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Analysis of Fault and Determination of Damping Co-efficient and DC-Offset in a High Voltage Transmission Line

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Abstract

Fault analysis in transmission and distribution system is an important requirement to safeguard the power system. Fault analysis in a system is carried out for proper choice of protective relaying components in the transmission and distribution system. In addition, an estimate is made regarding the characteristics of the fault for protection by circuit breaker. In order to study the complete performance of faults on transmission lines, the variation of damping coefficient and DC offset of the system is discussed. In this paper, a single phase to ground fault is simulated. The short circuit currents are calculated by simulating faults at various points on the wave of supply and at various distances to account for fault current, damping and DC offset. The fault simulation is done using Electromagnetic Transient Programme

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Keywords: DC Offse; Damping Constant; Transmission Line faults

1. Introduction

Transmission lines of electrical power system frequently suffer from a large variety of faults. These faults can be detected by relays and other protection equipment installed at both ends of the line. The circuit breaker interrupts the fault and relieves the system from faulty section. It is also necessary to restore the fault lines and the components after the fault is cleared. However, the location of fault needs to be identified and the fault is required to be fixed, before the line becomes operative again. Many approaches to detect fault location have been published in literature [1, 2].

Typically, fault current consists of a symmetrical AC component and a DC offset current. To understand this concept, let us consider a transmission line excited by an equivalent voltage source. The fault can be simulated by closing the switch at $t = t_1$. A typical RL circuit is shown in Fig.1.

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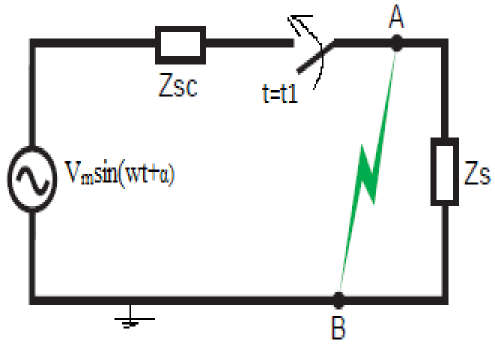

Figure.1 Typical RL Circuit

When a fault occurs between A and B, the negligible impedance between these points, Z_s results in a very high short circuit current 'I_{sc}' which is limited only by the line impedance, Z_{sc} = R+jwL. The current 'I_{sc}' exists under transient conditions depending on the reactance X and the resistances R of the line.

In power distribution network, reactance X is normally much greater than resistance R and the R / X ratio is between 0.1 and 0.3. However, the transient conditions and fault current depend on the distance between the fault location and the generator.

In this work, the short circuit currents are calculated in the power system by simulating the fault at different locations.

1.1. DC Offset and Damping Coefficient

A single phase fault is considered in the above analysis and similarly a 3 ϕ fault on 3 ϕ transmission line would always induce DC offset current in at least two phases.

The DC offset current depends upon

- Time at which fault strikes, α
- Phase angle ϕ of ac voltage
- Impedance of the line

The severity of DC offset component can be analysed with a typical example as below. If the occurrence of fault is at an angle, $\phi = 80^o$ on supply voltage of transmission line, then the fault instant, $t_0 = \frac{\pi}{2\times 2\pi\times 50} = \frac{1}{200}$ sec = 5 msec, the severity of dc offset current would be equal to $I = \frac{V_m}{|Z|}$, which is also the peak value of symmetrical AC component of the current. This leads us to an important conclusion. The solution for the current during short circuit consists of

a) Steady state component, $i_{ss} = I\sin(wt-\phi)$ (1)

b) Exponentially decaying component or unidirectional transient component,

$$i_{tr} = I\sin(wt-\phi)\exp(-kt/\tau) \quad (2)$$

The amplitude of the transient component depends on the time (t), point on the wave at which switch is closed. The unidirectional transient component or DC offset current, causes the total current asymmetry till the transient decays. For large X/R transmission lines, the following two instants are considered.

