A DISCRETE WAVELET TRANSFORM APPROACH TO FAULT LOCATION ON A 138KV TWO TERMINAL TRANSMISSION LINE USING CURRENT SIGNALS OF BOTH ENDS

Gaurav Kapoor

Department of Electrical Engineering, Modi Institute of Technology, India

Abstract

This paper presents discrete wavelet transform based fault locator for a three phase two terminal transmission line using fault current data of both terminals of transmission line. The magnitudes of approximate and detail coefficients of a three phase current achieved using discrete wavelet transform toolbox of MATLAB are used for the evaluation of fault location. The proposed technique has been checked for various types of faults with variation in location of fault. The test results of the proposed work demonstrate that the proposed technique is not affected by variation in fault type and fault location.

Keywords:
Discrete Wavelet Transform, Fault Location and Two Terminal Transmission Line Protection

1. INTRODUCTION

Location of faults on the modern extra high voltage three phase transmission lines is necessary to supply reliable flow of power. Detection, classification and location of faults on the two terminal transmission lines are done by many researchers using various techniques. In recent times, discrete wavelet transform has been effectively used for the protection of power system equipment like transformer, induction motor, three phase synchronous alternator, bus-bars and transmission lines. Various techniques to fault location on two terminal transmission lines have been reported by various authors so far. Along with the various schemes introduced, extreme learning machines based fault location technique has been proposed for locating fault on a HVDC transmission line in [1]. In [2], a travelling wave based fault location technique is used for the protection of hybrid multi-terminal power transmission system. Authors in [3] proposed wavelet transform based fault detection and faults discrimination technique for four terminal transmission lines connected to SVC using PV and wind energy source. In [4], machine learning in conjunction with wavelet transform is used for locating faults in hybrid transmission lines. In [5], location of fault of travelling waves using the combination of wavelet transform and recurrent neural network is introduced for the protection of three terminal transmission lines. In [6], a scheme based on discrete wavelet transform for fault detection, classification and location has been proposed for the protection of three phase transmission lines. In [7], feed forward artificial neural network is used for the classification and location of faults on 132kV transmission line using the samples of three phase current signals. In [8], a faulty phase selector technique based on adaptive cumulative sum approach has been proposed for the protection of double circuit transmission lines. Discrete wavelet transform is used in [9] for the location of faults and evaluation of fault distance on three phase transmission lines. Artificial neural network is used in combination with S-transform for the location of fault and selection of faulty phase in a triangle network [10]. In [11], wavelet transform based protection technique is proposed for protecting the extra high voltage asymmetrical three terminal transmission lines. Support vector machines is used in [12] for the recognition of location of faults in three phase transmission lines. Discrete wavelet transform is used in combination with back propagation neural networks for locating the faults on single circuit three phase power transmission lines [13]. Wavelet transform based approach is used in [14] for detecting and locating faults in HVDC power transmission system. Wavelet transform based high resistance fault detection and location technique is used in [15] for the protection of two terminal parallel transmission lines. In [16], a multi-resolution morphological gradient based ultra-high speed protection technique has been proposed for three phase transmission line protection. Wavelet transform is used in [17] for the protection of series compensated transmission lines. In [18], a fault location scheme based on artificial neural network is proposed for locating faults on three phase transmission lines. Support vector machine is used in [19] for the location of faults on three phase transmission lines. In [20], artificial neural network based algorithm has been introduced for the classification of double circuit transmission line faults.

The work described in this paper deals with the location of fault on a 138kV, 50Hz, two terminal transmission line using discrete wavelet transform approach. A discrete wavelet transform based fault location scheme has been developed and tested on a two terminal power transmission line for the evaluation of fault location. The performance of proposed scheme has been tested at various locations on a two terminal transmission line.

This paper is organized as follows: section 2 of the paper is devoted to the simulation study of two terminal transmission line using MATLAB, section 3 contains proposed DWT based fault location scheme, section 4 contains test results of the proposed technique, and section 5 contains the conclusion.

