Available online www.jsaer.com

***Journal of Scientific and Engineering Research*, 2017, 4(8):199-212**

Review Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Overhead Transmission Line Modeling Study

Isa S. Qamber, Sayed Ali Hassan, Taha Juma Ali, Maitham Farahat, Hussain A. Nabi

Electrical and Electronics Engineering Department, University of Bahrain, P.O. Box 33831, Isa Town, Kingdom of Bahrain

Abstract In the present study, faults that might occurred on the transmission lines and the impact of these faults on voltages and currents by using PSPICE (Version 9.1) and Laboratory Simulator, which are available in the department laboratory. The effectiveness of PSPICE in calculating the faults on voltages and currents are considered and demonstrated. Three fault cases studied. I the present study, the results obtained using the PSPICE and compared with the experimental results.

Keywords PSPICE, Experiments, Transmission Lines

1. Introduction

The study is presented with useful information about transmission lines, recruit the P-Spice in high voltage works, studying the transmission lines equivalent circuit at fault conditions and a comparison between PSPICE and Laboratory Simulator is carried out.

2. Overhead Transmission lines

The generators and loads are connected together through transmission lines. Transporting the electric power from one point to another is required as a service to the customer. Transmission line transmitting the power to the areas where it will be utilized, and after that arranging it to individual customers.

The power capability of a transmission line is proportional to the square of the voltage on the line [1]. Therefore, the high voltage levels are used to transmit and control power over long distances. If the power reaches the wanted area it is becoming available for use, where it is stepped down to a lower voltages in the distribution substations, and then delivered to customers by distribution lines. The overhead transmission line comprises of three conductors or packs of conductors containing the three phases of the power system. The conductors are usually aluminium cable steel reinforced (ACSR), which are steel core (for strength) and aluminium wires (having low resistance) wrapped around the core. The ACSR is defined as type of high-capacity, high-strength stranded conductor. The ACSR typically used in overhead transmission power lines. The outer strands are high-purity aluminum. In addition to phase conductors, a transmission line usually contains one or two steel wires called ground (shield) wires. These wires are connected to the tower and to the ground. In substantial transmission lines, these wires are situated over the stage conveyors, protecting them from lightning. In real overhead transmission lines, the line reactance X_L is normally much higher than the line resistance R; so, the line resistance is often neglected.

The maximum power handling capability of a transmission line is inversely proportional to its series reactance [1], which is a real problem for long transmission lines. Some very long lines include series capacitors to reduce the total series reactance and thus increase the total power handling capability of the line. Sag effect on Transmission Line is always taken under consideration, where sag means to be bending in shape [2]. In overhead transmission lines, the difference in level between points of supports (towers or utility poles) and the lowest point on the conductor is called Sag .Therefore, sag is causes by tension of the transmission line and must not be too low, otherwise the safety clearance may not be met. The factors that affect the sag are temperature, age and wind.

3. Model of transmission line

Short Transmission line:

A transmission line is defined as a short-length line if its length is less than 80 km (50 miles). In this case, the capacitive effect is negligible and only the resistance and inductive reactance are considered. Assuming balanced conditions, the line can be represented by the equivalent circuit of a single phase with resistance Fig. (1).

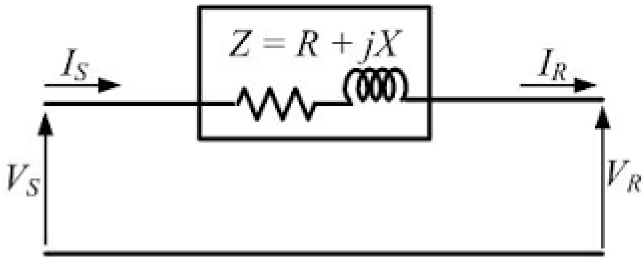

Figure 1: Short Transmission Line Model

Medium Transmission line:

If the line is between 80 km (50 miles) and 240 km (150 miles) long, the line is considered a medium length. The line single-phase equivalent circuit can be represented in a nominal π (Fig. 2 A) or T configurations (Fig. 2 B). The shunt capacitance of the line is divided into two equal parts, each placed at the sending and receiving ends of the transmission line. Both short- and medium-length transmission lines use approximated lumped-parameter models.

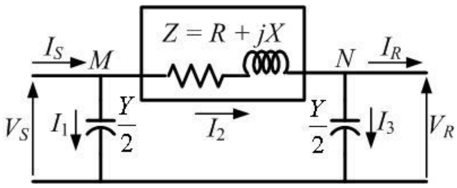

Figure (2 A): Nominal π Medium Transmission Line Model

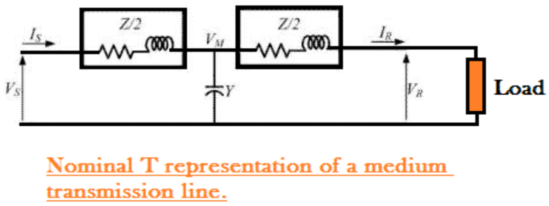

Figure (2 B): Nominal T Medium Transmission Line Model

Long Transmission line

If the line is more than 240 km long, the model must consider parameters uniformly distributed along the line. The single-phase equivalent circuit (Fig. 3) can represent the long transmission line.

3. Fault in Transmission line

Transmission lines fault studies are important part of power system analysis [3]. First, a fault represents the structural network change equivalent caused by the addition of impedance at the location of the fault. To simplify the calculation, each part of the system is modeled. Such a model is (Buses model) measuring the voltage and magnitude in each bus, (Transmission Line Model) measuring the electrical power transmits from sending end to receiving end. Basically there are three types of models for transmission lines. These three are short, medium, and long transmission lines which already defined earlier. As well, there are several types of faults (Single Line-to-ground), (Line-to-line), (Double line-to-ground), and (balance fault). Detecting and locating fault has been always the goal to achieve as early as possible with some techniques.

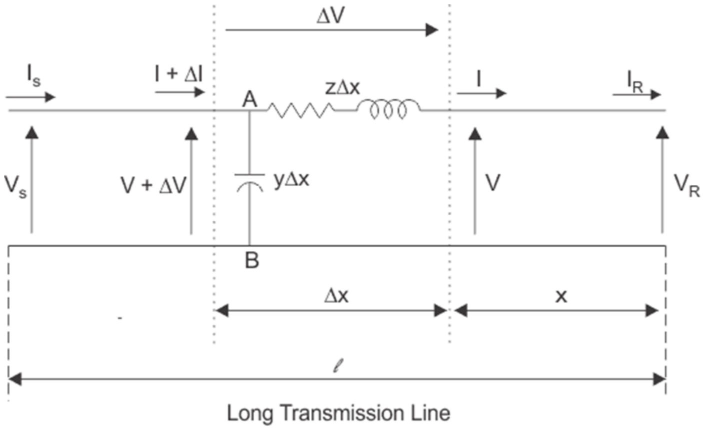

Figure 3: Long Transmission Line Model

4.1. Single Line –to- Ground Fault

The most happened type of shunt faults is Single Line-to-ground faults (SLG) through impedance as shown in Fig. (4) [4]. This type of fault happened when one line touched the neutral wire.

