International Journal of Science and Engineering Applications
Volume 8–Issue 08,366-370, 2019, ISSN:-2319–7560

Study and Analysis of Double-Line-To-Ground Fault

Ei Ei Phyu
Department of Electrical Power
Engineering,
Technological University,
(Thanlyin), Myanmar

Abstract: During normal operating conditions, current will flow through all elements of the electrical power system within pre-designed values which are appropriate to these elements' ratings. Any power system can be analyzed by calculating the system voltages and currents under normal and abnormal conditions. Faults could happen as a result of natural events or accidents where the phase will establish a connection with another phase, the ground or both in some cases. Faults can also be defined as the flow of a massive current through an improper path which could cause enormous equipment damage which will lead to interruption of power, personal injury, or death. In addition, the voltage level will alternate which can affect the equipment insulation in case of an increase or could cause a failure of equipment start-up if the voltage is below a minimum level. As a result, the electrical potential difference of the system neutral will increase. Hence, people and equipment will be exposed to the danger of electricity which is not accepted. In order to prevent such an event, power system fault analysis was introduced. In double-line-to-ground fault, two phases to ground will be involved and 10% of all transmission lines faults are under this type of faults. In this paper, double-line-to-ground fault on Thanatpin transmission line is analyzed with Matlab simulation.

Keywords: electric power transmission system; types of faults; double-line-to-ground fault; sequence networks; Matlab simulation.

---

1. INTRODUCTION

Electric power is generated, transmitted and distributed via large interconnected power systems. This could encounter various types of malfunctions is usually referred to as a Fault.

To prevent such an undesirable situation, the temporary isolation of the fault from the whole system it is necessary as soon as possible. This is accomplished by the protective relaying system. The process of evaluating the system voltages and currents under various types of short-circuits is called fault analysis which can determine the necessary safety measures & the required protection system to guarantee the safety of public.

Faults can be defined as the flow of a massive current through an improper path which could cause enormous equipment damage which will lead to interruption of power, personal injury, or death. In addition, the voltage level will alternate which can affect the equipment insulation in case of an increase or could cause a failure of equipment start-up if the voltage is below a minimum level. As a result, the electrical potential difference of the system neutral will increase. Hence, People and equipment will be exposed to the danger of electricity which is not accepted.

When different types of fault occurs in power system then in the process of transmission line fault analysis, determination of bus voltages and the rms line currents are possible. While consulting with the power system the terms bus voltage and rms current of line are very important. In case of three phase power system mainly two faults occurs, three phase balance fault and unbalance fault on transmission line of power system, such as single line to ground fault, double line to ground fault and line to line fault. The transmission line fault analysis helps to select and develop a better for protection purpose. By using MATLAB simulation in computer, the analysis of transmission line fault can be easily carried out.

In three-phase transmission line of power system; mainly two types of fault occurs, balance fault which is also called symmetrical fault and unbalance fault called as unsymmetrical fault. In this paper, only deals with the unsymmetrical fault which mainly occurs between two conductors and ground.

To study and analyze the unsymmetrical fault in MATLAB, there is a need of develop a network of positive, negative and zero sequence. In this paper, positive, negative and zero sequence voltage and current of buses at fault situation are analyzed.

2. TYPES OF FAULTS

There are two types of faults which can occur on any transmission lines; balanced faults and unbalanced faults also known as symmetrical and asymmetrical faults respectively. Most of the faults that occur on power systems are not the balanced three-phase faults, but the unbalanced faults. Faults can be classified into four categories. Line-to-ground fault, Line-to-line fault, Double line-to-ground, Three-phase fault. The first three of these faults are known as asymmetrical faults and three-phase fault is known as symmetrical fault.

2.1 Line-to- Ground Fault (LG)

This type of fault exists when one phase of any transmission lines establishes a connection with the ground either by ice, wind, falling tree or any other incident. 70% of all transmission lines faults. This type of fault occurs when one conductor falls to ground or contacts the neutral wire. It could also be the result of falling trees in a winter storm. This type could be represented as in Figure 1.

