International Journal of Electrical and Electronics Engineers
Volume 13, Issue No. 02, July-Dec 2021
ISSN (O) 2321-2055
ISSN (P) 2321 -2045

Simulation of Faults on Transmission Line using PSCAD/EMTDC

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ABSTRACT

This paper presents a simulation of faults on transmission line using PSCAD/EMTDC software. This work has been realized by creating a power system on the software, which consists of one generator of 400kV located on one side of the transmission line, a three-phase fault module that is used to simulate faults at various position on transmission line and a load. The line has been modelled using distributed parameters so that it more describes a very long transmission line. The transmission line and the three-phase module were used to simulate types of faults at various locations of fault inception angles, different fault's resistances, different sources, and load impedance. Based on the results in section III, the simulation model can be used for data generation in designing an artificial intelligence based relaying algorithms for protection of transmission line.

Index Terms—Transmission line, fault inception angles, three phase fault module, PSCAD

1 INTRODUCTION

In the past several decades, there has been a rapid growth in the power grid all over the world which eventually led to the installation of a huge number of new transmission and distribution lines. Moreover, the introduction of new marketing concepts such as deregulation has increased the need for reliable and uninterrupted supply of electric power to the end users who are very sensitive to power outages. There exists literature on the on transmission line and PSCAD simulation [1]-[3].

This work focus on the simulation of various fault conditions on transmission line: normal load condition, single line to ground fault, line to line fault, double line to ground and three line to ground fault conditions using PSCAD/EMTDC. The results obtained from the various conditions can be used for analysis to explore new protection algorithm for detected and classified of faults on transmission line.

This paper is organized as follows. In section II, the model of transmission line is presented. In section III, The simulation using PSCAD and the simulation studies of the transmission line are presented. Lastly, the conclusions are presented in section IV.

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2 Modelling of power transmission Line Using PSCAD/EMTDC

The system consists of a generating source of $400kV$ located on one side of the transmission line, three phase fault model which is used to simulate fault at various position on transmission line and a load.The line depict in fig 1 has been modelled using distributed parameters so that it more describes a very long transmission line.The two transmission lines together meant for 100km and the three phase module was used to simulate different types of fault at different locations of fault inception angle, different fault resistances, different sources and load impedance.

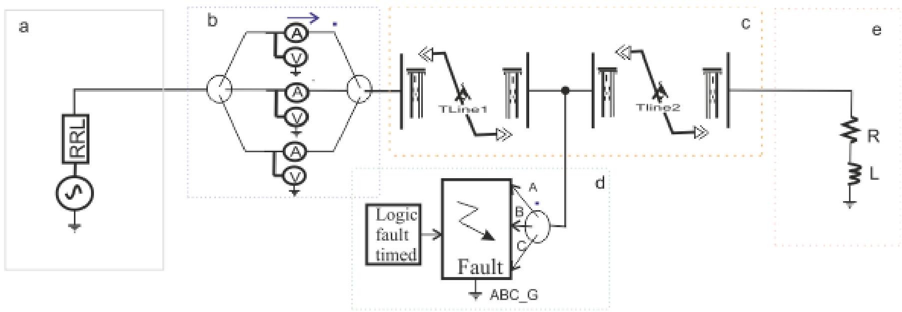

Figure 1: The studied model in PSCAD (fault location at 50km) : (a) generator of $400kV$ (b) multimiter (c) $100km$ transmission line (d) fault module and (e) load

2.1 simulation parameters

A transmission line is described by the following parameters: shunt conductance G because of leakage current between the phase and ground, series resistance R due to the conductor resistivity, shunt capacitance C owing to the electric field between conductors and series inductance L owing to magnetic field go around the conductors [4]. These parameters are estimated according to the following equations

$$L = 2X10^{-7} In \frac{D_g}{D_s} \quad H/m \qquad (1)$$

where L is the per phase inductance, D_s is the self geometric mean distance and D_g is geometric mean distance between the three phase conductors. Similarly, the shunt capacitance C of each phase to neutral is given by

$$C = \frac{2*\pi k}{In D_g/r} \quad F/m \qquad (2)$$

where r is the conductor radius and k is the permittivity of the dielectric medium. In addition, the series impedance per unit length/phase and the shunt admittance per unit length/phase is given by (3) and (4) respectively.

