Proceedings of the International MultiConference of Engineers and Computer Scientists 2015 Vol II,
IMECS 2015, March 18 - 20, 2015, Hong Kong

An Experimental Setup Investigation to Study Characteristics of Fault on Transmission System

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***Abstract*—This paper proposes the experimental setup for studying the characteristics of fault caused by balance and unbalance on a transmission system. The parameters of transmission system (inductance and capacitance) are calculated based on forms of transmission tower, size of conductor, types of conductor and arrangement of transmission line and, they normalized to obtain the values in the π- equivalent circuit model at voltage level of 400 V. In addition, the ATP/EMTP is used to compare the simulated results with the experimental setup in order to show the advantage of the experimental setup. The obtained results show that the similarity between the two waveforms. The experimental setup will be useful in the development of short-circuit protection system in laboratory.**

***Index Terms*— Experimental setup, Fault, Transmission line, ATP/EMTP**

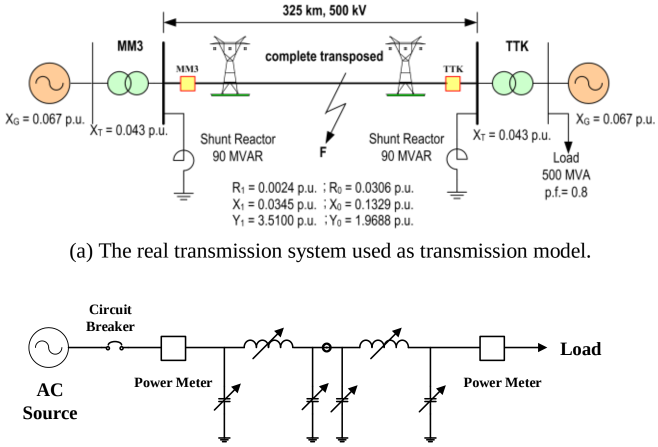
I. Introduction

Transmission system is an important part of electrical system, which sends electrical energy to the end user [1]. Studying about transmission system in real system is difficult and dangerous, thus the case study of transmission system, such as power flow, power system stability, and power system protection, has been almost studied and analyzed by simulation program or mathematical model. The commercial experimental setup of transmission system is rarely used due to its high cost. Based on the simulation program, there are several programs that have been developed for power system such as EMTP, PSS, PSS/E, PSS/ADEPT, PSCAD/EMTDC, ACUSUM/CUSUM, and etc. [2]-[12] However, some desired functions of both simulation program and mathematical model cannot be available to approximate the real system.

A fault in an electrical power system is the unintentional and undesirable creation of a conducting path or a blockage of current. It is important to determine the values of system voltage and current during faulted conditions so that protective devices may be set to detect and minimize their harmful effects [5]-[12]. Therefore, it is important to study the power system under fault conditions. This paper investigated the experimental setup built with aim to understand the characteristics of fault. The parameter of transmission system is normalized using per unit technique in order to downscale from 500 kV to 400 V. In addition, the various case studies are performed by changing the fault inception, the type of fault, the location of fault including varying the load.

II. Experimental Setup

The Thailand's transmission system at voltage level of 500 kV is employed as transmission system model as shown in Fig. 1(a). The experimental setup model as shown in Fig. 1(b) is downscaled by using per unit normalization from 500 kV to 400 V in laboratory. The π-lumped equivalent model is used as transmission system model for the experimental setup. Applying per unit normalization to the parameter of transmission line, the inductor and capacitor of transmission line are also calculated to determine size of these parameters while the resistor of transmission line is ignored as shown in Fig. 2. By considering Fig. 1(b) and Fig. 2(upper), the power supply of the system is from laboratory at voltage level of 400 V before connecting to variable voltage transformer. For the experimental setup protection, the 30 A circuit breaker is used as protective device of experimental setup. For measurement, the input variables such as voltage, real power, and current can be measured using power meter, and the current waveform is obtained using current probe clamping between point No.3 and point No.4 as shown in Fig. 2(upper). To implement the fault on the experimental setup, the fault control with magnetic contractor is performed.



(a) The real transmission system used as transmission model.