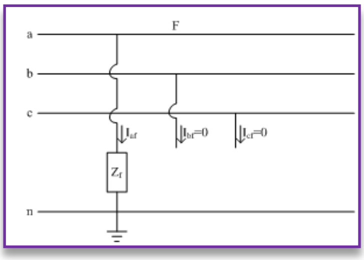

Figure 1. Single Line to Ground Fault

2.2 Line-to-Line Fault (LL)

This type of fault as a result of high winds, one phase could touch anther phase and line-to-line fault takes place. 15% of all transmission lines faults are considered line-to-line faults. As in the case of a large bird standing on one transmission line and touching the other, or if a tree branch fall on top of the two of the power lines. This type could be represented as in Figure 2.

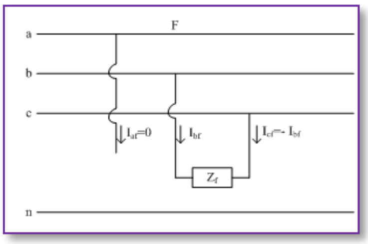

Figure 2. Line to Line Fault

2.3 Double-Line-to-Ground Fault (DLG)

This type of fault is caused by falling tree where two phases become in contact with the ground could lead to this type of fault. In addition, two phases will be involved instead of one at the line-to-ground faults conditions. 10% of all transmission lines faults are under this type of faults. The Double Line-to-Ground fault (DLG) is shown in Figure 3. This can be a result of a tree falling on two of the power lines, or other causes.

In double line-to-ground fault, the two lines contact with each other along with the ground. The probability of such types of faults is nearly 10 %. The symmetrical and unsymmetrical fault mainly occurs in the terminal of the generator, and the open circuit and short circuit fault occur on the distribution system.

In this paper, the calculation of double line to ground fault on 66/33 kV transmission line is emphasized.

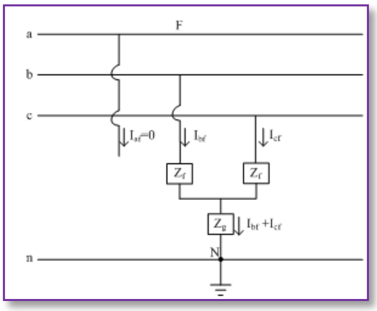

Figure 3. Double-Line-to-Ground Fault

2.4 Three-Phase Fault

In this case, falling tower, failure of equipment or even a line breaking and touching the remaining phases can cause three phase faults. In reality, this type of fault not often exists which can be seen from its share of 5% of all transmission lines faults. The balanced three phase, Figure 4, which can occur by a contact between the three power lines in many different forms.

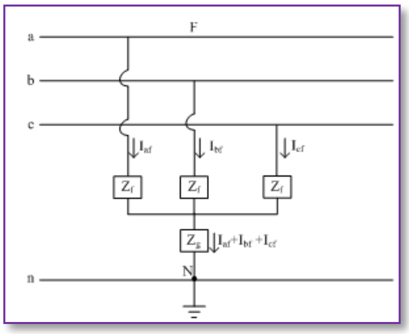

Figure 4. Three Phase Fault

3. DOUBLE-LINE-TO-GROUND FAULT CALCULATIONS

In double-line-to-ground fault, two phases established the connection with the ground.

To calculate the unsymmetrical faults, firstly, the positive sequence component of phase-a has been calculated. Thus, sequence reactances of thevenin equivalent circuits (Z_1, Z_2, Z_0) have been calculated. The fault currents of sequences have been determined by using these reactances and phase voltage Ea. The current and voltage values of other phases could be calculated via these components.

$$I_{a1} = \frac{E_a}{Z_1 + \frac{Z_0 Z_2}{Z_0 + Z_2}}$$

$$I_{a2} = -\frac{Z_0}{Z_0 + Z_2} I_{a1}$$

$$I_{a0} = -\frac{Z_2}{Z_0 + Z_2} I_{a1}$$

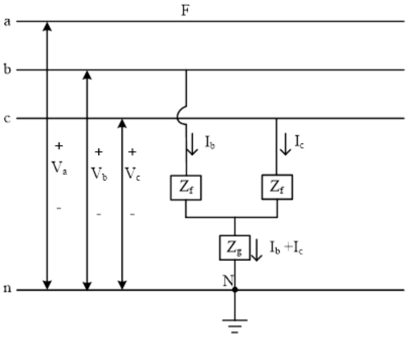

Figure 5 Double Line to Ground Fault Configuration

$$\begin{vmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{vmatrix} = \begin{vmatrix} 0 \\ E_a \\ 0 \end{vmatrix} - \begin{vmatrix} Z_0 & 0 & 0 \\ 0 & Z_1 & 0 \\ 0 & 0 & Z_2 \end{vmatrix} \begin{vmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{vmatrix}$$