First case, the fault is simulated when the supply voltage is passing through maximum value (V_{max}). The short circuit current will follow sinusoidal shape from the instant of fault. The short circuit current is, i(t) = I cos wt. It shows that there is no transient at all at this instant of fault. The current wave is symmetrical and has a maximum value of short circuit current.

In the second case the fault is simulated when voltage ‘v’ is passing through zero towards positive. The resultant current contains both the steady state and transient components, which is asymmetrical. It is also known that the occurrence of fault at other instants will give asymmetrical waves with small transients. The transient term vanishes in 2 to 3 cycles.

2. Transmission Line Simulation

To obtain the necessary information about the fault cases, a 400 kV, 200 km long transmission line model is considered. The 200 km long transmission line is divided in to 10 equal π models each with 20 km long. The line is represented by resistance (R), line inductance (L) and capacitance (C) of 1.3 Ω, 0.28 mH and 0.08 μF for every 20 km network. The short circuit inductance towards transformer side has been taken as 9mH. The transmission line is simulated using distributed parameter line model. A stray capacitance (Cg) of 0.001μF is considered at source side of the transmission line to account for the secondary side transformer capacitance. The single line diagram of the 3Φ system is shown in Fig. 2.

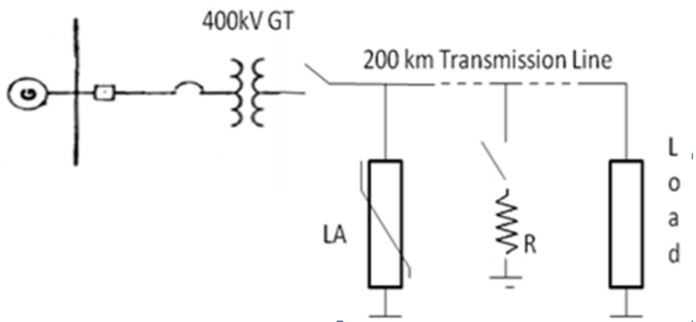

Figure 2 Single Line diagram of the transmission system

The Fault is simulated at every 20 km distance on the transmission line from the source side to the load side. The total simulation time is 60 msec with 1μsec time step. The Single line to ground fault is created at equidistance between load and source.

3. Results & Discussions

In order to simulate the single line to ground fault, a closing switch with series resistance equivalent to 0.1 Ω, as a fault resistance is chosen. A pre specified time to closing of the switch was considered. Immediately after the fault is simulated, the opening command for transformer side switch is communicated. Since, the switch opens in accordance with the specified chopping current, the phase switch opens with a time gap. The voltage at transformer terminal and current in the line during fault is recorded. Similar simulations were repeated at all discrete points along the length of line. The nature of current remains similar however a variation in the extent of transient is observed. A typical current waveform of single line to ground is shown in Fig. 3, for various discrete fault locations. The Unidirectional transient, due to which the waveform becomes asymmetrical, is as shown in the Fig. 4, for a fault at a distance of 40 km from the source.

Fig. 3 shows an initial transient of very short duration at the instant of closing the switch to ground through 0.1Ω fault resistance. After the transient subsides, the current follows the power frequency cycle. The Fault asymmetrical currents are observed at different locations on the line. Fig. 3 also reveals the variations in the current magnitudes and DC offsets, as the point of switching/fault instant are varied.

From Fig. 3, it can also be concluded that the magnitude of initial current during fault decreases as the location of the fault on the line increases.