$$z = R + j\omega L \qquad (3)$$

$$y = G + j\omega C \qquad (4)$$

Table 1: Source and load Parameters

Parameter	symbol	value	unit
Base MVA (3 phase)	S	100	
Base Voltage (rms)	V_{LL}	400	
Base frequency	f_b	50	
load inductance	L	0.5	
load resistance	R	5	
Impedance data format	RRL		

Table 2: Transmission Line Conductor Data

Parameter	symbol	value	unit
Positive Sequence resistance	$R1$	0.01809	Ω/km
Zero Sequence resistance	Ro	0.2188	Ω/km
Positive Sequence inductance	$L1$	0.0009297	Ω/km
Zero Sequence inductance	$L0$	0.003283	Ω/km

2.2 component used for the simulation

The outlined part (a, b, c, d and e) in the schematic diagram of Figure1 represents a power system which consists of electrical source (a), measurement system (b) that is used to measure quantities(e.gcurrent, voltage,power,etc.), transmission line components (c) that is used to simulate transmission line parameters, fault module d which is to

$$\begin{bmatrix} x_+ \\ x_- \\ x_o \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & e^{\frac{j2\pi}{3}} & e^{\frac{-j2\pi}{3}} \\ 1 & e^{\frac{-j2\pi}{3}} & e^{\frac{j2\pi}{3}} \end{bmatrix} \begin{bmatrix} x_a \\ x_b \\ x_c \end{bmatrix} \quad (5)$$

3 simulations

In this section, the simulation of power system is presented which is symmetrical but is altered unbalanced by a fault at particular location on the transmission line. Such fault can be created using a fault module by connecting the module at the desired position on the line. The types of faults and sequence component are also described in this part

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3.1 Normal conditions

Figure (2) illustrates the normal condition of three phase voltages,three currents and the ratio of sequence components currents (I_o and I_n), load current to the positive sequence component current. The result indicates that the system are balanced after the transient condition with $\frac{I_n}{I_p} = 0, \frac{I_o}{I_p} = 0$ and $\frac{I_p}{I_{Iload}} = 0.389$

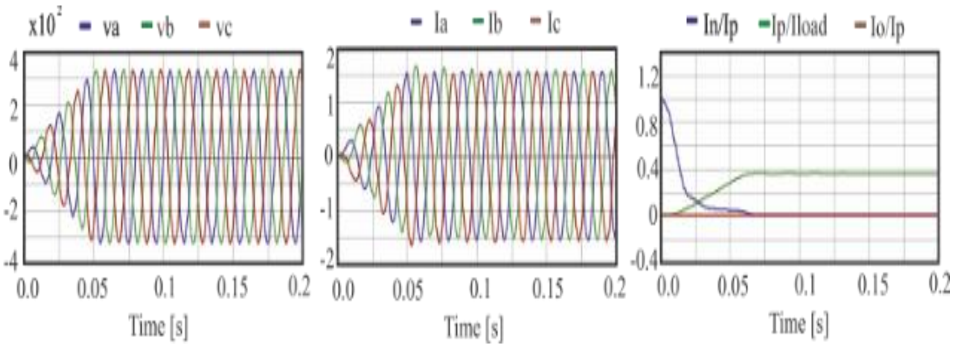

Figure 2: Normal conditions: three phase voltages (V), three phase current in (A) the ration of sequence components of currents

3.2 faults generation

Various types of faults were simulated on transmission line. The fault was created at 0km 50km and 100km on the line. The level of fault current depends on the fault position and the impedance of the line as shown in the simulation results. For each type of simulated fault, the fault was started at various angle of fault inception: $0^o, 45^o, 90^o, 135^o, 180^o, 225^o, 270^o, 315^o$.