The positive sequence reactance must be calculated from for the time variations of signals.

$$X_1(t)=\left\{\left(\frac{1}{X_d^{''}}\frac{1}{X_d^{'}}\right)e^{-t/\tau_d^{''}}+\left(\frac{1}{X_d^{''}}\frac{1}{X_d^{'}}\right)e^{-t/\tau_d^{'}}+\frac{1}{X_d}\right\}^{-1}$$

where, X_d'', X_d', X_d are direct-axis subtransient, transient and synchronous reactances; τ_d'', τ_d' are direct-axis fault subtransient and transient time constants; E_a, E are complex and RMS value of phase-a voltage of synchronous machine terminal before the fault occurrence.

3.1 Sequence Network for Double-Line-to-Ground Fault

Faulted power systems do not have three phase symmetry, so it cannot be solved by per phase analysis. To find fault currents and fault voltages, it is first transformed into their symmetrical components. This can be done by replacing three phase fault current by the sum of a three phase zero sequence source, a three-phase positive sequence source and a three phase negative sequence source. Each circuit is solved by per phase analysis called a sequence network. In this section, all the sequence components of fault voltages and currents for double-line-to-ground fault are determined.

Assuming the phase b and c are connected to the ground through the fault impedance Z_f. For double line to ground fault, fault current on phase a is $I_a = 0$.

Fault voltages at phase b and c are:

$$V_b = V_c = Z_f(I_b + I_c)$$

Fault currents in phase b and c are:

$$\begin{vmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{vmatrix} = \frac{1}{3}\begin{vmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{vmatrix}\begin{vmatrix} I_a \\ I_b \\ I_c \end{vmatrix}$$

$$I_{a0} = \frac{1}{3}(I_b + I_c)$$

$$V_b = V_c = Z_f 3I_{a0}$$

$$\begin{vmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{vmatrix} = \frac{1}{3}\begin{vmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{vmatrix}\begin{vmatrix} V_a \\ 0 \\ 0 \end{vmatrix}$$

$$V_{a0} = V_{a1} = V_{a2}$$

$$I_{a0} + I_{a1} + I_{a2} = 0$$

Since, the zero, positive and negative sequence voltages are equal which imply that the sequence networks must be in parallel.

$$V_{a0} = \frac{1}{3}(V_a + V_b + V_c)$$

Since, $V_b = V_c$,

$$3V_{a0} = (V_a + 2V_b) = V_{a0} + V_{a1} + V_{a2} + 2(Z_f 3I_{a0})$$

Since, $V_{a1} = V_{a2}$,

$$3V_{a0} = V_{a0} + 2V_{a1} + 2(Z_f 3I_{a0})$$

$$2V_{a0} - 2(Z_f 3I_{a0}) = 2V_{a1}$$

$$V_{a1} = V_{a0} - (Z_f 3I_{a0})$$

Fault currents are:

$$I_{a1} = \frac{V_f}{Z_1 + \left[\dfrac{Z_2(Z_0 + 3Z_f)}{Z_0 + Z_2 + 3Z_f}\right]}$$

$$I_{a2} = -\frac{Z_0 + Z_f}{Z_0 + Z_2 + 3Z_f} I_{a1}$$

$$I_{a0} = -\frac{Z_2}{Z_0 + Z_2 + 3Z_f} I_{a1}$$

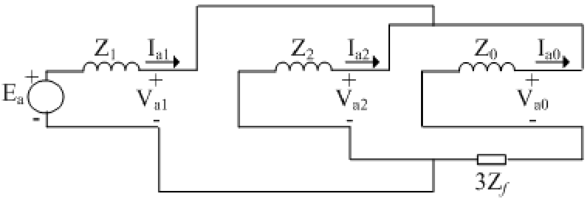

Figure 6. Equivalent Circuit of Double-Line-to-Ground Fault

3.2 Bayargyi Ayethuka Substation Transmission System

In order to do the analysis for a double-line-to-ground fault, 33kV Baryargyi Ayethuka to Thanatpin line is selected from 230 kV Kamanut sub-station.

