# AN INVESTIGATION STUDY OF TRANSMISSION LINE FAULT LOCATION USING TRAVELLING WAVE

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# ABSTRACT

The project report proposes that travelling wave will produced different location when the reflected wave is interpreted differently by the devices in the system. The security of Sarawak Grid depends very much on the availability of the transmission network. It is, therefore, important that any transmission line fault can be located speedily and accurately to minimize the down-time or repeated tripping. Currently, Sarawak Energy Berhad (SEB) is using Traveling Wave Fault Location System (TWS) to identify correct transmission line fault location. For a single-ended travelling wave fault location, the identification on the reflected wave is the core of getting precise location of the fault. Due to the polarity of the travelling wave reflected from the fault point or from the remote-end bus is affected by the bus configuration at both ends of the faulted line, it is difficult to identify whether the travelling wave is reflected from the fault point or the remote-end bus using the polarity of single modal travelling wave. A previous study only proposes method of locating by simulating the fault in a controlled environment. There are two types of traveling wave analysis techniques are proposed in the project report. The modelling of the simplified electrical network will be done using MATLAB Simulink where four types of fault; 3-phase fault, 2-phase fault, 2 phase-to-ground faults and single-phase fault will be simulated in the network. Analysis of the travelling wave waveforms are done after the signal processing of the faulted current waveform are carried out. Analysis of the travelling wave waveforms show that effects of variables such as fault inception angle, fault resistance, line distance and weak-end will produce a fault location which is not accurate. The data analyzed with the methods proposed in the project report found that the results reflect the finding in the simplified electrical network modelling. The simulation shows that the fault impedance has a minor effect (less than 5% error margin) on the traveling wave waveform and amplitude. However, the fault inception angle (less than 5°) can be a cause for the TWS fault location equipment to mis-operate and not capture the event.

## ABSTRAK

Laporan projek ini mencadangkan bahawa gelombang-menjalar akan menghasilkan lokasi yang berbeza apabila gelombang yang dipantulkan ditafsirkan secara berbeza oleh peranti dalam sistem. Keselamatan Grid Sarawak sangat bergantung kepada ketersediaan rangkaian penghantaran. Oleh itu, adalah penting bahawa sebarang gangguan pada talian penghantaran boleh ditempatkan dengan cepat dan tepat untuk meminimumkan masa gangguan atau pengulangan gangguan. Pada masa ini, Sarawak Energy Berhad (SEB) menggunakan Sistem Gelombang-Menjalar (TWS) untuk mengenal pasti lokasi gangguan pada penghantaran talian yang betul. Untuk lokasi gangguan gelombang-menjalar penamat tunggal, pengenalpastian pada gelombang yang dipantulkan adalah penting untuk mendapatkan lokasi tepat bagi gangguan. Kerana polariti gelombang-menjalar yang tercermin dari titik kesalahan atau dari bas jarak jauh dipengaruhi oleh konfigurasi bas pada kedua-dua hujung garis bersalah, adalah sukar untuk mengenal pasti sama ada gelombang perjalanan tercermin dari titik kesalahan atau bas jarak jauh menggunakan kekutuban gelombang perjalanan modal tunggal. Satu kajian terdahulu hanya mencadangkan cara mencari dengan mensimulasi semula gangguan dalam persekitaran terkawal. Terdapat dua jenis teknik analisis gelombang-menjalar yang dicadangkan dalam tesis. Pemodelan rangkaian elektrik yang mudah akan dilakukan menggunakan MATLAB Simulink di mana empat jenis gangguan; 3-fasa, 2-fasa, 2-fasa-ke-bumi dan 1-fasa akan disimulasikan dalam rangkaian. Analisis gelombang pada gelombang-menjalar dilakukan selepas pemprosesan isyarat bentuk gelombang semasa gangguan berlaku. Analisis gelombang pada gelombang-menjalar menunjukkan bahawa kesan pemboleh ubah seperti sudut permulaan (inception angle) gangguan, rintangan dan jarak talian penjana akan menghasilkan lokasi gangguan yang tidak tepat. Data dianalisis dengan kaedah yang dicadangkan dalam tesis mendapati bahawa hasilnya mencerminkan penemuan dalam pemodelan rangkaian elektrik yang dipermudahkan. Simulasi menunjukkan bahawa kesan rintangan mempunyai kesan kecil (kurang daripada 5% julat ralat) pada gelombang-menjalar dan amplitud. Walau bagaimanapun, sudut permulaan gangguan (kurang daripada 5°) boleh menjadi punca bagi peralatan lokasi gangguan TWS tidak menangkap peristiwa gangguan tersebut.

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| | | |
|---|---|---|
| Y | - | Admittance [$Ohm^{-1}$] |
| a | - | Attenuation Constant [Napers/m] |
| b | - | Phase constant |
| C | - | Capacitance [Farad] |
| $Z_0$ | - | Characteristics Impedance [Ohm] |
| G | - | Conductance [$Ohm^{-1}$] |
| L | - | Inductance [Henry] |
| v | - | Propagation speed of wave [m/s] |
| $\gamma$ | - | Propagation Constant |
| R | - | Resistance [Ohm] |
| $\Psi$ | - | Mother wavelet |
| H | - | Frequency (Hertz) |
| CWT | - | Continuous wavelet transforms |
| DWT | - | Discrete wavelet transforms |
| DSP | - | Digital Signal Processing |
| TWS | - | Traveling wave fault location system |
| FT | - | Fourier transform |
| EMTP | - | Electro-magnetic transient program |
| EHV | - | Extra High Voltage |
| FIR | - | Finite Impulse Response |
| CT | - | Current transformer |
| SEL | - | Schweitzer Engineering Laboratories Inc. |

## LIST OF APPENDICES

# CHAPTER 1

# INTRODUCTION

## 1.1 Problem Background

Electrical power grid is made up of generation, transmission lines, substations and distribution networks. Transmission lines are normally designed for extra high voltage (EHV) operation to connect the generation stations to the load centres. The generation/power stations are usually further away from load centres/user and therefore EHV transmission lines must cross large physical distances for the interconnection. Transmission lines are subjected to line faults due to lightning, mechanical failures, vegetation incursions and other natural elements that are impossible to completely protect. A fault on the transmission system has great impact on system stability and availability. It is therefore very necessary to locate, clear the fault and normalize the effected line immediately.

