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Fault Location of 230kv Transmission Line Using Travelling Wave Technique

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Abstract

Transmission lines are used for the exchange of power from power plants to distribution centers and then to load centers. Impedance and travelling wave methods are used to locate fault in the transmission system. Travelling wave fault location method produces accurate results than impedance method. Faults can destabilize the power system so that it has to be detected soon and they have to be isolated immediately. During fault, bothvoltage and current transients are developed in transmission lines which travel close to the speed of light. By using this transients, fault location can be detected within few seconds.

Keywords: Fault location, Travelling wave and Wavelet theory

Introduction

Power system protection is stated as transmitting, generating and distributing power as safe as possible even at the occurrence of faults. A relay is a component of power system protection, as safety practices are devised into all conditions of power system equipments. Protective devices will not stop system being faulted; they can only bind the damage caused by faults. A fault is any phenomenon that causes unnatural operation for the power system or apparatus serving the power system. Faults come uninvited and seldom go away voluntarily. Fault generates transients travels along with the line which is known as travelling waves (TWs). This paper shows how to measure the transients and to locate the fault using discrete wavelet transformation (DWT). This method helps to estimate accurate fault location precisely within couple of seconds. Precise fault location techniques for transmission lines may bring down the search duration that helps the power system personnel to locate the fault, leading to a quick revivalof the system.Typically, transient detection methods handle more than one sample of voltage or current to make feasible the required transient study.

Initially, a 230kV transmission system is considered and a fault is created manually. Due to which the travelling wave is generated and it is analyzed using discrete wavelet transformation to obtain the fault location.

Travelling Wave Technique

Travelling wave experienced in high voltage lines launches one of the shortest system transients, which transpires from some microseconds to several milliseconds. Short circuit in transmission lines and lightning or switching operations in a power system results in propagation of electromagnetic waves which is associated with travelling wave phenomenon. An abruptand significant deviation in voltage or current values at least in a pointinside the high voltage line as shown in figure 1 leads to the beginning of an electromagnetic wave which propagates from that point in opposite directions. The estimation of fault location in travelling wave technique is done by measuring the dissimilarity in arrival times of fault transients in both ends of the disturbed line. When a burden exists on a power line, there will be a disturbance in system and then the voltage and current varies at the fault point in form of transient. As a result, there will be voltage and current change transients travelling along the faulted line from where fault occurs to the remaining parts of the system. Those voltage and current change transients are called traveling waves.

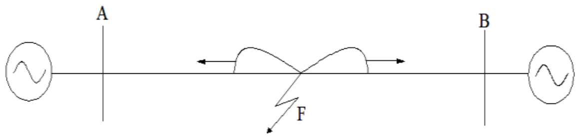

Figure 1: Travelling Wave Propagation As A Result of Fault

Bewley Lattice Diagram

Fault location can be identified using Bewley lattice diagram. Consider voltage (e) and current (i) at any point (x) along transmission line (l). By applying partial differentiation at that point, we get

$$\frac{\partial e}{\partial x} = -L\,\frac{\partial i}{\partial t} \& \frac{\partial i}{\partial x} = -C\,\frac{\partial e}{\partial t} \quad (1)$$

Here L is inductance per unit length, C is capacitance per unit length and resistance is negligible. Solutions of these equations are given as

$$e(x,t) = e_{fault}(x-vt) + e_{fault}(x+vt) \quad (2)$$

$$i(x,t) = \frac{1}{Z}\,e_{fault}(x-vt) + \frac{1}{Z}e_{fault}(x+vt) \quad (3)$$

Where Z=√(L/C) which represents characteristic impedance of the transmission line and

Velocity=√1/(L/C)