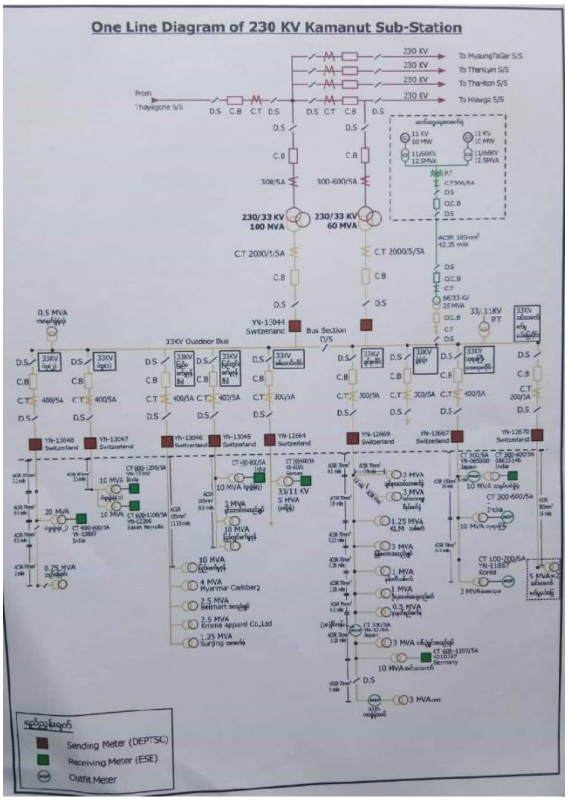

Figure 7 Single line diagram of 230 kV Kamanut substation

3.3 Sequence Impedance Parameters

For 33 kV, 10 MVA Bayargyi Ayethuka substation to Thanatpin line, sequence impedance parameters are shown in Table 1 and 2.

Table 1 Line Parameters

Description	Rating	Voltage Rating	Z1 (Ω)		Z2 (Ω)		Z0 (Ω)	
			R1	X1	R2	X2	R0	X0
Bayargyi Ayethuka substation	10 MVA	33 kV	0	j0.1289	0	j0.1289	0	j0.0309
Thanatpin Line	11 km	33 kV	1.0307	4.3428	1.0307	4.3428	4.1250	8.7362

Table 2 Per Unit Sequence Network Impedance Parameter

Description	Z1	Z2	Z0
Bayargyi Ayethuka substation	j0.032	j0.032	j0.0201
Thanatpin Line	0.2555+j1.0767	0.2555+j1.0767	0.093+j0.1969

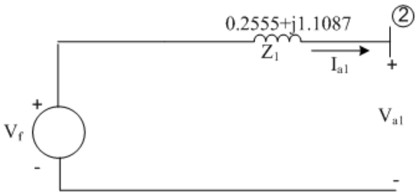

Figure 8 Positive Sequence Impedance Network

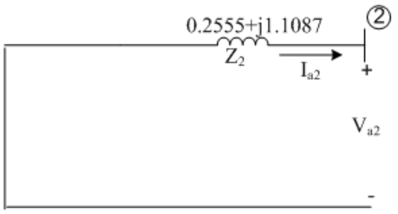

Figure 9 Negative Sequence Impedance Network

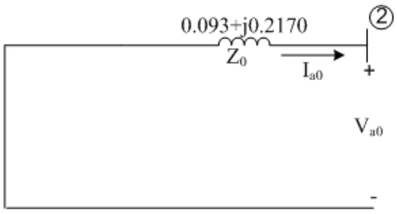

Figure 10 Zero Sequence Impedance Network

3.4 Line Currents and Line Voltages due to Double-Line-to-Ground Fault

For the study of fault analysis, assume that the load is disconnected, and fault impedance is zero (bolted fault). Assume that Bayargyi Ayethuka substation to Thanatpin Line as bus ②, and Thevenin equivalents of the sequence network due to double-line-to-ground fault is shown in Figure 11.