(b) The π-equivalent model used for experimental setup.

Fig.1. The system used for experimental setup.

Manuscript received January 22, 2015
This work was supported in part from King Mongkut's Institute of Technology Ladkrabang Research fund, Thailand
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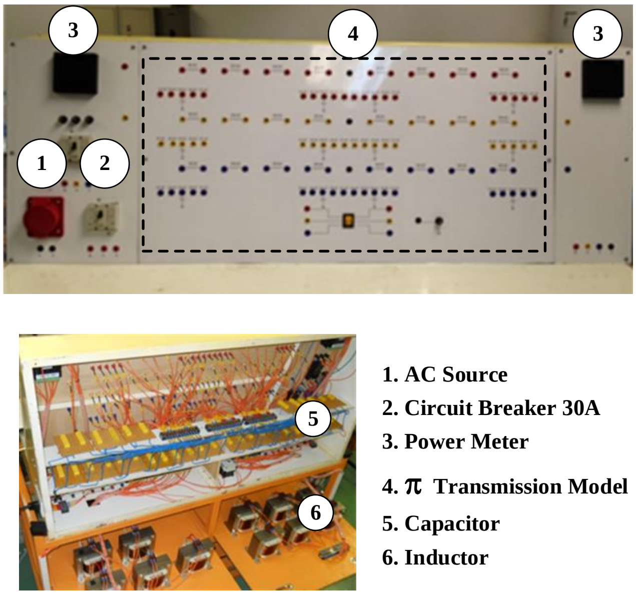


Fig.2. The panel of experimental setup.

By considering the experimental setup panel, the transmission line model can be separated into two lumped equivalent sections. For each section, the π-lumped equivalent transmission line model consists of the series impedance (inductor) and shunt admittance (capacitor).

III. EXPERIMENTAL AND SIMULATION RESULTS

In order to show the advantage of the experimental setup, the ATP/EMTP is investigated to compare with the experimental setup. The obtained case study from Fig. 3 and Fig. 4, is a fault occurred at the length of 30% measured from the variable voltage transformer (or bus MM3 as shown in Fig. 1(a)). Examples of experimental setup and ATP/EMTP-simulated fault signals at the sending end of transmission line model are illustrated in Fig. 3(a) and 3(b), respectively. By considering Fig. 3, the similarity between the two waveforms can be visually observed. An example of fault current signals is shown in Fig. 3; it is a phase A to ground fault, while the three-phase fault is shown in Fig. 4.

In addition, the fault patterns in the experimental setup are performed to study the behaviour of current signal during fault occurrence, so that the fault inception angle, fault type, fault location, and size of load are changed.

By changing the inception angle of fault, when the phase A to ground fault occurs at the length of 50% measured from the variable voltage transformer while the load of experimental setup is 60 W, it can be observed that, before the fault occurrence, the maximum amplitude of current signal has an approximately value of 0.5 A. During the fault occurrence, the maximum amplitude of current signal changes immediately on the faulty phase as shown in Fig. 5 and Table I.

Table I. The maximum amplitude of current signal for various fault inception angles.

Fault inception angle	Maximum amplitude of current (A)	
	Pre-fault condition	Post-fault condition
90	0.500	5.469
180	0.500	9.411

By changing the type of fault, when the fault occurs at the length of 50% measured from the variable voltage transformer while the load of experimental setup is 60 W; it can be observed that, before the fault occurrence, the maximum amplitude of current signal has also an approximately value of 0.5 A. During the fault occurrence, the maximum amplitude of current signal also changes immediately on the faulty phase as shown in Fig. 6 and Table II. In post fault condition three-phase fault current is higher when compared to single-phase fault from nature of fault that three phase fault contributes high current magnitude.

Table II. The maximum amplitude of current signal for various fault types.