2. DOUBLE CIRCUIT TRANSMISSION LINE

The power transmission system consists of a 138kV, 50Hz, three phase transmission line of 300km length connected to three phase sources at the sending end and receiving end. The transmission line is divided into six sections each of 50km length extended between two sources. During the healthy condition of a power system, the current is measured at Bus-2 located at receiving end side of a power system. During the occurrence of fault, the three phase fault current is measured at Bus-1 located at the sending end side of power system (as demonstrated in Fig.1.). These signals are additionally analyzed and then decomposed
using discrete wavelet transform toolbox of Matlab to remove approximate and detail coefficients at level-1 for the evaluation of fault location. The single line diagram of the proposed two terminal power system under consideration is represented in Fig.1. The proposed two terminal transmission line test system is modelled and simulated with pie parameter transmission line block using Simscape Power System toolbox of Matlab/Simulink.

![Fig.1. Proposed two terminal transmission line test system](image)

### 3. PROPOSED SCHEME

In the area of digital signal processing, the methods based on wavelet transform have become one of the most powerful mathematical tools and since 1980’s these methods became trendier. As a substitute to short time Fourier Transform (STFT), the wavelet transform (WT) was developed to grow above problems associated to its resolution trouble. More entirely, if a window of infinite length is chosen, one can attain perfect frequency resolution but without time information. Wavelet transform is recently developed mathematical tool that divides up data, function or operation into different frequency components. Fourier analysis cracks up a signal into wave of various frequencies whereas wavelet analysis breaks up a signal into shifted and scale version of the original signal. Multi-resolution analysis (MRA) is another technique which is used to examine signal to overcome the troubles associated with time and frequency resolution.

\[
DWTf(m,k) = \frac{1}{\sqrt{a^m_0}} \sum x(n) \psi \left( \frac{k-nb_0a^m_0}{a^m_0} \right)
\]  

(1)

where \( \psi \) is known as the mother wavelet, the scale parameter is expressed as \( a^m_0 \) and the parameters of translation are designated as \( a^m_0, n_0 \) and \( b_0 \). In the proposed work, daubechies-5 (Db5) is chosen as mother wavelet for analyzing the pre fault and post fault current signals.

The flow illustration of the proposed technique based on discrete wavelet transform for the evaluation of fault location on a two terminal transmission line is demonstrated in Fig.2. The primary stage is to simulate various fault occurrences varying the location of fault in a two terminal transmission line network, consequently processing the pre-fault and post-fault three phase current signals measured at both ends of the transmission line using discrete wavelet transform and then calculating the maximum and minimum scale of pre-fault and post-fault approximate and detail coefficients at level-1 at various locations. The location of fault can be estimated by subtracting the pre-fault wavelet coefficients from the post-fault wavelet coefficients and then adding the positive values of the coefficients [9].

The proposed DWT based fault location scheme is evaluated using a 138kV, 50Hz, two terminal power transmission line of 300km length.

![Flow diagram of proposed fault location technique](image)

### 4. PERFORMANCE ASSESSMENT

The performance of the proposed discrete wavelet transform based fault location technique is evaluated for various shunt faults varying fault type and locations of fault for confirming the suitability of the proposed technique. MATLAB has been used for accomplishing a variety of simulation studies. Test results of the proposed fault location scheme have been demonstrated in the following subsections. Using Eq.(2), the %Error in fault location estimation is calculated so as to estimate the effectiveness of the proposed fault location technique [4].

\[
%\text{Error} = \left( \frac{AFL - EFL}{TSL} \right) \times 100
\]  

(2)

where, AFL is authentic fault location, EFL is evaluated fault location and TSL is total length of section. Thus, the performance of the proposed technique is evaluated for various fault situations to check the effectiveness of the technique for varying locations of fault.