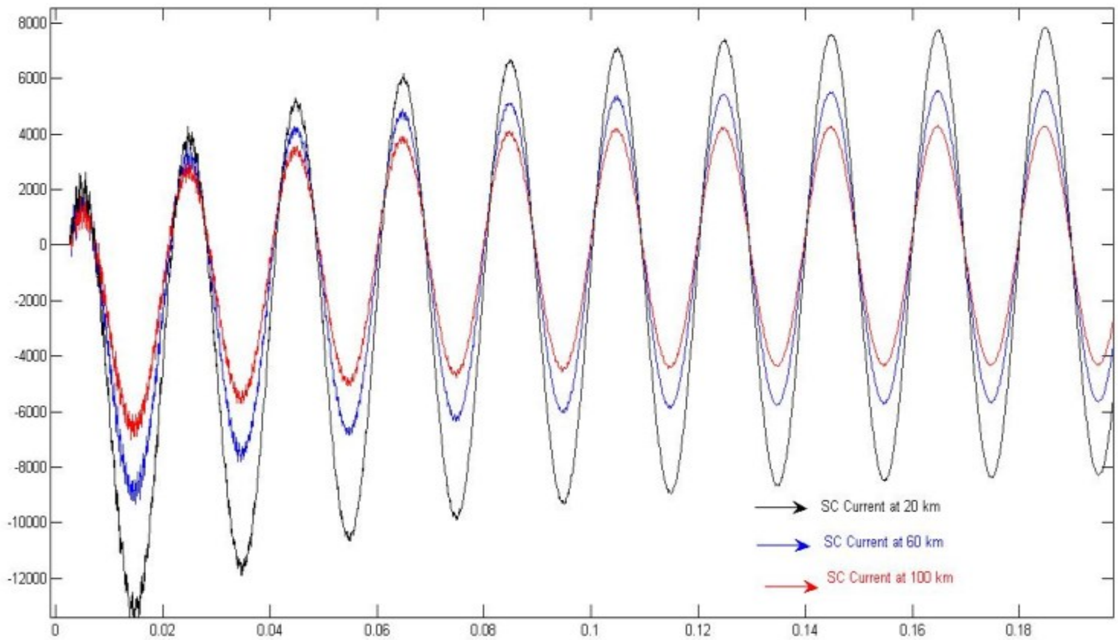

Figure 3 Current Waveform for LG Fault at different distances

The fault current is simulated at a distance of 40 km from the generator end is as shown in Fig 4. The variation of DC offset current and the fault current is also shown in Fig 4.

