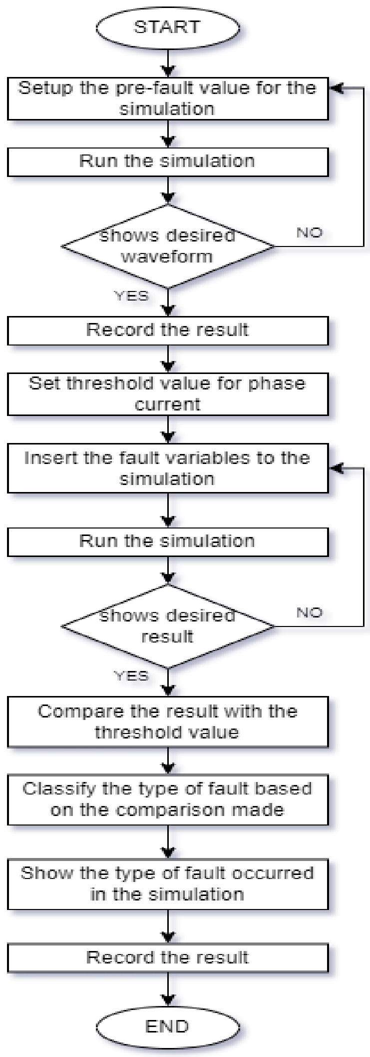


Figure 3: The flow process of systems works in the simulation

3. Results and Discussion

The results that had been gathered from the simulation are presented in this section. As a result of the fault that occurred on the cables, these results will also provide observations on the current analysis of when the fault occurred on the transmission lines. The results can be seen in four types of conditions which are no-fault, line to ground fault, line to line fault and line to line to ground fault.

A. Results on Waveform of Phase Current

Figure 4(a) shows the waveform of the phase current while Figure 4(b) shows the ground current when the simulation system consists of no-fault condition. Based on the result, it can be identified that the 3-phase current shows no increment value at any point on the waveform and the waveform shows a normal sinusoidal waveform. The tabulated value in Table 1 can be used as a threshold value to limit the normal reading of phase which is declared to be no fault. The assumed threshold value for this project is a maximum coefficient value that is below the value of 200 A.