Since Malaysia has a tropical climate, the rate of lightning occurring is high and vegetation growth is rapid. Transmission lines are located mainly in a corridor assigned away from major development and thus subjected to faults arising from faults caused by vegetation, animals, lightning and failure of transmission line hardware. For most of transmission line faults, single phase-to-ground faults dominates, and this fault type is will be studied in greater detail in this paper. Three phase faults are mainly due to mal-operation of switching operation with 3-phase portable earth not removed during energization. Double phase faults are not very common and may be due to conductor breakage. Although the effect on stability of the system is greater for the 3-phase and 2-phase faults, these rarely occur in real time.

During fault occurrence, the protection equipment would detect the fault and disconnect the faulted line from the electrical system. This action from the protective equipment and switchgears take less than 120 ms to complete and any fault location equipment is expected to give the operator a precise fault location immediately after the fault. Traditional impedance measurement and fault location has a wide tolerance depending on the fault type and system topology. This method is not dependable and therefore a better and more accurate method of fault location is required.

Traveling wave fault location has gained a wide acceptance with the ready availability of accurate due to GPS timing equipment. The accuracy of TWS location equipment is reported to be less than 300 m which is within 1 pole span of a typical EHV transmission line. The hardware setup of the TWS fault location system is simple to implement and to retrofit. The core system includes clamp on current transformers, detection and recording equipment, GPS timing equipment and a basic communication channel to the main station.

The location of fault is determined by accurate time tagging the arrival of traveling wave at each end of the line. No specific line parameters such as line impedance are required for this method. The only input required analysing fault data with the traveling wave fault locator are line length and wave velocity. TWS fault locator can locate phase-to-phase and phase-to ground fault, irrespective of the value of fault resistance, as well as broken conductors. It provides a level of accuracy (±150m regardless of line length) many times better than that offered by conventional 'one-ended impedance base' type fault locator (accuracy about 5%-10% of the total line length). It also can locate vegetation fault more easily as compared to the conventional 'impedance' type fault locator.

## 1.2 Problem Statement

Conventional method of using single ended impedance measurement for fault location has many challenges as described by Zimmerman, K and Costello, D (2004). Traditional impedance-based fault location is not accurate enough and result is dependent on system topologies and fault types. The errors caused by fault resistance and load, mutual coupling effect and in-feeds are some of the main contributors to inaccurate result of fault location. The method does not give accurate results and are not reliable for high impedance faults. In nature, vegetation faults are normally having a high impedance

Traveling wave fault location technique is gaining wide acceptance in locating line faults. The technique requires the study of traveling wave produced naturally during a fault and is not affected by the various system conditions associated in the impedance method. However, there are concerns with the accuracy of fault location due to a different set of constraints such as fault inception angle, fault impedance and algorithm to determine the fault location (Sawai, Suraj, Pradhan, A K and Naidu, OD, 2017). These constraints need to be investigated to justify the suitability to use traveling wave as an accurate and dependable fault location technique.

For single phase faults which dominates most of transmission line fault type in Malaysia (Abdullah Asuhaimi Mohd. Zin, Sazali PO. Abdul Karim, 2007), there has been reports from utilities that single phase faults caused by high fault resistance are not reliably captured by TWS system. The performance of traveling wave fault location technique has produced mixed results which roughly has a success rate of about 80%.

## 1.3 Research Objective

The objectives of the research are:

(a) To verify and simulate of a sample transmission system using MATLAB for a transmission line of 200 km with 2 generation sources at either ends of the line for the study of traveling wave fault location. The distance can be varied from 100 km to 400 km.

(b) To simulate and verify by analysis of the traveling waveform the fault distances of the modelled transmission line for all fault types at various fault distances, fault inception angles, fault resistances and generation source.

## 1.4 Project Scope

The research work carried out in this project are concentrated to the following aspects:

(a) Verification of fault location using traveling wave techniques
(b) Determination of fault location using traveling wave phenomenon
(c) Accuracy of fault location simulation
(d) Verification of the validity of traveling techniques for different fault types
(e) Observe the effects of fault inception angle on fault traveling wave
(f) Observe the effects of fault resistance on traveling wave
(g) Observe the effects of line distance on traveling wave
(h) Investigate the weak end condition on traveling wave

## 1.5 Project Outline

In this project report, a total of 5 chapters are presented. First chapter will introduce the background of the problem and the objectives of this study. Some limitation and scopes are explained. Chapter 2 will investigate literature review, theory, formula behind the finding the fault location.

Further detailed explanation on the proposed MATLAB-Simulink setup and implementation method will be enlightened in chapter 3. Collected data and short explanation on the result will be presented in chapter 4. Chapter 5 will present the conclusion of the project report and further works needed to be done to improve the TWS. Research schedules are explained in terms of Gantt chart for the whole frame of study

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