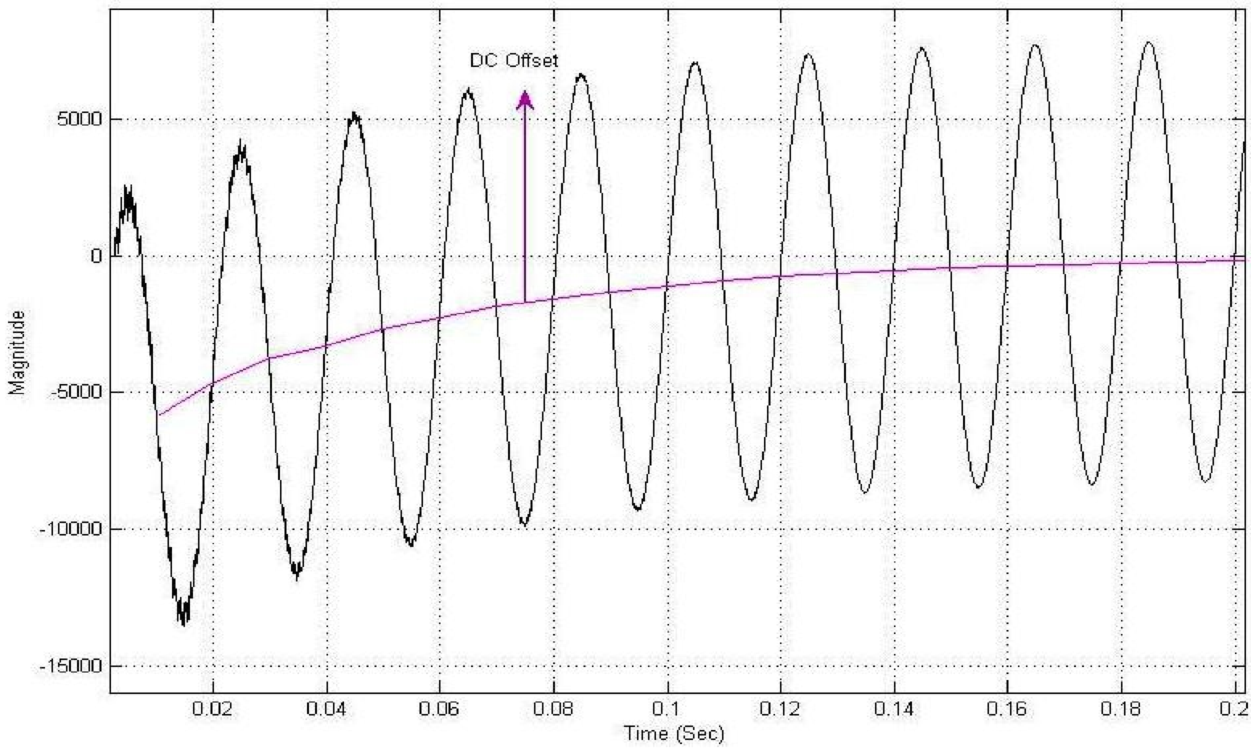

Figure 4 The variation of DC offset and fault current at a distance of 40 km

The fault is simulated at different points on the wave and the associated current waveforms are as presented in Fig. 5. It also describes the relation between the instant of a fault on a wave and the fault currents. The magnitude of transients will be large for the instant close to zero crossing of voltage waveform.

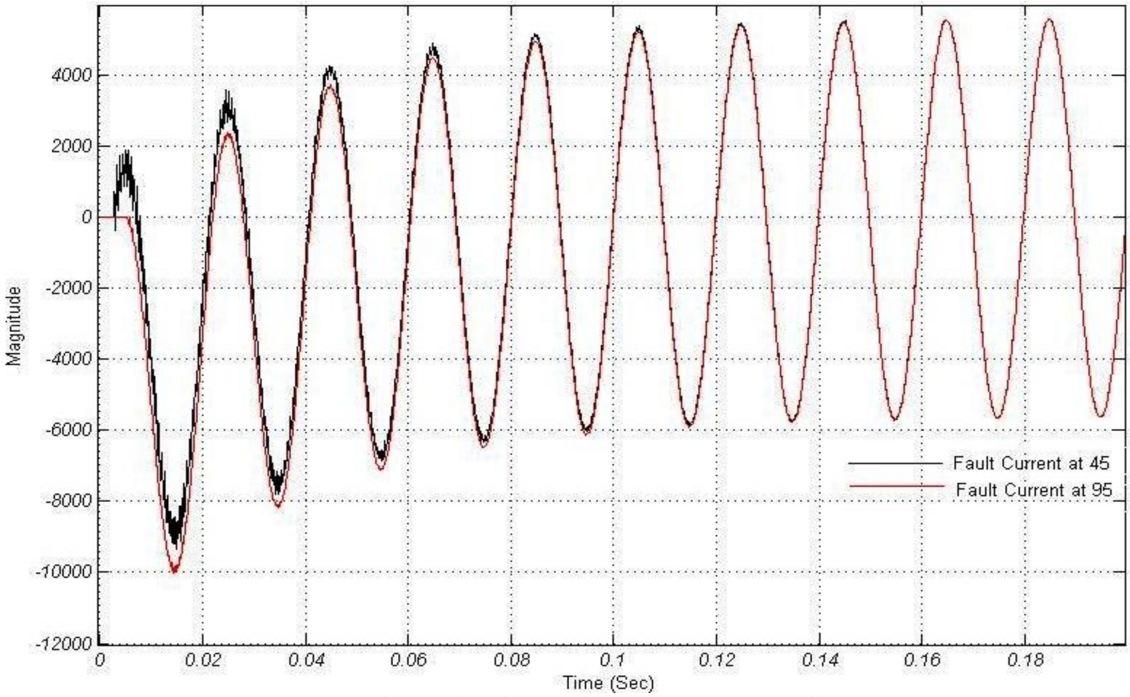

Figure 5 The variation of current for a point on a wave switching

The magnitude of DC offset is large for a fault point near to the source on a transmission system as shown in Fig.6.

