METHODS FOR TRANSMISSION LINE FAULT LOCATION

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Abstract: Transmission lines are used to transmit electric power to distribution centers and to load centers. The main fault location methods are impedance and travelling wave method Travelling wave method for location of fault on transmission line is better than Impedance method. In this paper travelling wave method is used. In transmission lines fault location of line is determined by means of calculation of travelling-wave propagation times. Due to fault transient develop on transmission line which propagates along the line. This transient is closed to speed of light. MATLAB Simulation wavelet analysis for fault location by travelling wave method can be determined.

Index Terms: Fault location, Matlab, Simulink, Transmission line, Methods of Fault location, Wavelet analysis

I. INTRODUCTION
An electric power system comprises of generation, transmission and distribution of electric energy. A transmission line is a passive and bilateral device. Location of faults in power transmission lines is one of the main concerns for all the electric utilities as the accurate fault location can help to restore the power supply in the shortest possible time. Faults in transmission lines often occur in remote location, and repairing them can be time consuming, especially if the location of fault is unknown. When a fault occurs on a power line, there will be a change of voltage at the fault point in form of transient. Consequently, there will be voltage and current change components traveling from the fault point along the faulted line to other parts of the system. These voltage and current change components are called fault generated traveling waves. Fault location locates the occurred fault with the highest possible accuracy. A fault locator is a part of protection equipment, which apply the fault-location algorithms for assessing the distance to the fault. Since faults can destabilize the power system they must be isolated immediately. There are many ways of fault location detection on transmission line.

There are two methods of fault location:
1. Impedance based
2. Traveling wave based

Uses fundamental concept of traveling wave fault location theory with wavelet. In this paper traveling wave fault location method is executed using wavelet analysis with Matlab. [8] Describe a technique to detect and classify the different shunt faults on a transmission line for quick and reliable operation of protection system. PSCAD/EMTDC software is used to simulate different operating and fault conditions on high voltage transmission line. [9] In this paper investigation of the problem of fault localization using traveling wave voltage and current signals obtained at a single end of a transmission line and multi ends of a transmission network using Fourier transform. [10] Presents recent fault location method based on the double terminal methods of traveling wave using CWT. [12] Discussed various traditional and new approaches to fault location using fundamental frequency component of fault voltage and current for the analysis. [13] Explains fault location algorithm typically rely on the calculation of impedance based.

II. EFFECT OF FAULT
A fault if not detected has the following effects on a power system:
1. Heavy short circuit current may cause damage to equipment or any other element of the power system due to over heating or flash over and high mechanical forces set up due to heavy current.
2. There may be reduction in the supply voltage of the healthy feeders, resulting in the loss of industrial loads. Short circuits may cause the unbalancing of the supply voltages and currents, there by heating rotating machines.
3. There may be a loss of system stability. The faults may cause an interruption of supply to consumers.

III. TRAVELING WAVE FAULT LOCATION
Traveling- wave fault location is method of estimating the location of a fault based on measuring the difference in arrival times of fault wave at the two ends of a faulted line. Fault location using traveling wave can be recognized with the help of Bewley lattice diagram. Consider voltage(e) and current(i) at any point x on transmission line. At this point apply partial differential equation.

\[ \frac{\partial e}{\partial x} = -L \frac{\partial i}{\partial t} \quad \text{&} \quad \frac{\partial i}{\partial x} = -C \frac{\partial e}{\partial t} \]  \[1\]

where L and C are the inductance and capacitance of the line per unit length. The resistance is assumed to be negligible. The solutions of these equations are.

\[ e(x,t)=e(x-vt)+er(x+vt) \]  \[2\] \& \n
\[ i(x,t)= \frac{1}{Z} ef(x-vt)- \frac{1}{Z} er(x+vt) \]  \[3\]

where \( Z = \sqrt{L/C} \) is the characteristic impedance of the transmission line and \( v=\sqrt{1/(LC)} \) is the velocity of propagation.
WT is the useful method for various signal processing applications. WT has been applied in signal processing and many have a considerable impact on power engineering, analysis for power quality problems resolution, power system transient classification, power quality disturbance data compression and incipient failure detection. The choice of the mother wavelet and wavelet parameters is crucial in these applications. The wavelet transform of a signal \( f(t) \in L^2(\mathbb{R}) \) is defined by the inner-product between \( \Psi_{ab}(t) \) and \( f(t) \) as:

\[
Wf(a,b) = \frac{1}{\sqrt{|a|}} \int f(t) \Psi\left(\frac{t-b}{a}\right) dt = (f(t) \Psi_{ab}(ab)) \quad [5]
\]