The simulation was carried out for the following types of faults:

- Line-to-Ground fault
- Line-to-Line fault
- Douple Line-to-Ground fault
- Three Line-to-Ground fault

3.2.1 Line-to-Ground fault

in this type of fault, phase a was shorted to ground at the fault location ($0km, 50km \quad and \quad 100km$). thus, the voltage V_a is zero and $I_b = I_c$ as depicted in fig (4d) and the currents and voltages are given by (6) in terms of symmetrical component based on (5) as

$$V_{a+} + V_{a-} + V_{ao} = V_a \qquad (6)$$

$$I_{a+} + I_{a-} + I_{ao} = \frac{I_a}{3} \qquad (7)$$

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V_{a+}positive squence component of voltage V_{a-}positive squence component of voltage V_{ao}positive squence component of voltage

3.2.2 Line-to-Line fault

similarly to the phase to ground, the phase a and phase b was shorted to ground. Thus, the voltage $V_a = V_b = 0$ and $I_c = 0$ as depicted in fig (4e). Also,the currents and voltages are given by (6) in terms of symmetrical component based on Eqn (5) as

$$V_{c+} = V_{c-} = V_{co} \quad (8)$$

$$I_{c+} + I_{c-} + I_{co} = 0 \quad (9)$$

3.2.3 Three Line-to-Ground fault

this is symmetrical fault in which all the three phase are shorted to ground. Thus, the voltage and currents are given by

$$V_a = V_b = V_c (10)$$

$$I_a + I_b + I_c = 0 \quad (11)$$

All These types of fault were generated using fault module and Timed fault logic that is used to control the starting and duration of fault.

3.3 sequence component extraction

The concept of symmetrical components was first developed by C.L Fortescue [5]. He shows that an unbalance phasors can be resolved into a balanced phasors known as symmetrical component of the original phasors. The three phase unbalance system can be resolved into three phase balance system as: positive sequence components consisting of three phasors having the same phase sequence as the origal phasor, negative sequence components consisting of three phasors having opposite to that of original and zero sequence components consisting of three phasors having equal in magnitude and phase. In this work, The line components were first processed using FFT algorithm and then derived the sequence components of the fundamental frequency.

As illustrated by Figures ($3a, b, c$, $5g, h, i$ and $6g, h, i$), The ratio of negative sequence current to positive sequence currents In/Ip differentiate the balance fault and unbalanced faults, the ratio of zero sequence currents to positive sequence currents Io/Ip differentiate the ground faults to phase faults and ratio of positive sequence currents to load currents $Ip/Iload$ used to differentiate between the balance fault and no fault condition.

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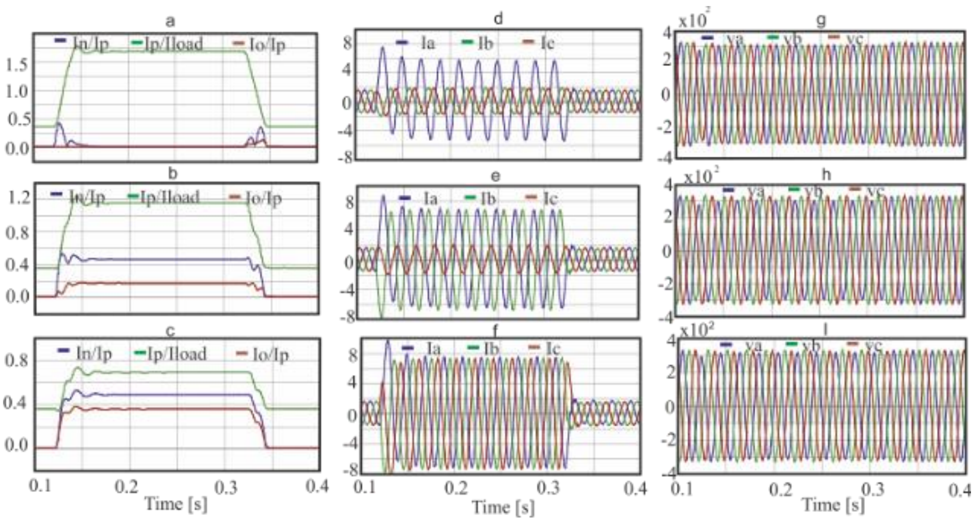

Figure 3: Fault simulation at $100km$ location on transmission line with a, b and c represent the ratio of sequence components currents for three line to ground, Double line to ground and single line to ground fault respectively. d, e, f and g, h, i represent the instantaneous currents and voltages during single, double and three lines to ground faults (fault start at $120ms$ and duration $0.2s$) respectively.