#### 4.1 PERFORMANCE DURING PHASE-'A-g' FAULT AT 50 KM FROM BUS-1

The performance of the proposed technique is observed for phase-'A-g' fault at 50km from Bus-1 of a two terminal power transmission network. The Fig.3 depicts the pre-fault three phase current of a two terminal transmission line network recorded at 300km from Bus-1. The Fig.4 demonstrates the three phase current at 50km from Bus-1 during phase-'A-g' fault with \( R_f = R_g = 0.001 \Omega \) at \( FIT = 0.0166 \) seconds. The three phase current signals as shown in Fig.3 and Fig.4 are further processed using discrete wavelet transform with Db5 wavelet to extract appropriate feature
vector for fault location evaluation. The Fig.5 depicts the pre-fault discrete wavelet transform coefficients of three phase current at 300km from Bus-1 which has been recorded at Bus-2 using 'Db5' wavelet. The Fig.6 points up discrete wavelet transform coefficients of a three phase current during phase-'A-g' fault at 50km from Bus-1 recorded at Bus-1 using 'Db5' wavelet. The Table.1 summarizes the pre-fault wavelet coefficients of three phase current at 300km and contains the maximum and minimum scale values of approximate coefficients and detail coefficients (horizontal detail, vertical detail and diagonal detail). Similarly, the Table.2 demonstrates the wavelet coefficients of three phase current during phase- 'A-g' fault at 50km from Bus-1 and contains the maximum and minimum scale values of approximate coefficients and detail coefficients (horizontal detail, vertical detail and diagonal detail). The Table.3 illustrates the maximum and minimum scale of coefficients of three phase current for phase-'A-g' fault at 50km using 'Db5' wavelet. From the Table.3, it can be observed that for evaluating the location of fault, the values of pre-fault coefficients of three phase current obtained at 300km are subtracted from the values of post-fault coefficients of three phase current obtained at 50km from Bus-1 and then the positive values of the coefficients are added. From the Table.3, it can be noticed that the fault location result of proposed technique is precise with the % error of -1.5333%.

Fig.3. Pre-fault three phase current at 300km from Bus-1

Fig.4. Three phase current at 50km from Bus-1 during phase-'A-g' fault

Fig.5. Wavelet coefficients of three phase current during no-fault at 300km from Bus-1 using 'Db5' wavelet

The performance of the proposed technique is examined for phase-'A-g' fault at 100km from Bus-1 of a two terminal power transmission network. The Fig.7 shows the pre-fault three phase current of a two terminal transmission line network recorded at 300km from Bus-1. The Fig.8 shows the three phase current at 100km from Bus-1 during phase-'A-g' fault with $R_f = R_e = 0.001\Omega$ at $FIT = 0.01166$ seconds. As already being discussed in the previous sub-section, the three phase current signals as shown in the Fig.7 and Fig.8 are further processed using discrete wavelet transform with Db5 wavelet to extract appropriate characteristic vector for fault location evaluation. The Fig.9 demonstrates the pre-fault discrete wavelet transform coefficients of three phase current at 300 km from Bus-1 which has been recorded at Bus-2 using ‘Db5’ wavelet. The Fig.10 illustrates the discrete wavelet transform coefficients of a three phase current during phase-'A-g' fault at 100km from Bus-1 recorded at Bus-1 using ‘Db5’ wavelet. The Table.4 demonstrates the wavelet coefficients of three phase current during no-fault at 300km and includes the maximum and minimum scale values of approximate coefficients and detail coefficients (horizontal detail, vertical detail and diagonal detail). Similarly, the Table.5 shows the wavelet coefficients of three phase current during phase- 'A-g' fault at 100km from Bus-1 and contains the maximum and minimum scale values of approximate coefficients and detail coefficients (horizontal detail, vertical detail and diagonal detail). The Table.6 summarizes the maximum and minimum scale of coefficients of three phase current for phase-'A-g' fault at 100km using 'Db5' wavelet.
wavelet. From the Table 6, it can be examined that for evaluating the location of fault, the values of pre-fault coefficients of three phase current obtained at 300 km are subtracted from the values of post-fault coefficients of three phase current obtained at 100 km from Bus-1 and then the positive values of the coefficients are added. From the Table 6, it can be noticed that the fault location result of proposed discrete wavelet transform based technique is precise with the % error of 2.4666%. Test results of fault location evaluation and the % error achieved by using discrete wavelet transform approach during single line to ground faults with varying location of fault are presented in the Table 7. Test results represents that the proposed DWT-based fault location scheme is not affected by varying the fault location.