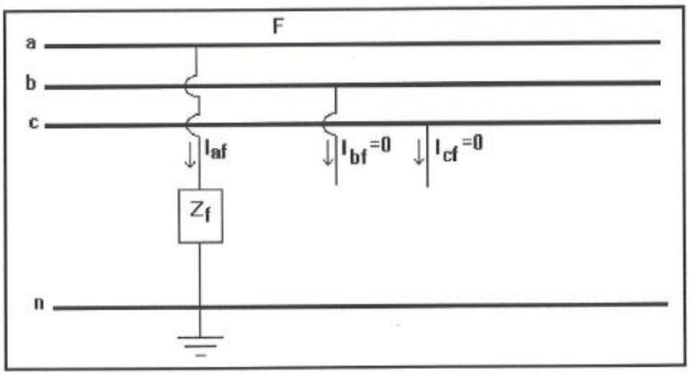

Figure 4: Single line fault equivalent circuit

4.2. Line to line fault

The second most occurring type of shunt faults is the Line-to-Line fault (L-L) [4] as shown in Fig. (5). It is the result of two conductors being short-circuited. As in the case of a large bird standing on one conductor of the transmission line and touching the other conductor, or if a tree branch fall on top of two conductors of the power lines.

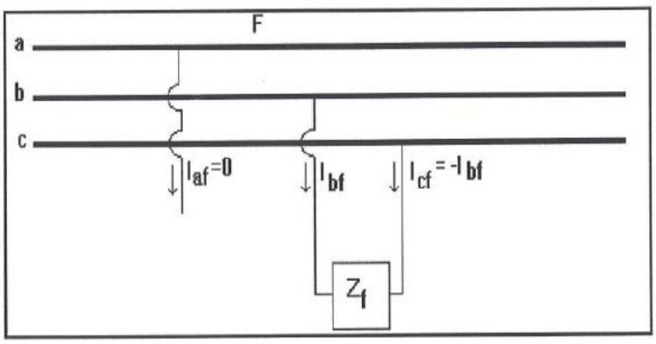

Figure 5: Line to line fault equivalent circuit

4.3. Line to line to ground

The third most occurring type of shunt faults is the Line-to-Line-to-Ground fault (LLG) as shown in Fig. (6). It is the result of two conductors with the ground being short-circuited.

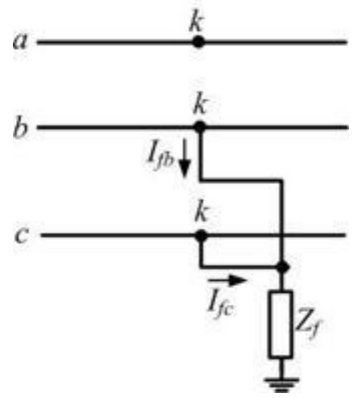

Figure 6: Line to line to ground fault equivalent circuit

4.4. Balanced Fault

The fourth type of fault is shown in Fig. (7) which is known as the balanced three phase [4]. It can occurs by a contact between the three power transmissions lines in many different forms. A line to line to line to ground fault presents low value impedances, with zero value for direct short circuits or metallic faults.

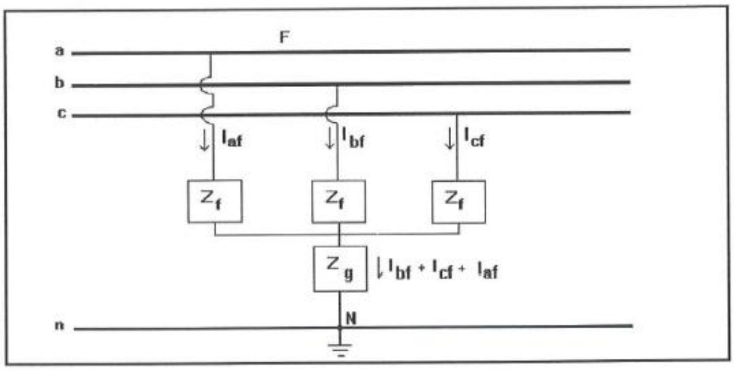

Figure 7: Balance three phase fault equivalent circuit

Research Literature

A studies have been carried out on the topic of overhead transmission lines and extensive researches have been appointed by many aouthors. Some of which are presented in this section.

Swapnil C. Naghate, Saurabh M. Dhuldhar, Ashvini B. Nagdewate [5] carried out their study on Transmission line fault simulation using matlab. Their study focuses on various faults. Also, identifying the effect of each type of fault on the transmission line . Matlab was used in their study for modeling and design transmission line and apply faults on the lines. The main Part of the study is analyzing the effects on bus system due to different faults such as voltage, current, power, with different sequence positive, negative and zero. Their research applied on three phase transmission line faults, Single Line to Ground fault, Double Line fault etc in transmission line ,opens the way to redesign and rearrange the bus system of the power system according to its results.

D.J. Lawrence, Cabeza, Hochberg [6] described the solution techniques, system model, and simulation studies. They concentrate on executed as a part of the improvement of a propelled transmission line fault location system. A reduced model of the transmission system around the Moses-Adirondack lines was developed, and a number of electromagnetic transients program (EMTP) cases were run to establish and simulate voltage and current information as fed to the fault location system. Sensitivity studies were performed to explore the effect of different framework models, and system conditions on fault location accuracy.

Pritesh Kumar, Vijayendra Kumar [7], developed auto analysis approach which can automatically characterize fault and subsequently perform the relay operation by tripping the system which require in order to safeguard the transmission system. The researchers used conventional symmetrical component method and simulink software (Matlab) to simulate different operating and fault conditions on high voltage transmission line namely single phase to ground fault, line to line fault, double line to ground and three phase short circuit.This research gives the general overview of fault location calculation on transmission line.

Vladimir Terzija, Gary Preston, Vladimir Stanojević [8] improved a new numerical algorithm used to analyze single line to ground faults on short overhead transmission lines. It depends upon synchronized sampling at two line ports, and an accurate fault model including the arcing phenomena and tower footing resistance at the fault point. The algorithm accurately estimates the arc voltage amplitude, tower footing resistance, and the fault location, simultaneously. Case studies based on simulated data are presented to demonstrate the effectiveness of the new method.

Denio T Silva , Jose L Silvino , Jose O Paulino , Julio C D de Melo [9] proposed a new method of locating a fault on overhead faults on overhead power transmission lines. Their method was based on the fact that both line to ground and line to line faults induce transient currents in the shield wire. Therefore, the tower closest to the fault experience greater transient currents. This fact sensors is known and can be distributed along the line which is placed on the top of every tower. Through these sensors a wide range of faults can be detected and located. The benefits of using such a system are enormous, including the ability if locating the precise location of the fault, it's applicable on both AC and DC currents, plus the cost of implementing such a system is quite low, even though the number of sensors used is great when the cost is compared with the cost of the power line itself. Other benefits also included, but they are not limited to the simplicity of the system, its accuracy and the ease of its instillation.