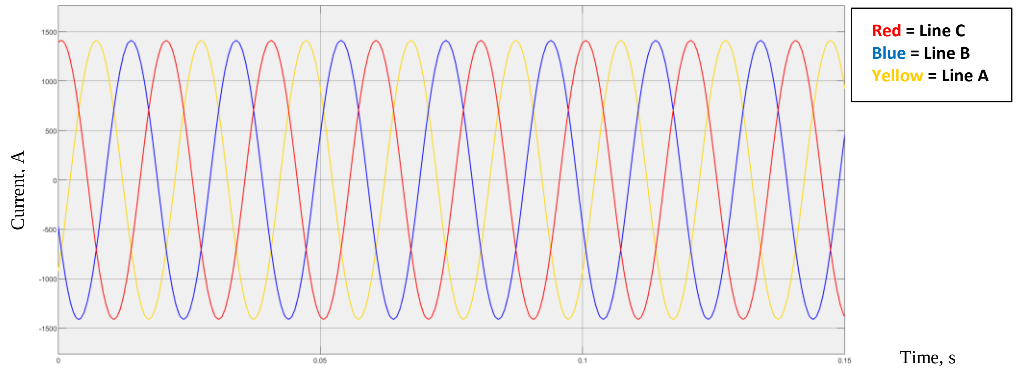


Figure 4(a): The 3-phase current waveform with no fault added to the simulation

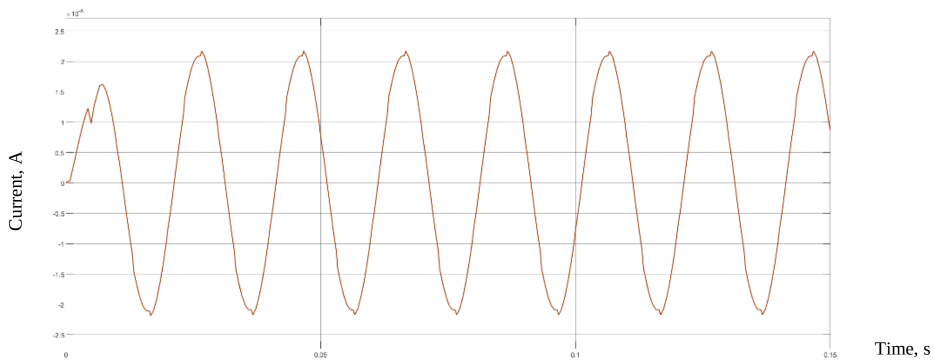


Figure 4(b): The ground current waveform with no fault added to the simulation

Table 1: The result collected from the simulated system

Type of Current	Maximum Coefficient of Current
Phase A	103.3885
Phase B	103.3885
Phase C	103.3885
Ground	1.539×10^{-9}

Figure 5 shows the maximum coefficient of the current value, and it also shows the detection and classification of fault types that occurred in the simulation. Hence, the presented result shows that the system cannot detect any fault that occurred in the simulation.

```
m =

   131.9439


n =

   131.9421


p =

   131.9421


q =

    3.9809e-09

No Fault is Detected
```

Figure 5: The value max. coefficient of current and the detection of no fault

The results show the waveform generated from phase current when the types of faults occurred. It can analyze that there is a temporary overcurrent when the fault occurs which causes instability in the waveform [10]. The result of waveform for four types of conditions which are line to ground fault, line to line fault, line to line to ground fault and three phase faults as can be seen in Figure 6.

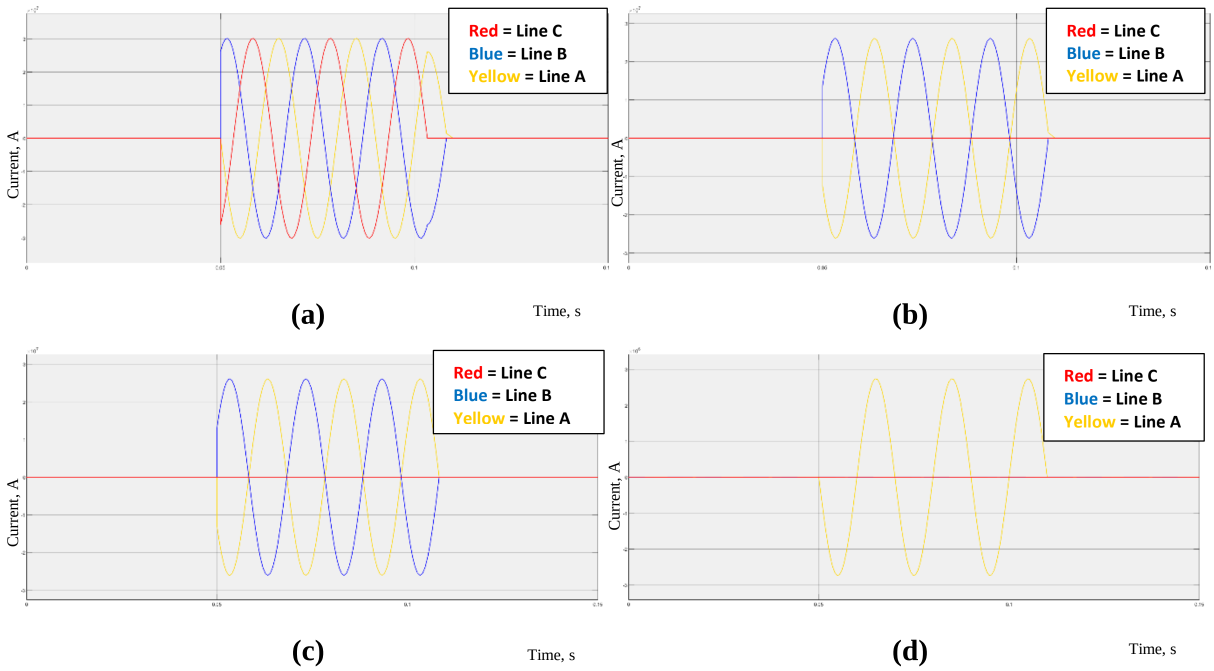
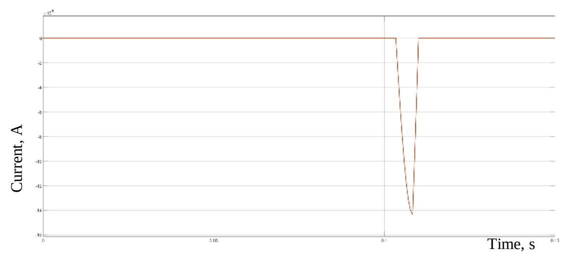
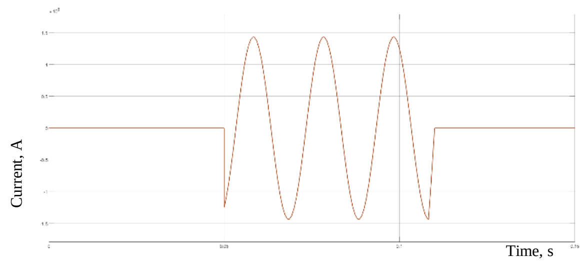