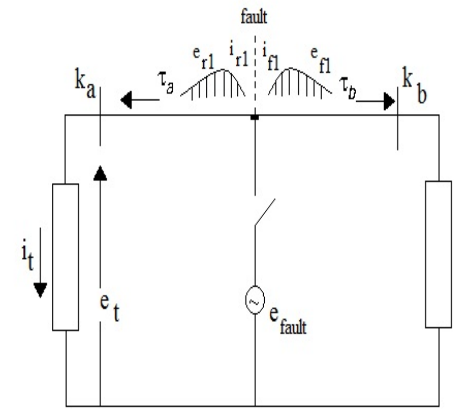

Figure 2: Travelling Wave Fault Location

From figure 2 the disturbed area x, waves which moves in different directions is ignored as it is less than the light speed, travels till end of the respected line. The discontinuities or change in impedance will be represented in the transmission line ends i.e. some fault transients will reflect back to the disturbed place and others will propagate along the transmission lines. Bewley lattice diagram clearly depicts the multiple waves produced at line ends. k_a and k_b, the reflection coefficients characterizing wave amplitudes are denoted by characteristic impedance ratios at the discontinuities. $\tau_A$and $\tau_B$represents the discontinuity time to travelfrom fault. This method depends upon the calculation of τ_A and $\tau_B$for the disturbed wave to attain the whole distance of the line l. we know that, the wave travels at speed nearer to light, the distance to the disturbance source can be computed by comparing the time difference of the waves arriving at the ends. By using voltage or current wave data, we obtain

$$x = \frac{V(\tau_A - \tau_B)}{2} \tag{4}$$

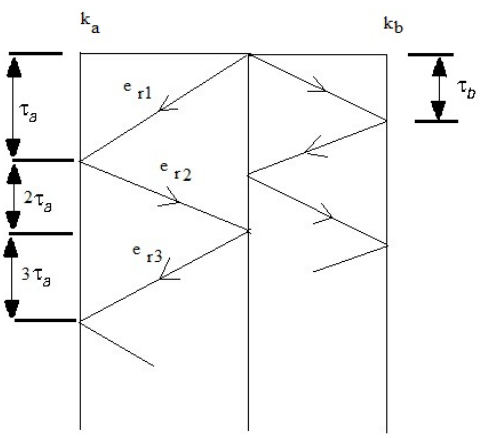

Figure 3: Bewley lattice diagram

For observing this fault wave, it can be generated in line by the switching capacitor banks or closing the circuit breaker.

Discrete Wavelet Theory

Wavelet theory helps for various applications of signal processing and it reflects better impact on power systems, power system transients and emergent fault detection. Selection of mother wavelet and wavelet parameters plays vital role in these applications.

The Wavelet transform of a signal f(t) ϵ L^2 (R) , it is defined by inner product between ψ_{ab} (t) and f(t) as:

$$Wf(a,b) = \frac{1}{\sqrt{|a|}} \int f(t)\, \psi\, (\frac{t-b}{a})dt$$

$$= (f(t)\ \psi_{ab}(ab)) \quad (5)$$

Where, $\psi_{ab}(t) = \frac{1}{\sqrt{|a|}}\, \psi\, (\frac{t-b}{a})$ (6)

1. Mother wavelet: Ψ (t) – Basic wavelet (i.e. Mother Wavelet) which can be taken as a band pass function (Filter). The Asterisk symbol (*) represents a complex conjugate and a,b ϵ R, a=/0 are the dilation and translation parameters
2. Scaling wavelet: In previous wavelet (i.e. mother wavelet) function, time remains continuous but time-scale parameters (i.e. b, a) are sampled on a “dyadic” grid in the time scale plane (b, a). Instead of continuous dilation and translation, basic wavelet can be dilated and translated discretely by choosing a= a_0^m and b=$nb_0a_0^m$, where a_0 and b_0 are fixed constants with a_0>1, b_0>0, m, nϵ Z is the set of positive integers. Then ,the discrete Mother wavelet becomes

$$\Psi_{m.n}(t) = a_0^{\frac{m}{2}} \psi(a_0^{-m}.t - n.b_0) \quad (7)$$

And the corresponding discrete scaling wavelet transform becomes

$$DW_{fm.n} = \int_{-\alpha}^{\alpha} f(t) \psi^*_{m.n}(t)\, dt \quad (8)$$

There are possibilities to recover the initial signal *f(t)* from its coefficients *Wf(a,b).* The modernized signal is defined as:

$$f(t) = \frac{1}{W_h} \int_{-\infty}^{\infty} \frac{da}{a^2} \int_{-\infty}^{\infty} Wf_{a,b}\, \psi_{a,b}(t)db \quad (9)$$

Where

$$W_h = \int_0^{\infty} \frac{|\psi(\omega)|^2}{|\omega|} d\omega \quad (10)$$

Due to good localization and dilation (or translation) process, wavelet exists locally in both domains of time and frequency. Orthogonal wavelet analysis gives hope for good time localization. Problems of fault location can be solved by using continuous wavelet transform, which is beneficial for expanding applied fields of wavelet transform. It also improves safety and reliability of power system.