Raunak Kumar [10] carried out a research on three phase fault detection through simulations using MATLAB, which is a software that simulates various operating and fault situation on high voltage transmission lines, through his studies the logic of voltage, current, and their relation with impedance the logic of detecting faults as used in the method. Most methods of detecting the classification and location faults are based upon impedance. The researcher uses the impedance measured in case of the fault and compared it to pre known line parameters. This method coupled with a simple soft computing technique detects classifies and give an approximate location of the fault, all this without having to use any bridge techniques. These studies have mainly made use of simulation techniques. It will be able to draw some conclusions. The present study is using both the simulation and experimental techniques.

6. Experimental Work

The experimental work needs a number of equipment. These are:

- Three-phase varic source (Fig. 8)
- Equivalent transmission line circuit (Fig. 9)
- Resistive load (Fig. 10)
- Variable resistance "Rheostat" (Fig. 11)
- Oscilloscopes (Fig. 12)
- Multimeters and experimental circuit (Fig. 13)

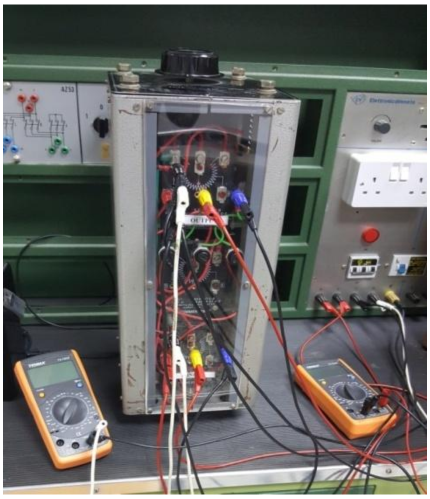

Figure 8: Thre –phase variac source

Figure 9: Equivalent transmission line circuit

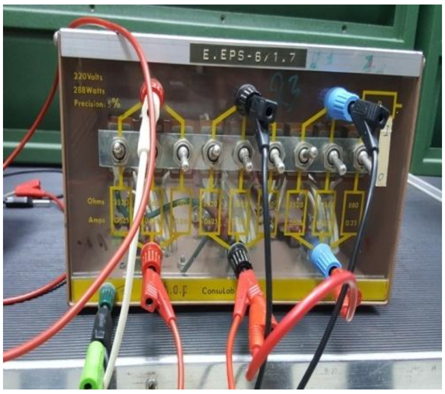

Figure 10: Resistive load

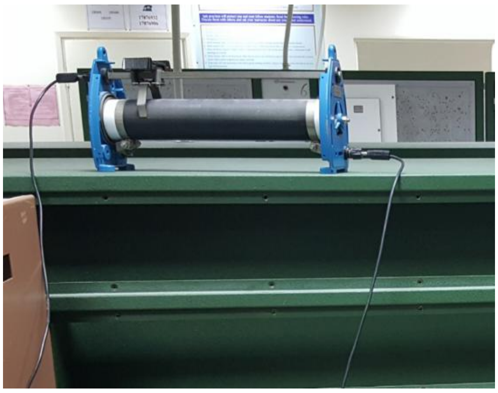

Figure 11: Variable resistance (Rheostat)

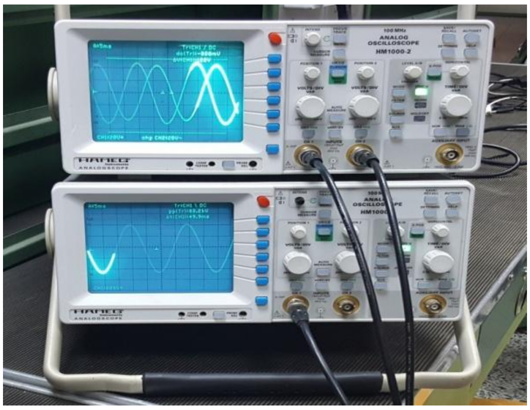

Figure 12: Oscilloscopes

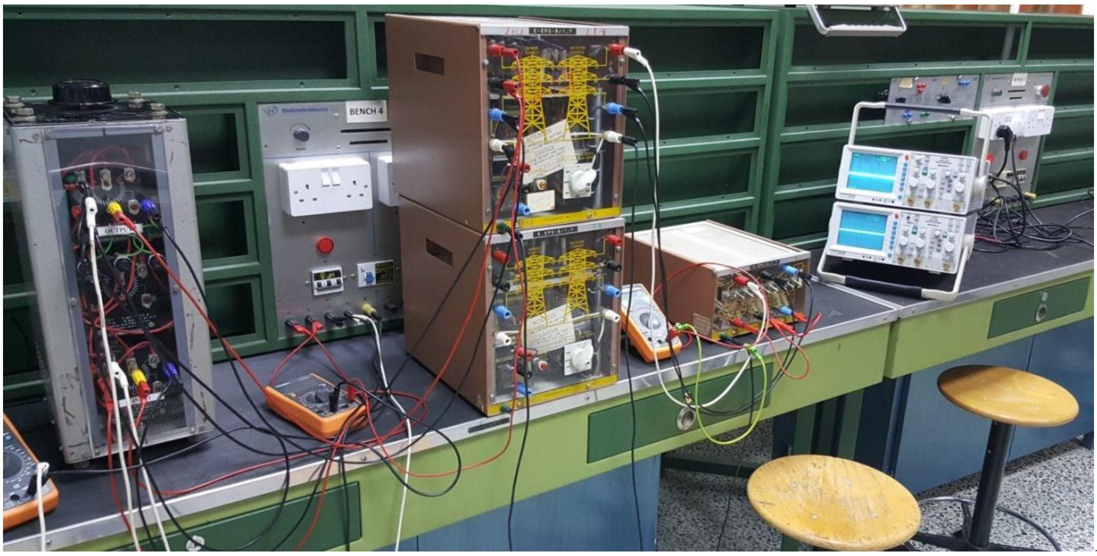

Figure 13: Experiment Circuit

Figure (13) shows practical simulation system as indicated to represents the experimental circuits. The purpose of the present study is to investigate traditional transmission line models and their behavior. The behavior tests are carried out at different simulations using the P Spice and experimental work. The equivalent circuits were developed to represent the short transmission lines. The line model performance was observed under loading condition. From the simulation results, the results can be obtained.

