Effect of Cross-Country Fault on Distance Protection in Transmission Line with Different Voltage Levels

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Abstract — **Transmission overhead line is one of the main elements in electric power system. Electrical power system comprises of generation, transmission and distribution. For transmission lines, it is used to transmit electric power to large load center. Nowadays, double circuit transmission lines on the same tower with a different voltage are widely used. This paper present the studies of the effect on distance protection, when fault that occur in the transmission line that have different voltages in the same tower. In this situation, PSCAD/EMTDC software has been used to simulate the output current and voltages in order to see the fault effect on distance protection. In the other words, the PSCAD/EMTDC software is used in model and analysis of the effect of cross-country fault on distance protection. In this paper, the result of cross-country fault on distance protection with different voltage levels is presented.**

Keywords – Transmission Line, Cross-Country Fault, Fault, Distance Protection, Protection Zone

I. INTRODUCTION

The purpose of a transmission network is to transfer the electric energy from generating unit to distribution system [1-7]. Transmission lines also interconnect neighboring utilities not only to economic dispatch of power during normal condition, but also transfer power during emergencies [3,7,8,9]. When a fault occurs on transmission line, the voltage at the point of fault is suddenly reduced to a low value. Thus, fault is an abnormal flow of electric current [17-18].

Faults on transmission lines must be detected correctly and quickly to prevent the disturbance or damage to system and maintain security and reliability of supply [3-6]. This fault can damage the power system in several ways. To reduce the effect of faults, distance protection relays are installed as a part of power system in order to protect the equipment from damages.

As already known, a cross-country fault is one where there are two faults occur at the same circuit, but in different locations and possibly involving different phases and voltages [8,12-14]. This type of fault can only occur at double or more circuit in transmission line. In this case, the distance protection must trip only for fault that occurs in protected zone, but sometimes it may not trip the internal faults or trip the external faults incorrectly.

To reduce the effect of fault, the distance protection has been used in power system transmission line [15-17]. Distance protection is comparatively simple to apply and it can be fast in operation for faults located along the protected circuit [2,3,5,17,8,18].

In this paper, the output of the simulation for the cross-country faults issues that affected the distance protection in transmission lines is presented. The theoretical analysis and the PSCAD/EMTDC simulation results show that the location of the fault was able to detect the high impedance ground fault in selective ways.

II. POWER SYSTEM PROTECTION

A. Background

Transmission lines in power system exhibit the electrical properties of the inductance, resistance, capacitance and conductors [3,16,14,19,18,10]. These parameters are essential for the development of transmission line models that are used in power system analysis. The selection of the voltage level for transmission lines is based on the amount of the power and the distance of the transmission line.

Among the many cause of the fault, the cross-country fault is the rare fault that occurs in power system. These faults often occur at the worst possible time and locations. Sometimes, it will occur with maximum amount of current and cause big damages [5].

In this situation, the distance protection is used to detect the fault and prevents it from causes a big damage. These distance protections detect the fault and closed the system, cleared the fault that occurred in transmission line and after that it will enable the system to function as usual.

B. Power System Configuration

Power system is a complex system in the world. Double circuit transmission lines are being used more widespread as they increase the power transmission capacity and increase the reliability of the system [7,15-17,8,12-14,19]. Double circuit transmission lines are defined as lines that share the same structure or right of way for all, or a portion of, their length. It may enhance the transmission capacity of each way, other than to reduce the use of ground and can save cost.

Faults have two types which are symmetrical and unsymmetrical faults [1,4,8]. Single line to ground fault is the most common fault while the three phase short circuit fault is the most severe faults. Whenever the fault occurs, the loss of supply will be faced by the consumers. Cross-country fault can be defined as a fault that is possibly involving different phase and occurring at two different locations in power system [1,2,4,7,14-17].

To protect the components in transmission lines from damages, distance protection relays are used and operated within a certain distance. In transmission system, distance protection works by utilizing the fact that the measured impedance from a point is directly proportional to the distance.

If the apparent impedance is less than the impedance-reach, then it is concluded that a fault has occurred in the protected line between the relay location and the impedance reach of the relay. Combination of an impedance reach and its associated time delay is known as a protection zone. It is common to provide distance relays with three protection zones but, depending on the application, extra zones can be included in the relay. The incidence of a fault within a protection zone of a distance relay must initiate and complete the operation of the relay.

For this research, PSCAD/EMTDC software has been used to simulate the system in order to generate the current and voltages during cross-country fault condition. Based on the simulation, the result will be compared with fault and cross-country fault.

III. POWER SYSTEM NETWORK

The steps for the simulation are:

A. *System Studied*

Figure 1 shows that the system that has been used in the simulation which is based on the single line diagram of the power system for two terminals with different type of voltages in a transmission line system.