Figure 6: The 3-phase current waveform with fault added (a) for 3-phase to ground fault (b) for double line-to-ground fault (AB-G); (c) for line-to-line fault (A-B); and (d) for line-to-ground fault (phase A)

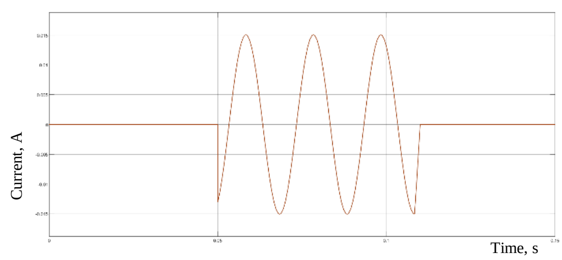
Figure 7 depicts the ground current for each type of fault. It can be analyzed that when the fault occurred, it also affected the ground current, as evidenced in the waveform captured. Figure 8 depicts the output of the systems, which gives the maximum coefficient for each phase current and is used to define the type of failure that occurred in the simulation. Based on the results, it indicates the categorization of the fault that was recognised in the simulation system, which is the type of fault variables that had happened.



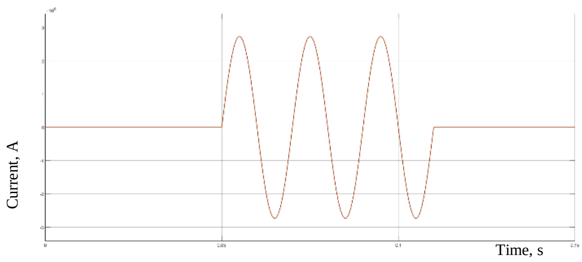
(a)



(b)

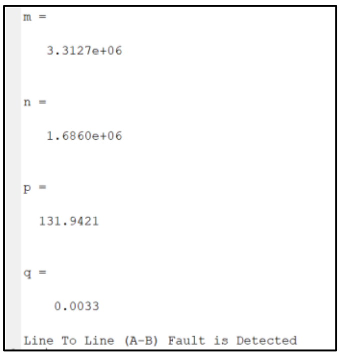


(c)



(d)

Figure 7: The ground current waveform with fault added (a) for 3 phase to ground fault (b) for double line to ground fault (AB-G); (c) for line-to-line fault (A-B); and (d) for line to ground fault (phase A)



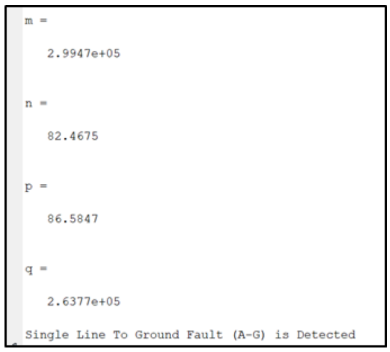
```
m =
   3.3127e+06

n =
   1.6860e+06

p =
  131.9421

q =
    0.0033
Line To Line (A-B) Fault is Detected
```

(a)



```
m =
   2.9947e+05

n =
   82.4675

p =
   86.5847

q =
   2.6377e+05
Single Line To Ground Fault (A-G) is Detected
```

(b)

Figure 8: The value max. coefficient of current and the detection of (a) line-to-line fault (A-B) and (b) line-to-ground fault (phase A)

B. Results on Maximum Coefficient of Phase Current

This study analysed the accuracy of data classification and detection with the implementation of four types of faults that led to 11 types of faults as variables. Table 2 shows the compiled data of the maximum coefficient of phase current for every fault type that occurred in the simulation works.