Where, \( \Psi_{ab}(t) = \frac{1}{\sqrt{|a|}} \Psi\left(\frac{t-b}{a}\right) \quad [6] \)

A. Mother wavelet

\( \Psi(t) \) is a basic wavelet or mother wavelet, which can be taken as a band-pass function (filter). The asterisk denotes a complex conjugate, and \( a,b \in \mathbb{R}, a\neq 0 \), are the dilation and translation parameters. The CWT was originally introduced by Goupilaud, Grossmann, and Morlet.

B. Scaling wavelet

In the previous wavelet function, the time remains continuous but scale-parameters \( (b,a) \) are sampled on a so-called “dyadic” grid in the time-scale plane \( (b,a) \). Therefore, instead of continuous dilation and translation the mother wavelet may be dilated and translated discretely by selecting \( a = a_0^{-m} \) and \( b = nb_0^{-n} \), where \( a_0 > 1 \), \( b_0 > 0 \), \( m, n \in \mathbb{Z} \) is the set of positive integers.

IV. WAVELET THEORY (WT)

During installation of traveling wave fault locator, the propagation speed can be determined by generating a wave in the transmission line by switching capacitor banks to the transmission line or by closing a circuit breaker. According to the principle of superposition, the faulted power system can be equivalently divided into a normal operating power system with a fault component power system. In the fault component power system, the superposed source is a voltage source with the voltage value equal to the pre-fault voltage value of the circuit. The traveling wave was generated by abruptly input this superposed voltage into the fault point.

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Wavelets exist locally in both the domains of time and frequency, owing to the good localization and the dilation/translation operation. Analysis by orthogonal wavelets shows little hope for achieving good time localization. We study how to use CWT to solve the problems of fault location in transmission lines. It is very advantageous for expanding the applied fields of WT and problems of fault location in transmission lines. It is very satisfactory as on double ended line ,and the results will be simulated to evaluate the validity of this approach. We study how to use CWT to solve the problems of fault location in transmission lines. It is very advantageous for expanding the applied fields of WT and problems of fault location in transmission lines. It is very satisfactory as on double ended line ,and the results will be simulated to evaluate the validity of this approach.

\[ f(t) = \frac{1}{W_a} \int_{-\infty}^{\infty} \frac{da}{a^2} \int_{-\infty}^{\infty} W_{f,a,b}(t) db \]  

(9)

where

\[ w_h = \int_{-\infty}^{\infty} |\psi(\omega)|^2 d\omega < \infty \]  

(10)

\[ \tau_s \text{ and } \tau_a \text{ are time of line disturbance to reach end of the line}(\text{total length of the line } l) \text{ and } v \text{ is speed of wave propagation. Calculate location of fault.} \]

5. By using formula

\[ x = \frac{v(\tau_s - \tau_a)}{2} \]

6. Compare this value with actual distance and calculate distance for % error.

\[ \% \text{Error} = \frac{\text{Calculated} - \text{Actual}}{\text{Actual}} \times 100 \]

VI. CALCULATION

A three phase fault say LG is simulated at 40 km away from bus A. The fault waveform is shown in Figure 4. Figure shows a 400KV, 3 phase, 50 Hz 100 MVA modle having following parameters:

- Zero sequence resistance R0 = 0.01273 Ω/KM
- Zero sequence inductance X0 = 4.1264e-3 H/KM
- Zero sequence Capacitance C0 = 7.751e-9 F/KM
- Positive sequence resistance R1 = 0.3864 Ω/KM
- Positive sequence inductance L1 = 0.9337e-3 H/KM
- Positive sequence Capacitance C1 = 12.74e-9 F/KM

Here are fault location results under various fault locations and fault types, had b

\[ \tau_s - \tau_a = 0.1425 \text{ ms.} \]

Propagation velocity, \( v = 1/\sqrt{(LC)} = 2.889 \times 10^5 \text{ km/sec.} \)

Now, from equation (3)

\[ x = 41.15 \text{ km} \]

And

\[ \% \text{Error} = \frac{\text{Calculated} - \text{Actual}}{\text{Actual}} \times 100 = 2.875 \% \]

This observation is shown in Table 2.