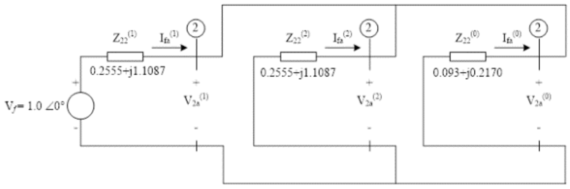

Figure 11 Thevenin Equivalents of the Sequence Networks for Double Line to Ground Fault at Bus ②

Positive, Negative and Zero sequence fault current at bus ②,

$$I_{fa}^{(1)} = \frac{1}{(0.2555+j1.1087)+\dfrac{(0.2555+j1.1087)\times(0.093+j0.2170)}{(0.2555+j1.1087)+(0.093+j0.2170)}} = 0.0299-j0.6452$$

$$I_{fa}^{(2)} = -(0.0299-0.6452)\times\frac{(0.093+j0.2170)}{(0.2555+j1.1087)+(0.093+j0.2170)} = 0.0133+j0.1107$$

$$I_{fa}^{(0)} = -(0.0299-j0.6452)\times\frac{(0.2555+j1.1087)}{(0.2555+j1.1087)+(0.093+j0.2170)} = -0.0412+j0.5345$$

Fault current at bus ②,

$$\begin{bmatrix} I_{fa} \\ I_{fb} \\ I_{fc} \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} -0.0412+j0.5345 \\ 0.0299+j0.6452 \\ 0.0133+j0.1107 \end{bmatrix}$$

$$= \begin{bmatrix} 0 \\ 1.1818\angle 153.45^\circ \\ 1.1818\angle 33.45^\circ \end{bmatrix} \text{pu}$$

The actual values of current due to double-line-to-ground fault at bus ②,

∴ $I_{fa} = 0$
$I_{fb} = 1.8609$ kA
$I_{fc} = 1.8609$ kA

Positive, Negative and Zero sequence fault voltages at bus ②,

$$V_2^{(1)} = V_2^{(2)} = V_2^{(0)} = 1-[(0.0299+j0.6452)\times(0.2555+j1.1087)] = 0.2770+j0.1317$$

Line-to-neutral fault voltage at bus ②,

$$\begin{bmatrix} V_{2a} \\ V_{2b} \\ V_{2c} \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} 0.2770+j0.1317 \\ 0.2770+j0.1317 \\ 0.2770+j0.1317 \end{bmatrix}$$

$$= \begin{bmatrix} 0.920\angle 25.43^\circ \\ 0 \\ 0 \end{bmatrix} \text{pu}$$

The actual values of phase to ground voltgaes due to double-line-to-ground fault at bus ②,

∴ $V_{2a} = 5.8428$ kV
$V_{2b} = 0$
$V_{2c} = 0$

4. RESULT AND DISCUSSION

4.1 Simulink Model for Double-Line-to-Ground Fault in Proposed Line

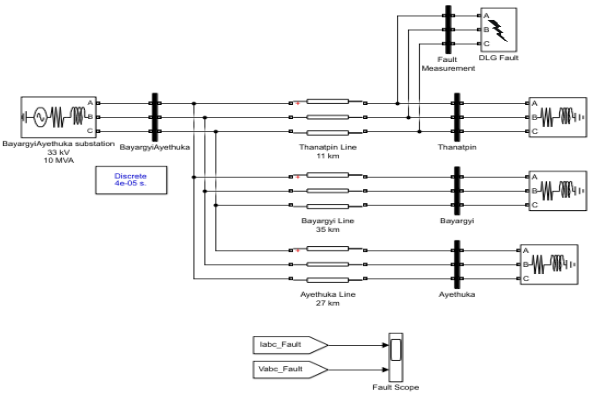

Figure 12 Simulink model of Double-Line-to-Ground Fault near Thanatpin Line

In order to study and analyze the transmission line fault, the simulation circuit arrangements are used which is shown in Figure 12, and bolted double-line-to-ground fault is created near Thanatpin bus.

4.2 Simulation Result and Discussion

Before performing transient tests, the model must be initialized at steady-state condition. For the desired fault, by using the utility of the fault breaker to obtain the double-line-to-ground fault currents and voltages near Thanatpin bus.

Figure 13 shows the current and voltage results of double line to ground fault at faulted bus.