Table 2: The compile data of maximum coefficient for each phase current and ground current

Type of Fault	Max. coefficient of Phase A Current	Max. coefficient of Phase B Current	Max. coefficient of Phase C Current	Max. coefficient of Ground Current
Three Phase To Ground Fault	1.3993×10^6	1.2100×10^7	4.9700×10^6	1.0597×10^5
Three Phase Fault	1.3019×10^6	1.3019×10^6	6.0160×10^6	$\mathbf{0.0012}$

Double Line To Ground Fault (AB-G)	1.7063×10^6	5.7076×10^6	$\mathbf{94.6087}$	2.3667×10^5
Double Line To Ground Fault (AC-G)	7.0853×10^6	$\mathbf{94.6054}$	3.3931×10^6	5.7617×10^5
Double Line To Ground Fault (BC-G)	$\mathbf{88.3633}$	1.2730×10^7	4.6555×10^6	6.3027×10^4
Line To Line (A-B) Fault	3.0080×10^6	1.5310×10^6	$\mathbf{106.2039}$	$\mathbf{0.0030}$
Line To Line (A-C) Fault	1.4039×10^6	**93.7974**	3.0080×10^6	$\mathbf{0.0013}$
Line To Line (B-C) Fault	**106.1996**	8.2857×10^5	6.0160×10^6	$\mathbf{0.0015}$
Single Line To Ground Fault (A-G)	2.6689×10^5	$\mathbf{132.0942}$	$\mathbf{103.3885}$	2.6679×10^5
Single Line To Ground Fault (B-G)	**88.3633**	1.0999×10^6	**132.0938**	3.9179×10^5
Single Line To Ground Fault (C-G)	$\mathbf{132.2265}$	$\mathbf{103.3885}$	4.9532×10^5	1.2203×10^6
System Without Fault	$\mathbf{103.3885}$	$\mathbf{103.3885}$	$\mathbf{103.3885}$	$\mathbf{1.5399 \times 10^{-9}}$

C. Discussions

Based on the Wavelet technique, the data collected are based on the transient signal in the power system and the analysis made is based on the temporary over current that happen in the simulation. As stated before, the assumed threshold value for this project is 200 A. This value is selected since the value of maximum coefficient of each phase current will not exceed the value of 200 A when there is no fault occurred on the line. As example, it can be seen for three phase faults that the value of coefficient for ground current is below threshold value. The classification on types of fault can be made based on the threshold value of maximum coefficient for phase current according to the fault variables. This threshold value is used in the coding to clarify the type of fault and the result shows the type of fault variables occurred in the transmission line.

4. Conclusion

The MATLAB Simulink simulation program was used in this project to successfully develop a modest transmission line system that can handle 33 kV. The analysis was conducted by using the designated power system model with algorithm that calculates the accurate detection and classification of fault in the transmission line. Using the simulation software, this project was also able to precisely simulate the no-fault and with-fault conditions in the transmission line system. This study analysed the accuracy of data classification and detection with the implementation of four types of faults that lead to 11 types of faults as variables. To obtain a complete analysis of the condition, this study also effectively analysed the 3-phase current's increment and decrement of value based on the fault that occurred. It did this by using the Wavelet technique. The Wavelet technique is the technique used to identify the power system disturbance between transmission line which in this project focused on the power systems faults. The algorithm that has been design for the system utilize the current threshold value obtained by detailed analysis of the test. After detection of fault, the Wavelet Transform is used to identify the fault type. The sinusoidal signal data collected can be analysed on detailed coefficient signal to set the algorithm on the condition of fault for the system to automatically detect and classify the type of fault occurred.

Acknowledgement

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