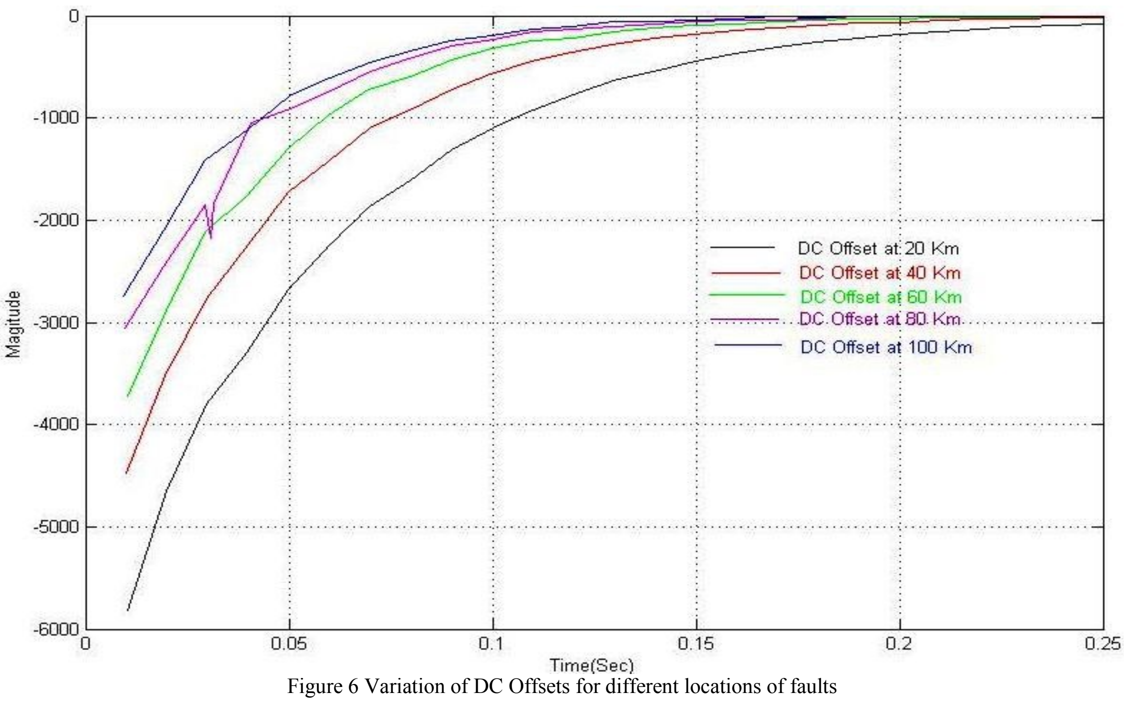

Figure 6 Variation of DC Offsets for different locations of faults

Table 1 explains the relation between the damping coefficient and the distance of fault from line end. The damping remains coefficient irrespective of point on the wave switching. We can also establish the dependency of the damping coefficient on the location of fault on a transmission line as given in Table 1. The Table 1 shows that with increase of fault distance from source there is an increase in damping coefficient. A Small difference in damping coefficient 'k' with distance is due to discretion error.

Table 1: The relation between Damping Coefficient and the point on a wave

Distance of fault on the line	Damping Coefficient (k)		
	Point on a Wave		
	2.5 msec	4.7 msec	5.3 msec
20	0.36	0.36	0.36
40	0.45	0.46	0.46
60	0.51	0.52	0.52
80	0.54	0.59	0.58

4. CONCLUSIONS

This paper describes the relationship between the damping coefficient and distance of fault due to single line to ground fault in a 400 kV, 200 km long transmission line. Results are also presented on variation of DC offset with point on wave switching. The initial currents during the fault are also studied since this information is mandatory for designing the protection devices. An estimate of damping coefficient of fundamental frequency shows as inverse linear relationship between damping constant and location of fault.

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