Fault type	Maximum amplitude of current (A)	
	Pre-fault condition	Post-fault condition
Single line to ground fault	0.500	9.411
Three phase fault	0.500	9.438

By changing the location of fault, when the phase A to ground fault occurs while the load of experimental setup is 60 W, it can be observed that, before the fault occurrence, the maximum amplitude of current signal has also an approximately value of 0.5 A. During the fault occurrence, the maximum amplitude of current signal also changes immediately on the faulty phase as shown in Fig. 7 and Table III. In post fault condition, fault current occurred at 50% length of transmission line is much higher than that at 60% length of transmission line. The reason is transmission line impedance in 50% case is much lower when compared to transmission line impedance in 60%. This causes an increase in current magnitude.

Table III. The maximum amplitude of current signal for various fault locations.

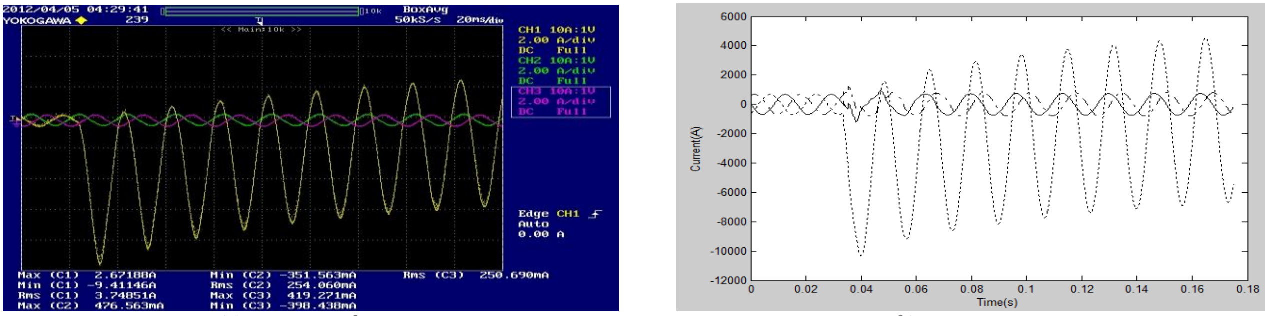
% length of fault location	Maximum amplitude of current (A)	
	Pre-fault condition	Post-fault condition
50	0.500	9.438
60	0.500	3.901

By changing the inception angle of fault, when the phase A to ground fault occurred at the length of 50% measured from the variable voltage transformer while the load of experimental setup is 60 W, it can be observed that, before the fault occurrence, the maximum amplitude of current signal has an approximately value of 0.5 A. When increasing load current in normal condition, current is increased to be 0.667. During the fault occurrence, the maximum amplitude of current signal changes immediately on the faulty phase as shown in Fig. 8 and Table IV. Current magnitude in case of 100 W load becomes higher due to increasing of load current in normal condition

Table IV. The maximum amplitude of current signal for various loads.

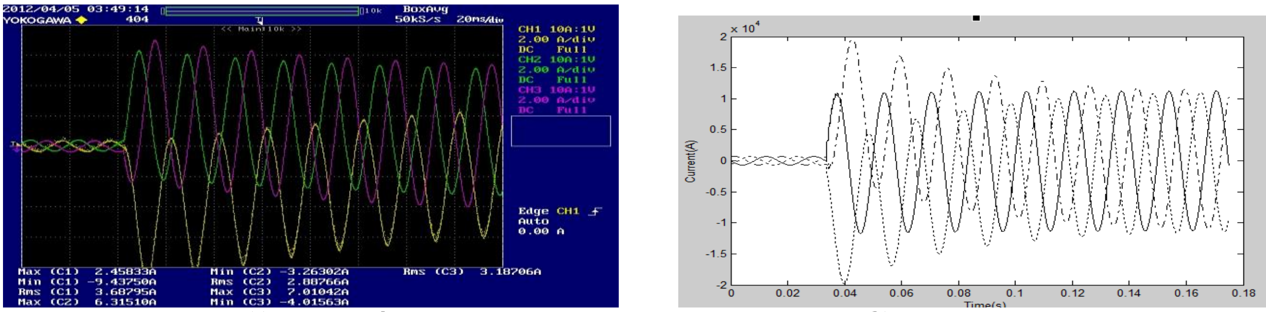
Size of load (Watt)	Maximum amplitude of current (A)	
	Pre-fault condition	Post-fault condition
60	0.500	9.411
100	0.667	10.45