6.1. Oscilloscope output

The simulation of a transmission line terminated by a 250 Ω - fault resistor where necessary, as shown in the following cases:

- **Single line to ground fault results on the oscilloscope screen (Fig. 14):**

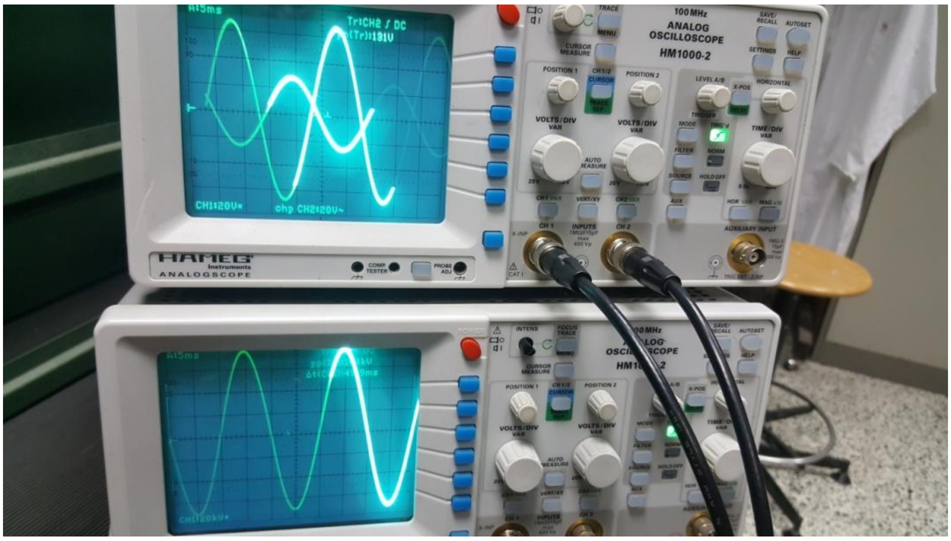

Figure 14: Oscilloscope output of single line fault

- **Line to Line fault results (Fig. 15):**

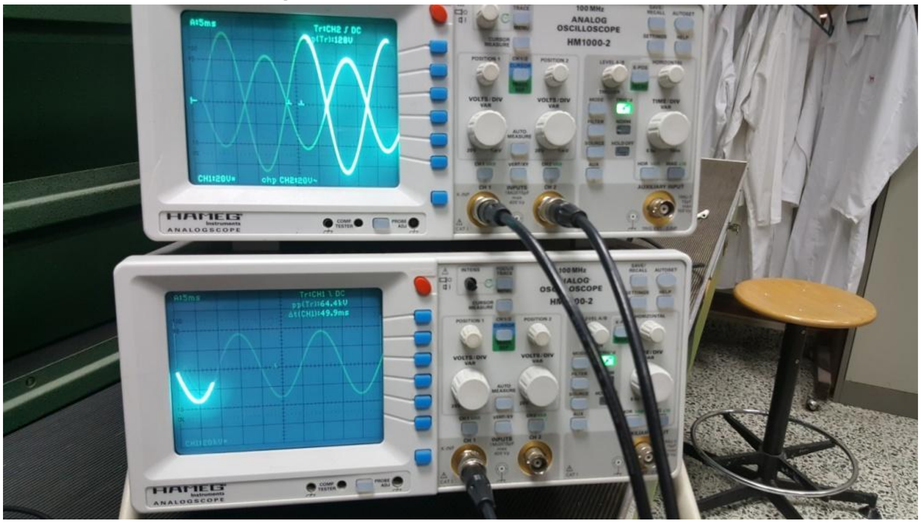

Figure 15: Oscilloscope output of line to line fault

- **3-phase balance fault results (Fig. 16 and Fig. 17):**

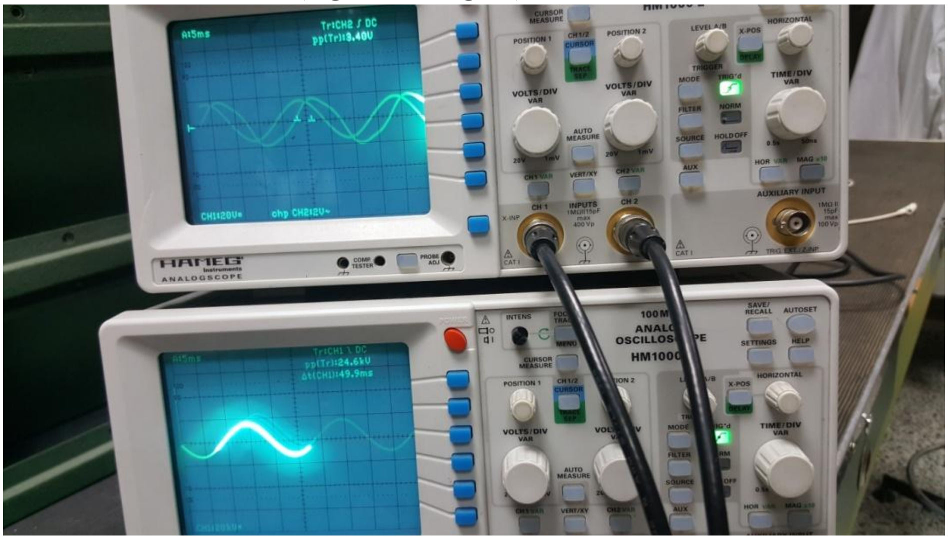

Figure 16: Oscilloscope output of 3-phase balance fault

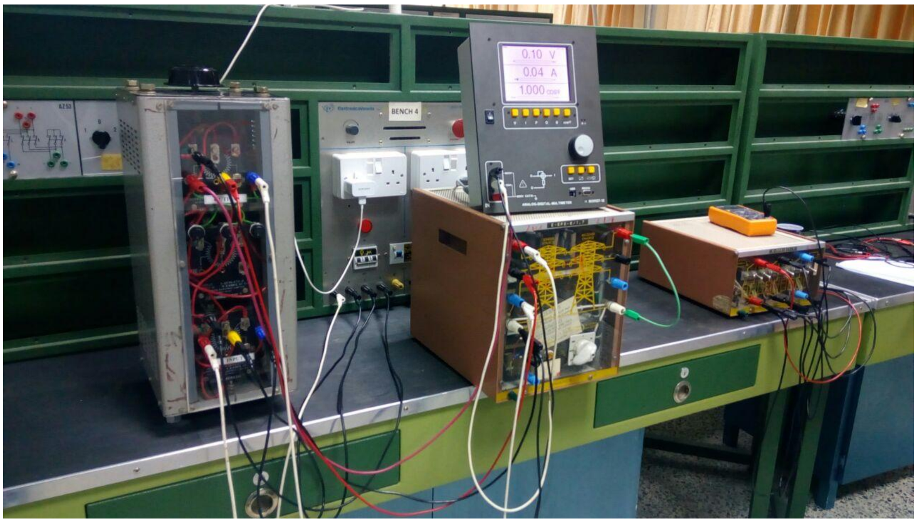

Figure 17: Three-phase Transmission Line Impedance Test Fault

Transmission Line Impedance = 56.84+j184.7889 Ω

After obtaining the value of transmission line impedance, the equivalent circuit is plugged in P-Spice making several fault types and measuring the current and voltage in each phase. Similar or approximate results were obtained compared with the experimental works.