VII. RESULT & DISCUSSION

Here are fault location results under various fault locations on the line. Each Table below shows calculated and actual fault location of the transmission line. Simulation studies were carried out on the typical model of 400 kV transmission line systems shown in Figure. 3. A variety of fault scenarios, including different fault locations and fault types, had been simulated to evaluate the validity of this approach. The scheme can also be tested on many other transmission line even on double ended line and the results will found to be satisfactory as those presented here.

Table 1 Parameters of Transmission line

<table>
<thead>
<tr>
<th>Length of Transmission Line</th>
<th>200 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive sequence resistance R</td>
<td>0.01273 Ω/KM</td>
</tr>
<tr>
<td>Positive sequence inductance L</td>
<td>0.9337e-3 H/KM</td>
</tr>
<tr>
<td>Positive sequence Capacitance C</td>
<td>12.74e-9 F/KM</td>
</tr>
<tr>
<td>Zero sequence resistance R0</td>
<td>0.3864 Ω/KM</td>
</tr>
<tr>
<td>Zero sequence inductance X0</td>
<td>4.1264e-3 H/KM</td>
</tr>
<tr>
<td>Zero sequence Capacitance C0</td>
<td>7.751e-9 F/KM</td>
</tr>
</tbody>
</table>

Table 1 Observation for LG Fault

<table>
<thead>
<tr>
<th>Distance Km</th>
<th>Calculated</th>
<th>% error</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>20.65</td>
<td>3.25</td>
</tr>
<tr>
<td>40</td>
<td>41.15</td>
<td>2.875</td>
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<tr>
<td>50</td>
<td>51.45</td>
<td>2.90</td>
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<td>75</td>
<td>77.10</td>
<td>2.80</td>
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<tr>
<td>125</td>
<td>128.6</td>
<td>2.88</td>
</tr>
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</table>

Table 2 Observation for LLG Fault

<table>
<thead>
<tr>
<th>Distance Km</th>
<th>Calculated</th>
<th>% error</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>20.70</td>
<td>3.50</td>
</tr>
<tr>
<td>40</td>
<td>41.25</td>
<td>3.125</td>
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<td>50</td>
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<td>75</td>
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</tr>
<tr>
<td>125</td>
<td>128.70</td>
<td>2.96</td>
</tr>
</tbody>
</table>
In this paper fault location on transmission lines for single ended is presented. This part of the work has addressed the problem of fault distance estimation utilizing the travelling wave signals. The travelling wave theory was introduced and the properties of the travelling waves on transmission lines were also discussed. The objective of this thesis was to propose an automated technique based on travelling waves for finding the fault location in transmission lines and to test the performance of the technique. The techniques were tested using data generated by executing various cases in MATLAB/ SIMULINK. Unlike the impedance measurement methods which can locate short-circuit faults in normal AC power lines only traveling wave technique can be used to measure distance to fault in all kinds of power lines. The application of the wavelet transform to estimate the fault location on transmission line has been investigated. The ability of wavelets to decompose the signal into frequency bands in both time and frequency allows accurate fault detection. The most suitable wavelet family has been made to identify for use in estimating the fault location on transmission line. Finally it is shown that the proposed method is accurate enough to be used in detection of transmission line fault location. It is possible to achieve greater accuracy with multi end methods compared to other fault location method.

REFERENCES

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[15] Vinay K Gupta was born in Varanasi, U.P, India on 24 May 1987. He completed his M.tech in Power Systems at Indian Institute of Technology (Banaras Hindu University), Varansi, India in 2014. He currently working as Assistant Professor in Department of Electrical Engineering, Pratap University, Jaipur also worked as lecturer in Srinathji Institute for Technical Education, Meerut,U.P.,India. His area of interest is Power System Protection, Networks and Control Systems.
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Table 3 Observation for LL Fault

<table>
<thead>
<tr>
<th>Fault Distance Km</th>
<th>Calculated</th>
<th>% error</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>20.65</td>
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</tr>
<tr>
<td>40</td>
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</tr>
<tr>
<td>125</td>
<td>128.7</td>
<td>2.96</td>
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VIII. CONCLUSION

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