B. *Power System Modelling*

In this paper, the result and analysis have been done using PSCAD/EMTDC software in order to generate the current and voltages during cross-country fault condition. From this Figure 1, the output for current and voltages during cross-country fault can be determined.

In this analysis, if there is a fault occurs in line, the trip signal will be sent to trip the circuit breaker. The trip signal is measured at the secondary side of distance protection relay module. In order to determine the trip signal, the apparent impedance of each phase and ground element is calculated as shown in Table 1:

TABLE I: APPARENT IMPEDANCE

Element	Apparent Impedance
a-b	$(\overline{V_a} - \overline{V_b})/(\overline{I_a} - \overline{I_b})$
b-c	$(\overline{V_b} - \overline{V_c})/(\overline{I_b} - \overline{I_c})$
c-a	$(\overline{V_c} - \overline{V_a})/(\overline{I_c} - \overline{I_a})$
a-g	$(\overline{V_a})/(\overline{I_a} + k_0\overline{I_{res}})$
b-g	$(\overline{V_b})/(\overline{I_b} + k_0\overline{I_{res}})$
c-g	$(\overline{V_c})/(\overline{I_c} + k_0\overline{I_{res}})$

The calculation for apparent impedance cannot be obtained directly from the network. Both of the voltage and current have to pass through Capacitive Voltage Transformer (CVT) and Current Transformer (CT). After that, the signal is reduced by the turn ratio and sent to Fast Fourier Transform Module (FFT) in PSCAD/EMTDC [14].

Figure 1 shows that the simple model transmission line that has been designed to represent the real system. The transmission line is represented by using the Bergeron line model system which is available in the software and the generators is represented by using the equivalent potential source and equivalent source impedance. The bulk of data are generated using multiple run component of PSCAD/EMTDC software. With this, the variable parameter in PSCAD can be used in designing the model.

C. *System Methodology*

The cross-country fault can be defined as a fault that is possibly involving different phases and occurring at two different locations and voltages simultaneously in power system. Based on this research, the effect of cross-country fault on distance protection will be determined by using PSCAD/EMTDC software. By using this software, the output current and voltage will be identified and the result of cross-country fault will be calculated. By using the simulation from PSCAD/EMTDC, the comparison between ordinary fault and cross-country fault can be done.

PSCAD/EMTDC is used to generate fault current and voltage signals under cross-country fault scenarios [9,21-23]. The transmission line in the system is being represented using the Bergeron line model. In order to get a better result, the analysis has been done on every kilometer of the transmission line.

After that, the analysis are needed to be done in order to find the suitable distance relays protection for every different type of cross-country fault that occur. In this paper, the analysis will focus on Mho distance relay characteristics only.

D. *System Modelling and Analysis*

The transmission line network in this paper is used to generate the fault current and voltage during cross-country fault. The system studied is composed of a double-circuit transmission lines that are connected to the sources at each end as shown in Fig. 1.

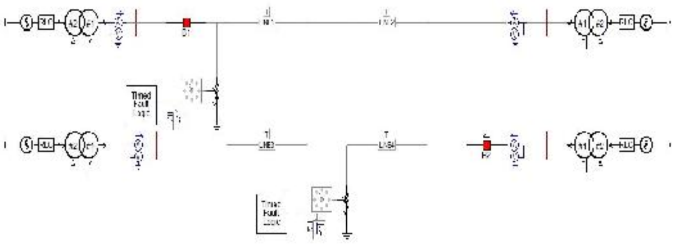


Fig. 1. Simple Single Line Diagram Modeling

All components are modeled by PSCAD/EMTDC simulation software such as different fault on transmission line, fault timing and fault position that is adjusted manually by dividing the line into two part of required length. The transmission line is simulated using distributed parameter line model. Fig. 1 shows that the different circuit with different value of voltages.

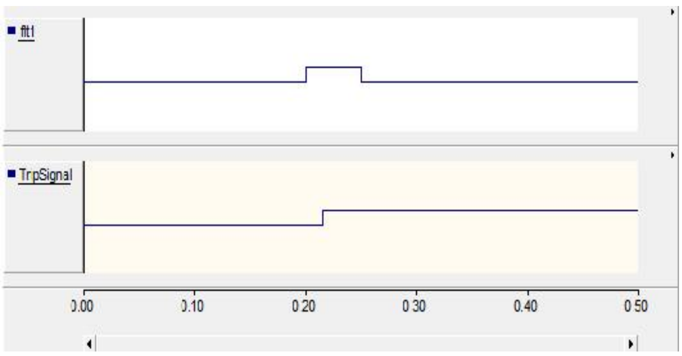


Fig. 2. Time Occur and Trip Signal

The data for this analysis is collected for one cycle of fault and the time for fault occur is fixed at 0.2 sec for the duration of 0.05 sec as shown in Fig. 2. The simulation is based on different types of fault including three phase fault, phase to phase fault, phase to phase to ground fault and single phase to ground fault.