Algorithm

1. Simulate model of 230kV transmission system with LL (Line to Line) and LG (Line to Ground) fault.
2. Fault analysis through simulation scope.
3. Program wavelet analysis in Matlab to obtain fault location
4. Execution of program is done by using the information of time $\tau_A$andτ_B.
5. Location "x" can be evaluated using the formula

$$x = \frac{V(\tau_A - \tau_B)}{2}$$

Where τ_A and $\tau_B$are the duration (i.e. time) of line disturbance to reach the both ends of the line and *V*is wave propagation velocity.

6. Calculate the error % by comparing true and calculated value

$$\%\text{Error} = \frac{Calculatedvalue - Truevalue}{Truevalue} * 100$$

Simulation and Results

The 230kV transmission system is simulated using Matlab and the values of τ_A and $\tau_B$is obtained from the fault generated waves. The values used for simulation of transmission system are tabulated in table 1.

Table 1: 230kv Parameters of Transmission System

Transmission line length	100km
Positive sequence resistance R1/km	0.01273 Ω/km
Positive sequence inductance L1/km	0.9337e-3 H/km
Positive sequence capacitance C1/km	12.74e-9 F/km
Zero sequence resistance R0/km	0.3864 Ω/km
Zero sequence inductance L0/km	4.1264e-3 H/km
Zero sequence capacitance C0/km	7.75e-9 F/km

From this we can calculate the velocity of propagation. For example we consider L-G (Line to Ground) fault at 50km,

V=1/√(LC)

L=0.9337e-3 H/km & C= 12.74e-9 F/km

From this we get,

Propagation velocity, *V*= $2.889*10^5$ km/sec.

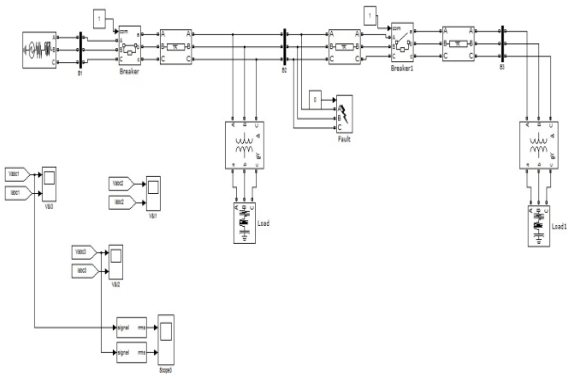

Figure 4: Simulation of 230kV Transmission system

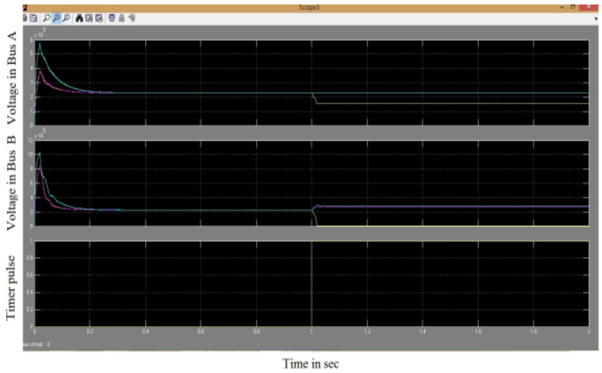

Figure 5: Output for Line to Ground fault

From this output we can observe the value of fault location from the scope output by,

$(\tau_A - \tau_B)$ =0.3561ms

So we get x= 51.45.

The observed values of fault location are tabulated as

Table 2: Observed Values From Simulation

Titles	$(T_A - T_B)$	Actual Distance	Calculated Distance	Error%
LG Fault	0.1429ms	20	20.65	3.25%
	0.3561ms	50	51.45	2.9%
	0.5337ms	75	77.10	2.8%
LL Fault	0.1433ms	20	20.70	3.5%
	0.3586ms	50	51.80	3.6%
	0.5323ms	75	76.90	2.53%

Conclusion

This paper clearly determines the location of faults in simple way without having any prior information of the fault. It also doesn't need the fault to exist for longer time, so that fault can be identified within few microseconds. This assures the safety of the power system. Inthe system considered, wavelet transformation is adapted to locate the fault precisely. Automatic regulation of wavelet window's width depends on the period of disturbance wave under study which can be observed as a fact by analyzing the wavelet transform, which is observed by time dilation of the preferred mother wavelet. In order to obtain precise location, Arrival time of waves at both the ends of transmission line traveling with different speeds are calculated. Then this data helps to estimatethe distance of the fault location along the preferred lines.This travelling wave technique is well preferred because of its independency withconfiguration and equipments installed in the transmission system.

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