ISBN: 978-988-19253-9-8
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)



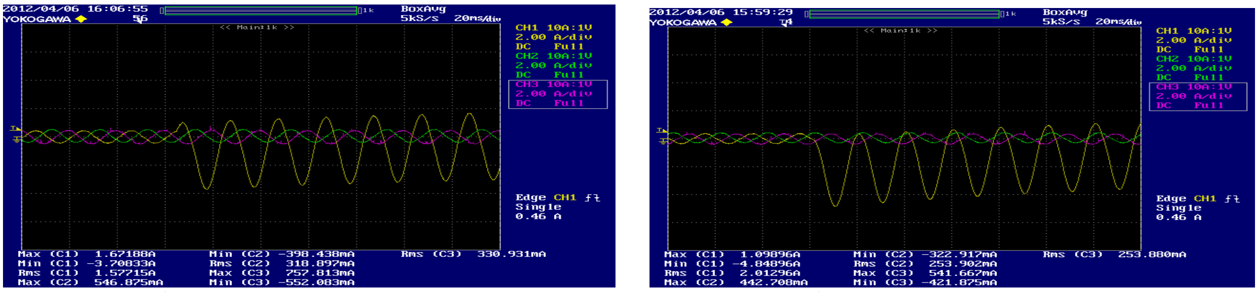
(a) experimental setup (b) ATPDraw/EMTP

Fig.3. Current waveform in case of single to ground fault at 30% of transmission line



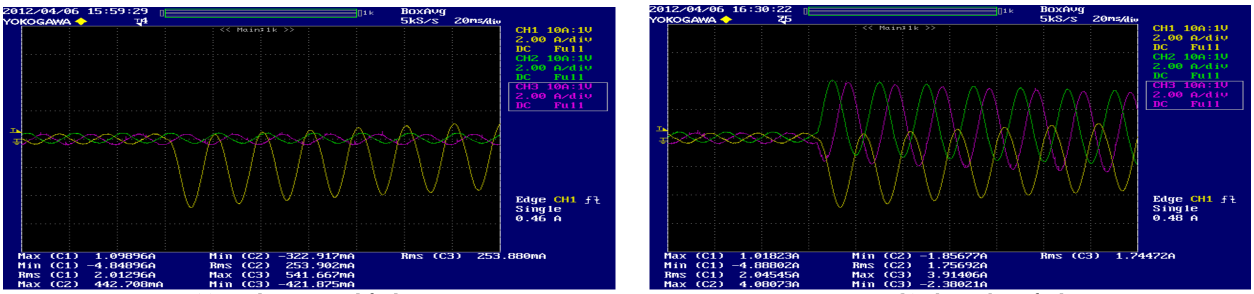
(a) experimental setup (b) ATPDraw/EMTP

Fig.4. Current waveform in case of three phase fault at 30% of transmission line



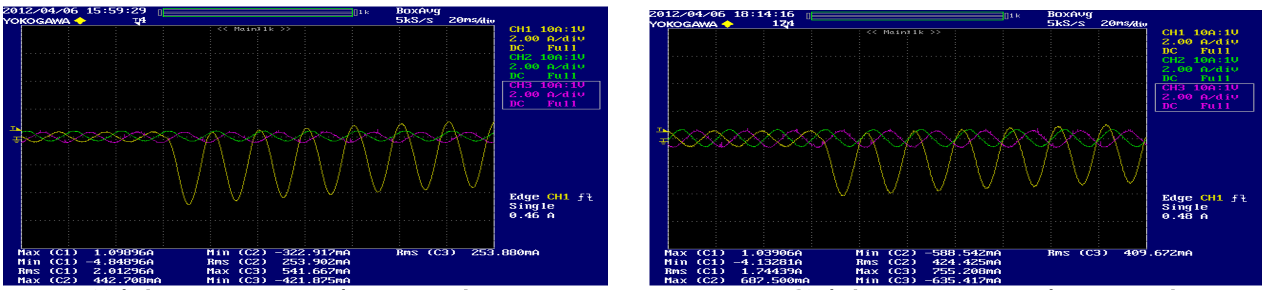
(a) fault inception angle with 90 degrees (b) fault inception angle with 180 degrees