7. Programs Simulation, Results and Discussion

7.1 Background about P-Spice

PSpice is the Simulation Program with Integrated Circuit Emphasis is a computer aided design program [11]. The SPICE is an analog circuit simulator and stands for Simulation Program with Integrated Circuit Emphasis. At the University of California at Berkeley it was developed in the late 1970's for IC analysis and design. Most of these programs are used in testing and evaluating the performance of various designs. But P-Spice in particular is the most commonly used as a macro-modeling language in solving high voltage problems. It is commonly used alongside basic circuit components (resistors, capacitors, etc.) to solve practical problems encountered in design and analysis of overhead transmission lines. The reason behind using this program because of its great utility and used by a various amount of individuals including: engineers in the industry, researchers during their research and also by engineering professors and students in universities. A vast multitude of examples exist for the use of SPICE when it comes to electric engineering. In 1988, Etezadi-Amoli and Florence [12] used SPICE to demonstrate how a generator based electrical system would function with a fault , and then again how it would function once that fault was removed. Also using SPICE, Muyshondt and Potnoy [13] were able to make great breakthroughs. They were able to develop two controlling schemes for saturation switch, and a method of using P-Spice to find the poles and zeros of any arbitrary network. An example of the practical use of P-Spice also exist here, in the Arabian gulf, in the Kingdom of Saudi Arabia by the Saudi Consolidated Electric company in transmission lines. The uses of P-Spice as shown are evidently enormous, especially when it comes to students as it serves to protect them from being exposed to high voltage experiments while at the same time presenting them with accurate simulation to further supplement their education.

7.2. Model of Transmission line

First step for using P-Spice (Version 9.1) is representing each model of transmission line circuit (per phase equivalent circuit), and measure the voltages in the sending and receiving terminals.

7.3 Simulation of Fault in 3 –phase circuit

By using P-Spice program it has been tried to match the values from the practical components to simulation in order to get accurate results. Several faults were carried out on transmission line, and observe the results of each fault due to voltages and currents.

- **Single line-ground (Fig. 18 A to Fig. 18 C)**

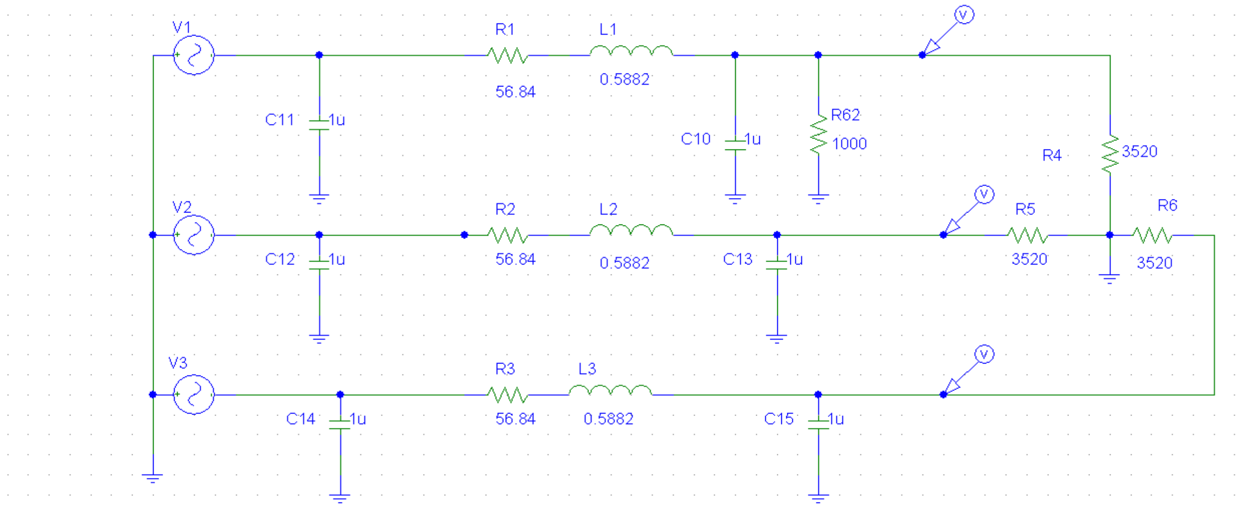

Figure 18 A: Electrical Equivalent Circuit of single line –ground Fault

Fault Resistor (R_f) = R_{62} = 250 Ω: Output voltage

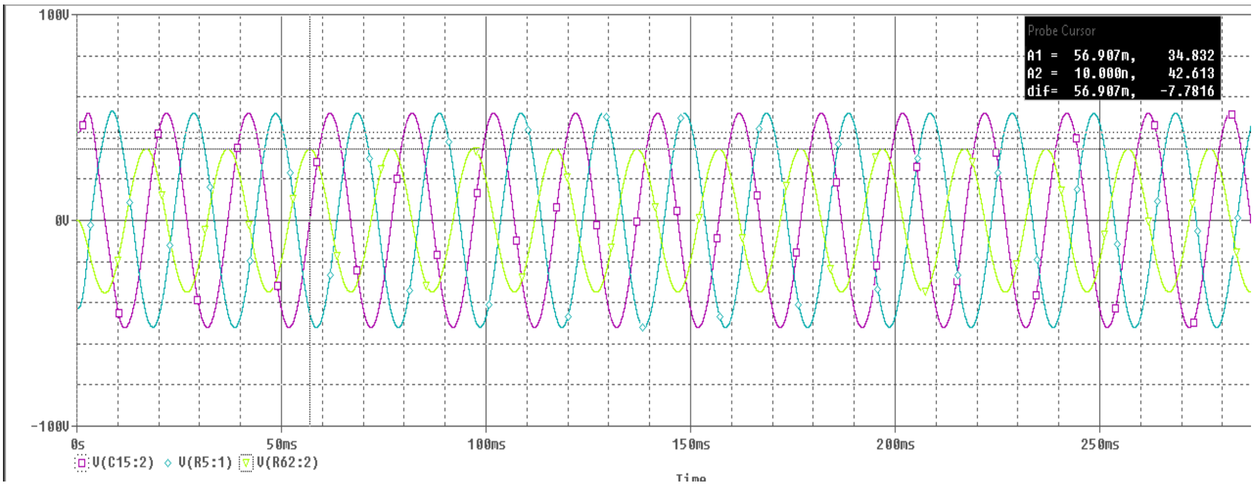

Figure 18 B: Single Line –Ground Voltage Output at R_f = 250 ohm

Output current:

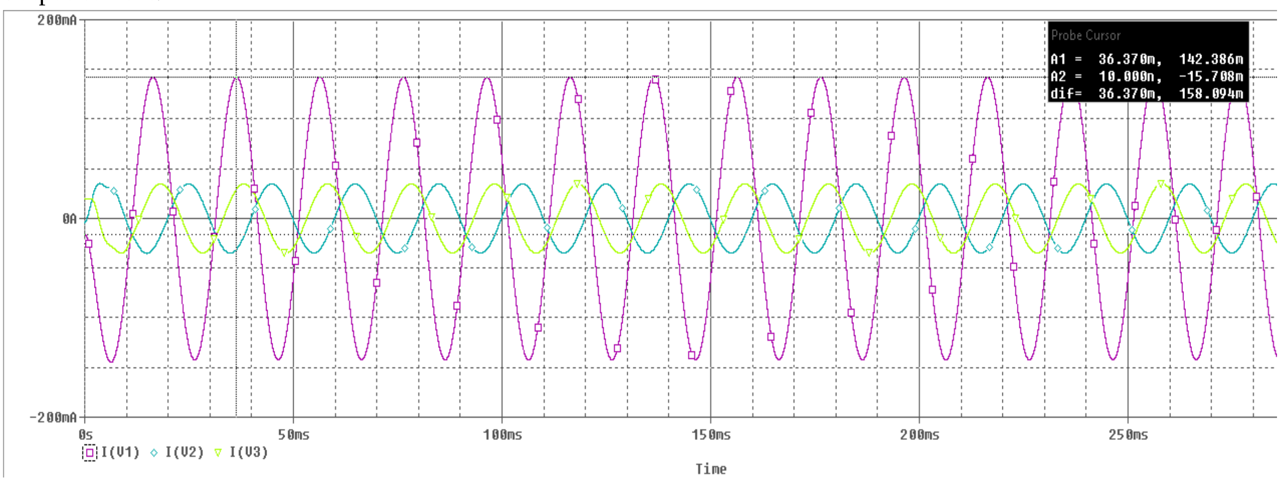

Figure 18 C: Single line –ground current output at R_f = 250 Ω

- **Line to line fault (Fig. 19 A to Fig. 19 C)**

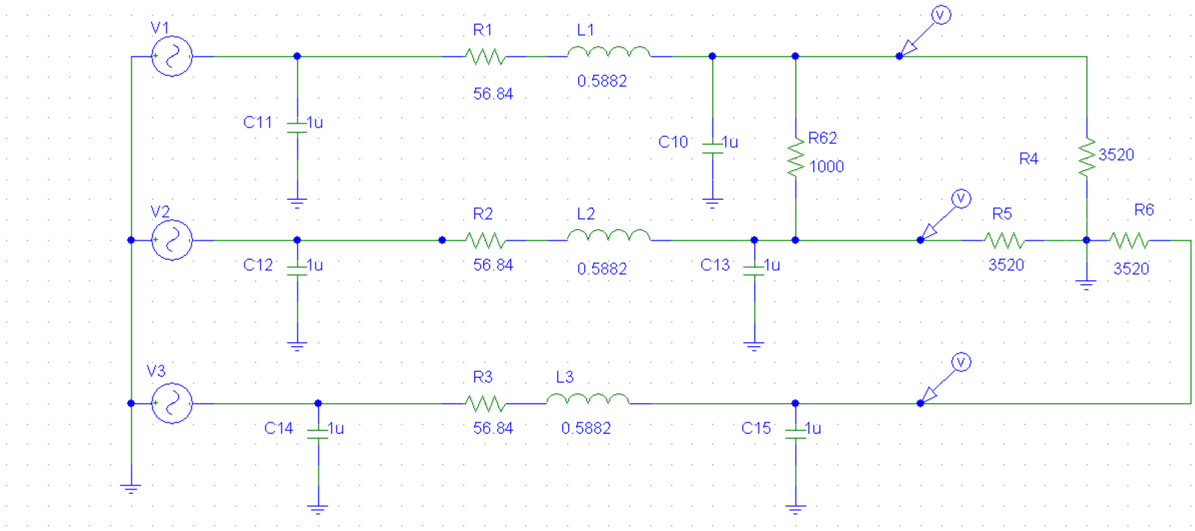

Figure 19 A: Electrical Equivalent Circuit of line to line fault

Fault Resistor (R_F) @ 250 Ω:

Output voltage :

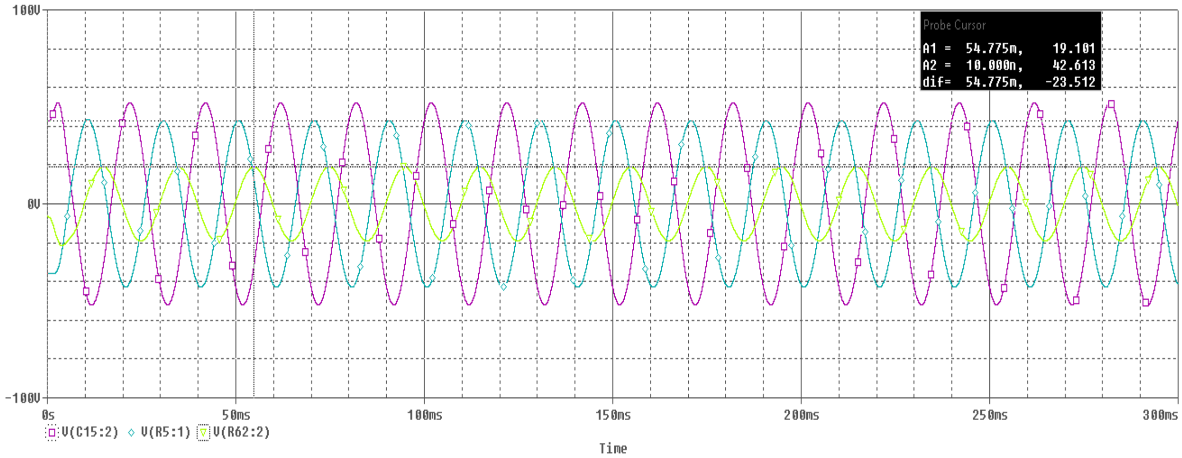

Figure 19 B: Voltage of line to line fault at R_f = 250 ohm

Output current:

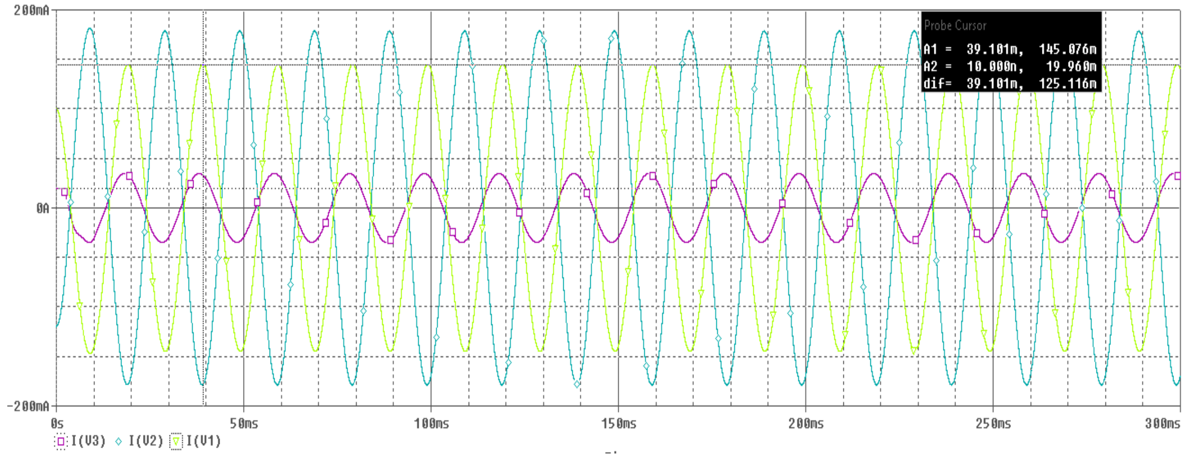

Figure 19 C: Current of line to line fault R_f = 250 ohm

The simulation of line – line shows that only the phase (A) and phase (B) was effected by the fault which occurs by different values of (Z_f) as we can see above the value of voltage and current of both phases are different, the value of phase (C) stay as normal value.