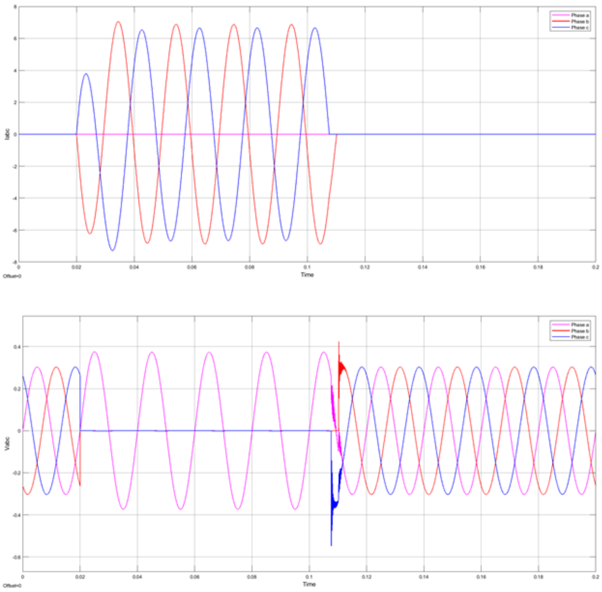

Figure 13 Currents and Voltages output waveforms

The period for creation of fault is of 0.02 to 0.11 second. In double line-to-ground fault simulation, phase b and c currents magnitude 2.35 pu and 2.22 pu respectively and phase a current magnitude is zero during fault period. Phase b and c voltages are zero and phase a voltage magnitude is 1.126 pu during fault. After 0.11 sec, the system is regained in steady-state. All the voltages and currents are in stable condition.

The results were compared with software solutions to validate the accuracy of the hand calculations.

In hand calculation results, the current magnitude values of phase b and c are more than that of simulation results because of the presence of capacitance and magnetization effect in MATLAB simulation. The voltage magnitude values of phase a are nearly the same in both hand calculations and simulation results.

5. CONCLUSION

Most of the faults that occur on power systems are unsymmetrical faults, which may consist of unsymmetrical short circuits, unsymmetrical faults through impedances, or open conductors. Unsymmetrical faults occur as single line to ground faults, line to line faults or double line to ground faults.

Since any unsymmetrical fault causes unbalanced currents to flow in the system, the method of symmetrical components is very useful in an analysis to determine the currents and voltages in all parts of the system after the occurrence of the fault. Faults on a power system are considered by applying Thevenin's theorem, which allows finding the current in the fault by replacing the entire system by a single generator and series impedance, and the bus impedance matrix is applied to the analysis of unsymmetrical faults can be calculated.

Unbalanced voltages and currents can be resolved into their symmetrical components. Problems are solved by treating each set of components separately and superimposing the results. A knowledge of the positive, negative and zero sequence network is necessary for power flow studies, fault calculations, and stability studies. If the fault calculations or stability studies involve unsymmetrical faults on otherwise symmetrical systems, the negative and zero sequence networks are also needed. Synthesis of the zero-sequence network requires particular care because the zero-sequence network may differ from the others considerably.

This paper investigates the problem of double line to ground fault calculation in three phase power systems. And, the proposed model of three phase transmission line system is simulated with MATLAB software. The hand calculations and the software results are nearly the same corresponding to the same proposed network.

6. ACKNOWLEDGEMENTS

First of all, the author would like to express her special thanks to Dr. Myo Thein Gyi, Union Minister of Education, the Republic of the Union of Myanmar, for his encouragement to do research works for regional development and applied science. The author grateful thanks o to Dr. thein Gri, Rector of Technological University (Thanlyin) for her kind guidance, suggestion and directions throughout the preparation of research work, and valued motivations and encouragement as well. Finally, the author also sincerely thankful to our colleagues form the Department of Electrical Power Engineering, Technological University (Thanlyin) offered strong moral and physical support.

7. REFERENCES

[1] John J. Grainger & William D. Stevenson, Jr., 1994. Power System Analysis. McGraw-Hill Book Inc.

[2] Hadi Saadat, 1999. Power System Analysis. McGraw-Hill Book Inc.

[3] J.C.Das, 2002. Power System Analysis Short-Circuit Load Flow and Harmonics. Marcel Dekker Inc.

[4] Jorge Santamaria, 2011. Analysis of Power Systems Under Fautl Conditions. M.S Thesis.

[5] William Patrick Davis, 2012. Analysis of Faults in Overhead Transmission Lines. M.S Thesis