3.4 variation of simulation parameters

3.4.1 Source Impedance

the impedance is varied keeping the other parameters constant in order to observe fault current changes. Varying the source impedance was achieved by varying a series resistance, shunt inductance and shunt resistance. The simulation was carried for two values of source impedance: ($1.0\Omega 1.0\Omega 0.1H$) and ($3.0\Omega 3.0\Omega 0.3H$).

3.4.2 load Impedance

a three-phase series RL is considered as load and the load impedance is varied keeping the other parameters constant. Similarly, The simulation was carried for two values of load impedance: ($1.0\Omega 1.0\Omega 0.1H$) and ($5.0\Omega 5.0\Omega 0.5H$).

3.4.3 Fault resistance

Two values of fault resistance (0.0Ω and 0.01Ω) were used in this simulation to represent the branch resistance during a faulted state.

3.4.4 Location of faults

three positions on transmission line were used to create fault on the line. This include at the sources location $0km$, at the middle of the line $50km$ and at the end of the line i.e. $100km$ at the load point.

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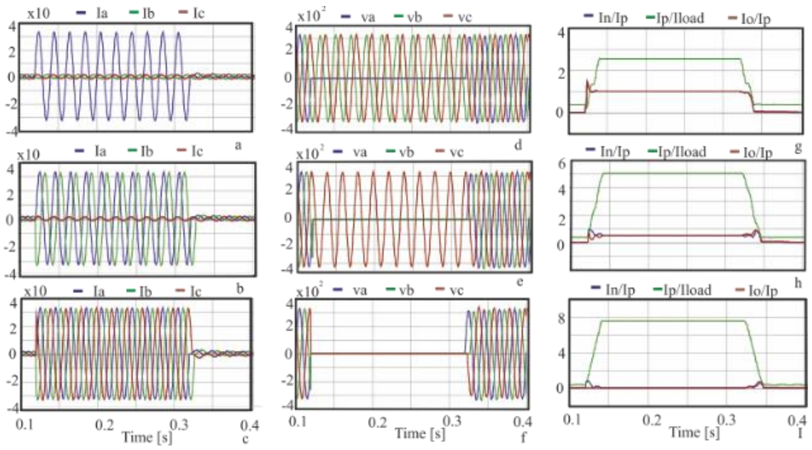

Figure 4: Fault simulation at $0km$ location on transmission line with g, h and I represent the ratio of sequence components currents for three line to ground, Double line to ground and single line to ground fault respectively.

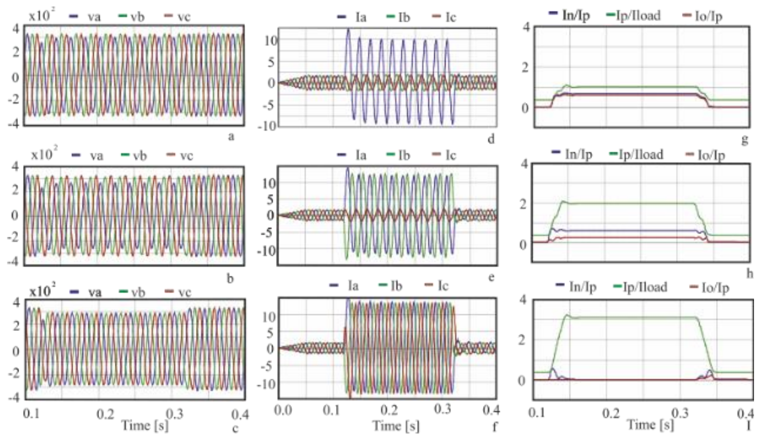

Figure 5: Fault simulation at $50km$ location on transmission line d, e and f representing the instantaneous currents during single line to ground, Double line to ground and three line to ground fault respectively.

4 CONCLUSIONS

This paper presents a simple power system model which is simulated using PSCAD and results are obtained at various types of fault on transmission line such as Line-to-Ground fault, Line-to-Line fault, Douple Line-to-Ground fault and Three Line-to-Ground fault.

As shown from the simulation results in fig. 1,2,3 and 4, the sequence component and instantaneous of voltages and currents data generated from the model can be used to design a proper relaying algorithms for protection of transmission line.

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