Table 3. Maximum and minimum scale of coefficients of three phase current for phase-'A-g' fault at 50 km using 'Db5'

<table>
<thead>
<tr>
<th>Coefficients</th>
<th>Db5 max</th>
<th>Db5 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coefficients at 50 km</td>
<td>697.1</td>
<td>35.13</td>
</tr>
<tr>
<td>Pre-fault coefficients</td>
<td>697.1</td>
<td>231.0</td>
</tr>
<tr>
<td>Differences</td>
<td>0</td>
<td>-29.9</td>
</tr>
</tbody>
</table>

Estimated Distance (km) = 54.6 km

Table 4. Wavelet coefficients of a three phase current at 300 km during no-fault

<table>
<thead>
<tr>
<th>Coefficients</th>
<th>Maximum Scale</th>
<th>Minimum Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approximate (A1)</td>
<td>697.1</td>
<td>35.13</td>
</tr>
<tr>
<td>Horizontal (H1)</td>
<td>368.7</td>
<td>-262.5</td>
</tr>
<tr>
<td>Vertical (V1)</td>
<td>330.2</td>
<td>-314.2</td>
</tr>
<tr>
<td>Diagonal (D1)</td>
<td>237.9</td>
<td>-194.5</td>
</tr>
</tbody>
</table>

Table 5. Wavelet coefficients of a three phase current at 100 km during phase-'A-g' fault

<table>
<thead>
<tr>
<th>Coefficients</th>
<th>Maximum Scale</th>
<th>Minimum Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approximate (A1)</td>
<td>697.1</td>
<td>-14.73</td>
</tr>
<tr>
<td>Horizontal (H1)</td>
<td>316.3</td>
<td>-268.4</td>
</tr>
<tr>
<td>Vertical (V1)</td>
<td>384.8</td>
<td>-317.1</td>
</tr>
<tr>
<td>Diagonal (D1)</td>
<td>251.8</td>
<td>-232.9</td>
</tr>
</tbody>
</table>

Table 6. Maximum and minimum scale of coefficients of three phase current for phase-'A-g' fault at 100 km using 'Db5'

<table>
<thead>
<tr>
<th>Coefficients</th>
<th>Db5 max</th>
<th>Db5 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coefficients at 50 km</td>
<td>697.1</td>
<td>-14.73</td>
</tr>
<tr>
<td>Pre-fault coefficients</td>
<td>697.1</td>
<td>35.13</td>
</tr>
<tr>
<td>Differences</td>
<td>0</td>
<td>-52.4</td>
</tr>
</tbody>
</table>

Estimated Distance (km) = 54.6 + 13.9 + 24.1 = 92.6 km

Table 7. Fault location evaluation and % Error varying fault location

<table>
<thead>
<tr>
<th>Authentic fault location (km)</th>
<th>Fault location evaluated (km) using ‘Db5’ wavelet</th>
<th>% Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>54.6</td>
<td>-1.5333</td>
</tr>
<tr>
<td>100</td>
<td>92.6</td>
<td>2.4666</td>
</tr>
</tbody>
</table>

5. CONCLUSION

This paper presents a fault location technique for shunt faults that occur on the two terminal transmission lines using discrete
wavelet transform. Widespread simulation studies have been done to estimate the impact of variation in fault type and the location of fault. The proposed technique uses the maximum and minimum scale values of level-1 pre and post fault DWT approximate and detail coefficients of a three phase current signal measured at both terminals of a three phase two terminal transmission line. Simulation results for various shunt faults exemplifies that the discrete wavelet transform based fault location technique is suitable and dependable under various fault circumstances. The future extension of this technique will be on fault detection, classification and location evaluation of series capacitor compensated three phase and six phase transmission lines.

REFERENCES