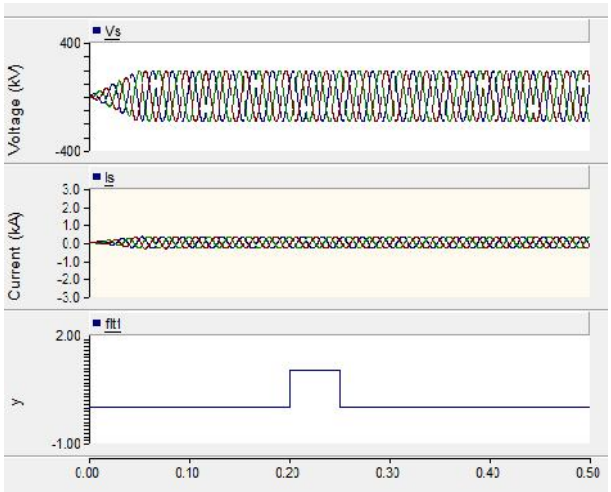
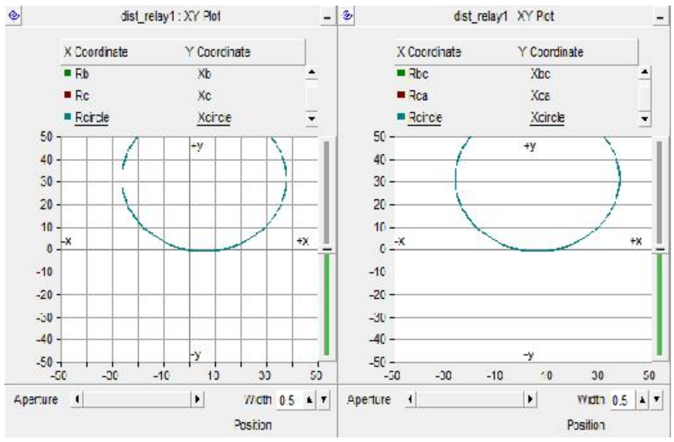


Fig. 3. Output Voltage and Current (Fault in Normal Condition)



(a) (b)

Fig. 4. Distance Protection Relay (Fault in Normal Condition) a) Impedance Z b) Resistance

Fig. 3 shows that the output for voltage and current waveforms from the simulation. where since there is no faults occur in the system, so it works as in a normal condition. Therefore, there is no effect to the distance protection as shown in Fig. 4.

From this analysis, the first fault analysis is for single line to ground fault that occurs simulteneously which involves different voltages level. Fig. 5 shows the output voltage and current for single line to ground fault.

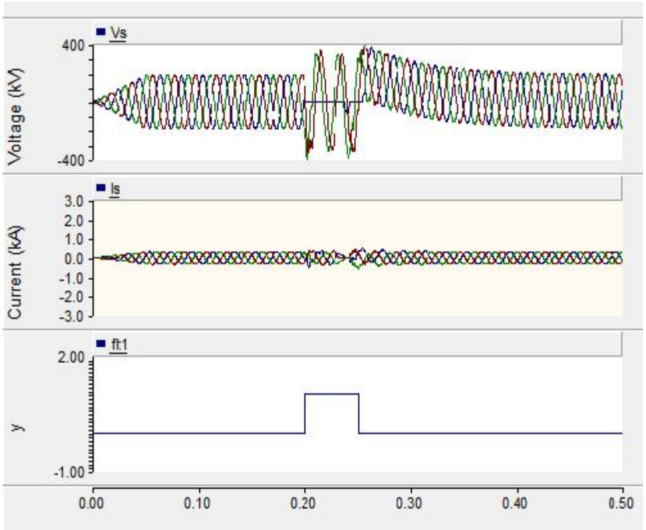
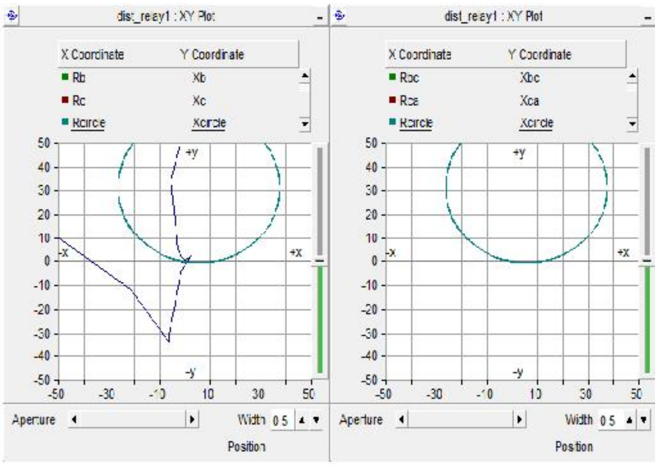


Fig. 5. Output Voltage and Current (Single Line to Ground Fault Condition)

In the Fig. 5, it can see that the output for voltage and current change when the fault occur on the system. During that time, the circuit becomes unstable and will not operate until the fault has been fully cleared.