- **3- phase balance fault (Fig. 20 A to Fig. 20 C)**

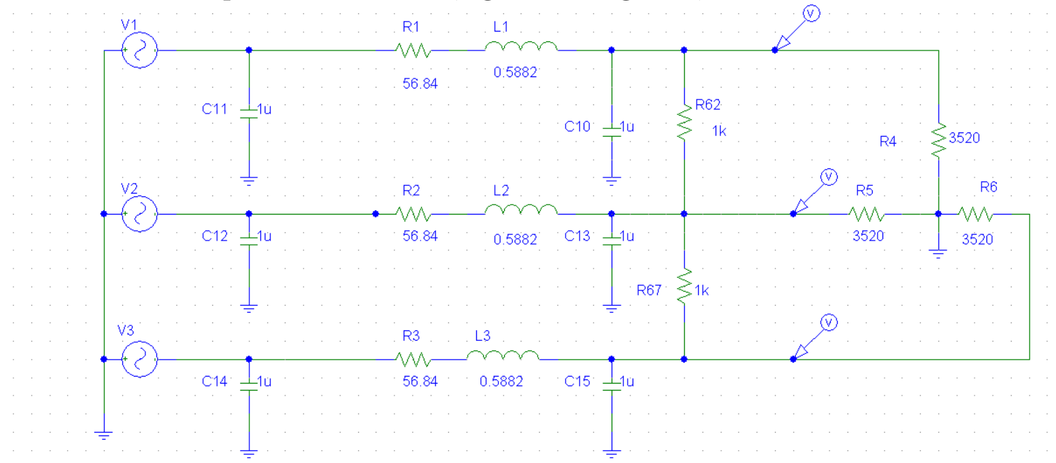

Figure 20 A: Electrical Equivalent Circuit of 3-phase balance fault

Fault Resistor (R_F) = 250 Ω:

Output voltage:

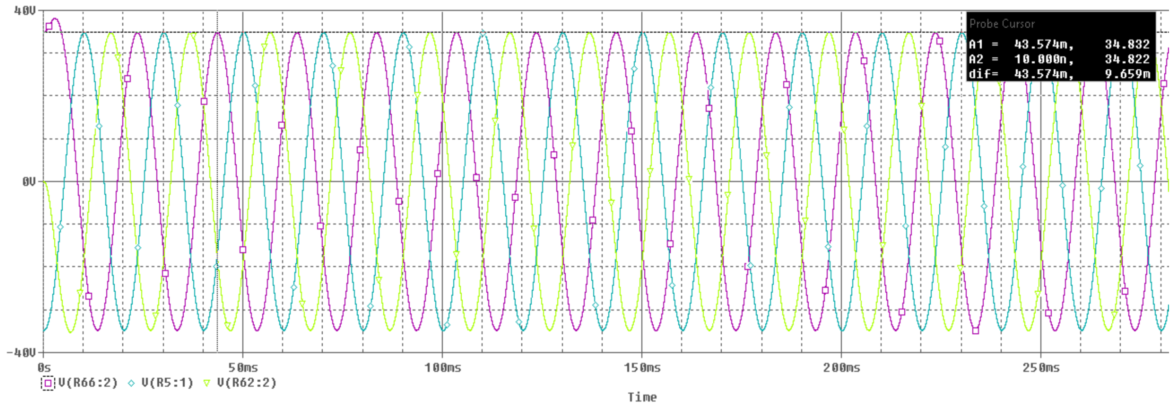

Figure 20 B: Voltage of 3-phase balance fault R_f = 250 ohm

Output Current:

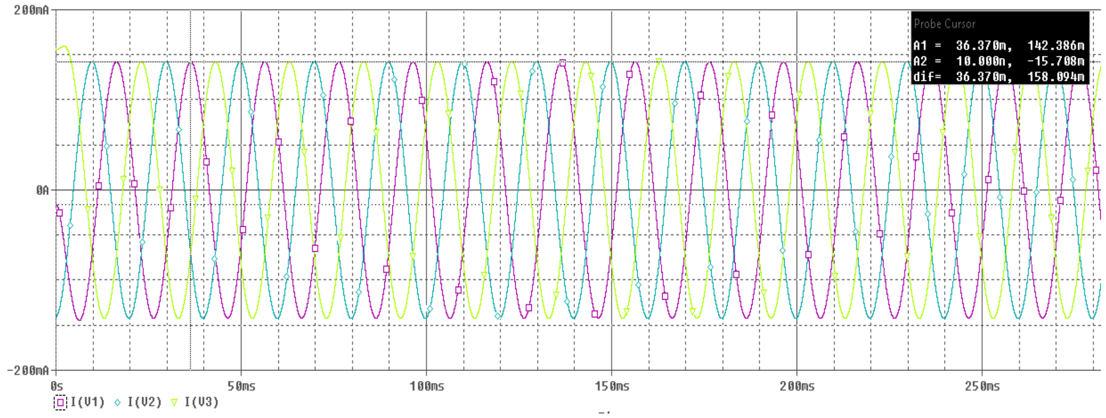

Figure 20 C: Current of 3-phase balance fault R_f = 250 ohm

The simulation of three- phase balance fault shows that the phase (A) and phase (B) and phase (C) was effected by the fault which occurs by different values of (Z_f) as shown above, where the value of voltage and current of all phases are the same.

7.4. P-SPICE Results

Table 1: Different Types of Faults Results, where $R_f = 250\ \Omega$

Resistance	Voltage	Current	Type of fault
250 Ω	Phases voltage A= 33.2 V B= 49 V C= 49 V	Phases current A= 0.142A B= 0.0348 A C= 0.0348 A	Single Line to ground fault
250 Ω	Phases voltage A= 45V B= 25V C= 49 V	Phases current A= 0.145 A B= 0.178 A C= 0.0348 A	Line to Line fault
250 Ω	Phases voltage A=33.2 V B=33.2 V C= 33.2 V	Phases current A=0.142 A B= 0.142 A C= 0.142 A	Three Phase Balance Fault

7.5 Experiment Work Result

@250 ohm

Table 2: Different Types of Faults Results

Type of fault	Voltage	Current
Single line fault	Phases voltage A=36 V B= 49 V C= 49 V	Phases current A= 0.18 A B= 0.04 A C= 0.04 A
Line to line fault	Phases voltage A=43.5 V B= 20.8 V C= 49 V	Phases current A=0.12 A B= 0.23 A C= 0.04 A
3 phase balance fault	Phases voltage A= 36 V B= 36 V C= 36 V	Phases current A= 0.18 A B= 0.18 A C= 0.18 A

7.6 Comparsion Between the results

PSPICE circuit simulation program can be used for DC, AC analysis, and transient. It is extremely important for integrated circuit analysis. The obtained results are compared using both PSPICE and experimental results. After obtaining the results above, the results of laboratory simulator versus P-SPISE result are compared and illustrated in both figures Fig. (21) and Fig. (22). The PSPICE becoming an excellent asset to instructors and students. PSPICE is of great value not only in electrical engineering, but also in many other disciplines. After comparison it has been noticed that the results are closed together and acceptable.