Fig.5. Current waveform captured from oscilloscope for various fault inception angles



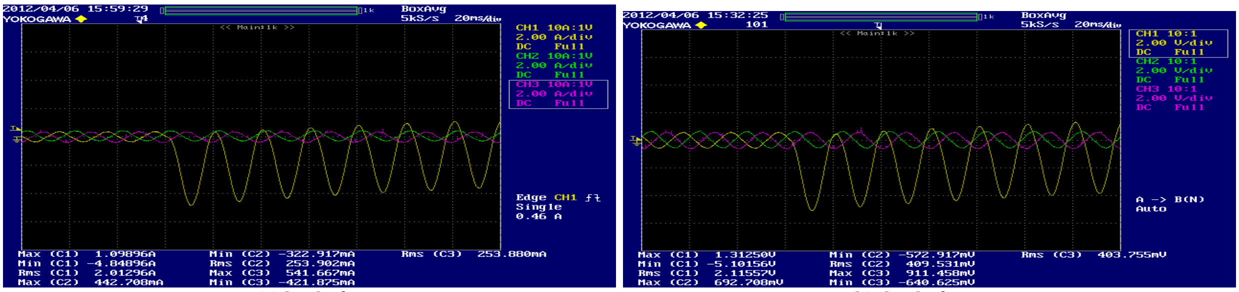
(a) single to ground fault (b) three phase fault

Fig.6. Current waveform captured from oscilloscope for various fault types



(a) fault occurrence at 50% of transmission line (b) fault occurrence at 60% of transmission line

Fig.7. Current waveform captured from oscilloscope for various fault locations



(a) load of 60W (b) load of 100W

Fig.8. Current waveform captured from oscilloscope for various loads

IV. CONCLUSION

A fault in an electrical power system is important; the power system under different fault conditions must be studied, in order to provide data for system protection. This paper has proposed the experimental setup in order to study about the characteristics of fault; this bench is less expensive than the commercial one. Calculation of parameters based on forms of transmission towers, size of conductor, types of conductor and arrangement of transmission line was carried out in order to convert the obtained values by normalization to the π- equivalent circuit model at voltage level of 400 V. The results from all fault characteristics study are shown in Fig. 9. The obtained results can be summarized as follows:

- The maximum amplitude of current during the fault occurrence has a sudden change compared to those before the occurrence of fault and its change plays an important role in the behaviour of fault.
- By considering the type of fault in case of the length of 50% measured from the variable voltage transformer, the maximum amplitude of current tends to increase with the number of phase that fault occurs.
- By considering the location of fault in case of the single to ground fault, the maximum amplitude of current tends to significantly decrease with the increase of the location of fault.

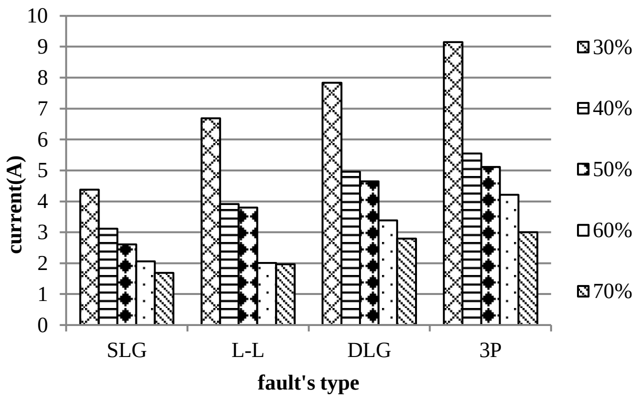


Fig.9. Results of fault current for various fault types and various fault locations from the experimental setup in case of load of 60W.

For a further improvement of experimental setup, the configuration of the experimental setup can be performed for underground distribution system. Moreover, the fault inception angle must be chosen at any angles. As a result, the experimental setup will be useful in the development of short-circuit protection system in laboratory.

ACKNOWLEDGMENT

This work is supported by the King Mongkut's Institute of Technology Ladkrabang Research fund. The authors would like to thank for this financial support.

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