(a) (b)

Fig. 6. Distance Protection Relay (Single Line to Ground Fault Condition)
a) Impedance Z b) Resistance

When the fault occurred in transmission line, distance protection on the system will interrupt. Fig. 6 shows that the output for distance protection relay during single line to ground fault that occur in the system. When the R-X Trajectory of the impedance has crossed the reach zone (using zone 1), it shows that the single line to ground fault at this situation is still in protected zone and will operate normally after the fault has been cleared.

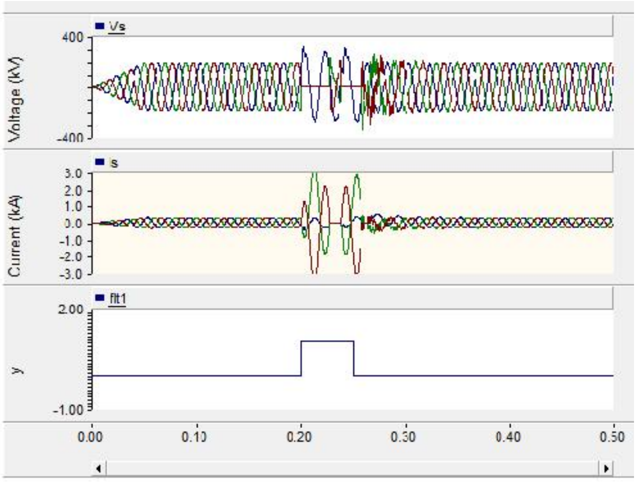
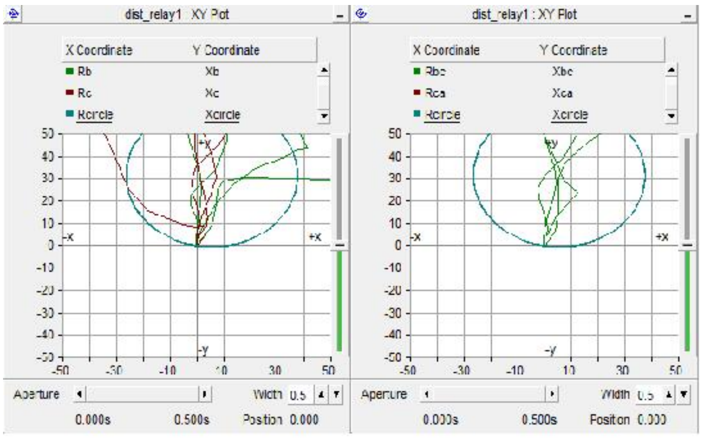


Fig. 7. Output Voltage and Current (Line to Line Fault Condition)

Different effect for different kinds of fault that occurred in transmission line system can be found. When the line to line fault occurred, the voltage and current waveforms are as shown in Fig. 7. From the observation, voltage and current from the line are interrupted and this will make the system become unstable.



(a) (b)

Fig. 8. Distance Protection Relay (Line to Line Fault Condition)
a) Impedance Z b) Resistance

The simulation output for distance protection relay is shown in Fig. 8. From the analysis, the fault that occurred in this system is still in protected zone. When the R-X Trajectory signal is detected, the tripping signal will be sent to trip the breaker. The tripping signal at breaker can be verified from the phase and ground element that can be identified during the abnormal condition in Polarised Mho Distance Relay.

IV. CONCLUSION

Fault always occurs in different ways and different types. In this paper, the effect of the voltage with different type of fault that occurred in the transmission line is determined. Based on the theoretical part before, there are types of fault that could possibly occur in transmission line. But in this paper, it only focuses on the effect of the single line to ground fault and line to line fault on transmission line. From this analysis, it shows that the output for current and voltage are still in protected zone when the faults occurred. This analysis is done using PSCAD/EMTDC simulation software. The cross-country fault can also be analyzed based on the sampled output voltage and current waveform. From this analysis, it shows that the amplitude and phase angle of the faulted current and voltage signals are obtained from FFT Module that are provided inside the simulation software. From here, the R-X Trajectory can identify the cross-country fault that occurred in transmission line system and for the calculation of the apparent impedance, it needs the output current and voltage that obtained from FFT Module. It is concluded that the cross-country fault that occurred in transmission line can be detected by using the simulation software in distance protection either it still in protected zone or not in order to protect the component in transmission line from damages.

ACKNOWLEDGMENT

This project is supported by Universiti Teknologi Malaysia (UTM) and Malaysia Ministry of Higher Education (MOHE) under RUG VOT no 03H45

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