- (P-SPICE) versus (Experimental work)

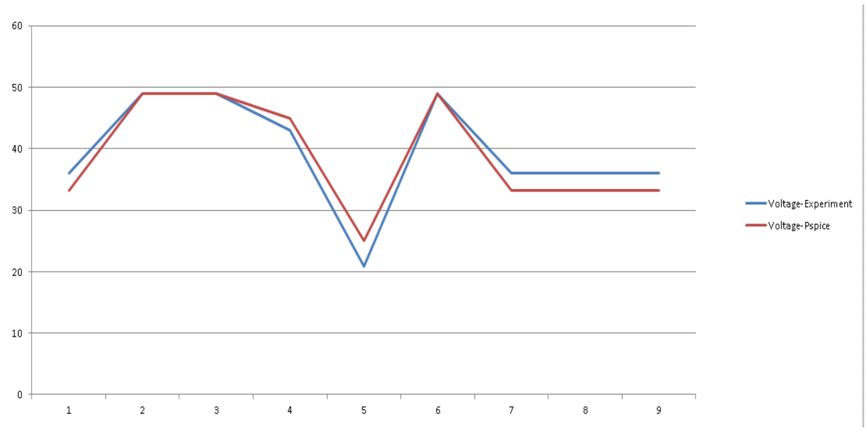

Figure 21: Comparison between Experiment work vs P-spice voltages

- (P-SPICE) versus (Experimental work)

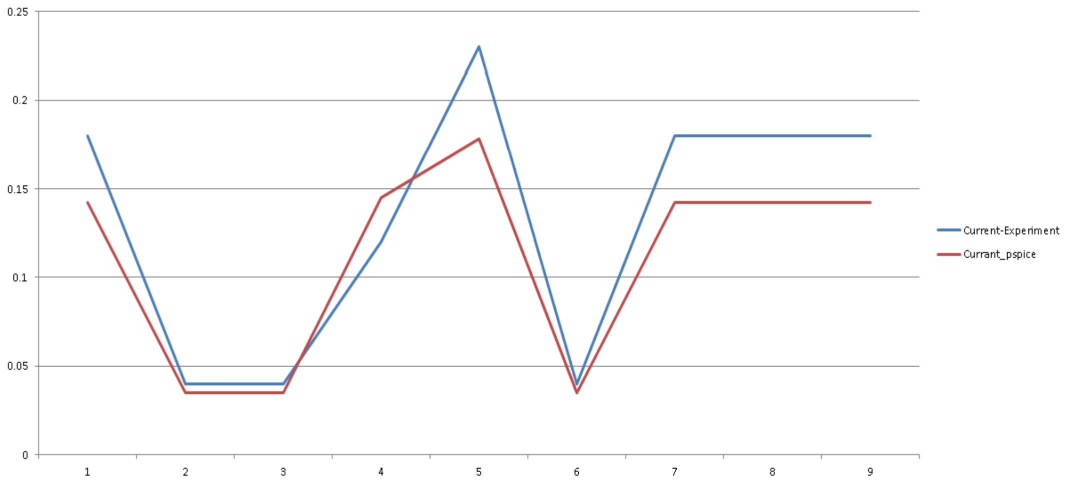

Figure 22: Comparison between Experiment work vs P-spice current

8. Conclusion

The paper presents both PSPICE and Laboratory Simulator that automate the calculation of the fault voltages and currents. Three types of faults of the considered models are studied. Their results are obtained. These simulations are enormous, especially for undergraduate engineering students. It is evident from analysis presented and the models considered in the present article that the PSPICE circuit simulation program is effective tool for calculation. This analysis would help both the instructors and students gain a better insight.

References

[1]. Presented by Dr. Gleb V. Tcheslavski (2008). *Lecture 9: Transmission lines*,pp.1-28, http://doctord.dyndns.org/courses/textbooks/Chapman/Lecture%2009%20-%20Transmission%20lines.pdf

[2]. Oluwajobi F. I., Ale O. S. and Ariyanninuola A (2012). Effect of Sag on Transmission Line, *Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS)* 3 (4): 627-630 © Scholarlink Research Institute Journals: 1-4.

[3]. Papiya Dutta, Ahad Esmaeilian, and Mladen Kezunovic (2014). Transmission-Line Fault Analysis Using Synchronized Sampling, *IEEE Transactions on Power Delivery*, Vol. 29, No. 2, April 2014: 942 - 950.

[4]. William Patrick Davis (2012). "Analysis of faults in overhead transmission lines". *California State University, Sacramento, Senior Project*, March 2012: 1-75.

[5]. Swapnil C. Naghate, Saurabh M. Dhuldhar, Ashvini B. Nagdewate (2015). Technology Transmission Line Fault Analysis by Using Matlab Simulation, *International Journal of Engineering Sciences & Research Technology*, 4 (2): February 2015: 1-4.

[6]. David J. Lawrence, Luis Z. Cabeza, Lawrence T. Hochberg (1992). Development of an advanced transmission line fault location system ,Input transducer analysis and requirements" *IEEE Transactions on Power Delivery*, November 1992, Volume: 7, Issue: 4: 1963 - 1971

[7]. Pritesh Kumar, Vijayendra Kumar (2016). Review paper on three phase fault analysis with auto reset technology on temporary fault or remain tripped otherwise", *Asia Pacific Institute of Information Technology, Report*: 1-6.

[8]. Vladimir Terzija, Gary Preston,Vladimir Stanojevi´c,Nagy I. Elkalashy, and Marjan Popov (2015). Synchronized Measurements-Based Algorithm for Short Transmission Line Fault Analysis, *IEEE Transactions on Smart Grid, Journal Paper*, Vol. 6, No. 6, Nov. 2015: 2639-48

[9]. Dênio T. Silva1, José L. Silvino, José O. Paulino, Julio C. D. de Melo (2010). Fault Location on Overhead Power transmission line by measuring current from shield wires", *Conference Paper*, December 2010: 1-7.

[10]. Raunak Kumar (2013). Three Phase Transmission lines fault Detection, Classification and Location, *International Journal of Science and Research Technology*, 2013: 1-4.

[11]. Isa S. Qamber (1995). "SPICE application in education: insulator strings of overhead transmission lines", *Electric Power Systems Research*, Vol. 35: 187-192.

[12]. M. Etezadi-Amoli and T. Florence (1988). The SPICE 3 pro-gramming language and its application to power sys-tem analysis, *IEEE Trans Power Systems*, Vol. 3, No. 4, 1988: 1872–1876.

[13]. G. P. Muyshondt and W. M. Potnoy (1989). "Development of high frequency SPICE models for ferrite core inductors and transformers", *Conference Record of the IEEE Industry Applications Society Annual Meeting (Cat. No.89CH2792-0)*, 1-5 Oct. 1989, San Diego, CA, USA: 1328-1333.