Implementation of MODWT on Real Time Power Quality Disturbance Signal

S. Upadhyaya, A. Panda

Abstract: Maximal overlap discrete wavelet transform (MODWT) is the upgradation of traditional wavelet transform (WT), has been employed for localization of different power quality disturbance signal (PQDS). Every signal has been break down up to fourth level to localize the disturbances. The co-efficient of MODWT have been again employed for classification. The selected indices have been obtained utilizing the detail coefficient of this variant of WT. These features are the inputs to the data mining classifier. Decision Tree (DT) have been implemented for discrimination of PQ disturbance signals. Various PQDS have been generated in noisy and noise free climate. Besides this, the aforementioned techniques is examined with three phase signals bring out from transmission line panels.

Keywords: Artificial Neural Network (ANN), Decision Tree Classifier (DT), Maximum overlap discrete Wavelet Transform (MODWT), Power quality disturbance signals (PQDS).

I. INTRODUCTION

Power Quality is an umbrella that covers the whole power system under which the generated disturbance are mitigated by implementing suitable devices with advanced techniques. This important aspect of power quality changes the overall beauty of the system. Various factors like the solid state devices, short circuit etc., which deviates the waveform of voltage and current from being a sinusoid [1]. These prosperity influence the quality of power, which alter the total harmony. So, a healthy system require good voltage profile in the form of enhancement power quality.

The proper localization of the various types of PQDS are needed for maintenance of voltage profile. Techniques such as the Fourier transform (FT), the short-time Fourier transform (STFT), wavelet transform (WT), Neural Network, Fuzzy logic, S-transform have been employed for study of power quality disturbance signals (PQDS) [2], [3]. The FT is a fast signal analysis method which only provides the information about the frequency component. Similarly, STFT gives the time frequency information [4]. But, it fails to analysis the transient signals perfectly [5]. Similarly, the S-transform requires large computation [6]. The beauty of wavelet transform is its multi-resolution property. MODWT is the upgradation of traditional wavelet transform (WT), Neural Network, Fuzzy logic, S-transform have been employed for study of power quality disturbance signals (PQDS) [2],[3]. The FT is a fast signal analysis method which only provides the information about the frequency component. Similarly, STFT gives the time frequency information [4]. But, it fails to analysis the transient signals perfectly [5]. Similarly, the S-transform requires large computation [6]. The beauty of wavelet transform is its multi-resolution property. MODWT is the upgradation of traditional wavelet transform (WT), Neural Network, Fuzzy logic, S-transform have been employed for study of power quality disturbance signals (PQDS) [2],[3]. The FT is a fast signal analysis method which only provides the information about the frequency component. Similarly, STFT gives the time frequency information [4]. But, it fails to analysis the transient signals perfectly [5]. Similarly, the S-transform requires large computation [6]. The beauty of wavelet transform is its multi-resolution property. MODWT is the upgradation of traditional wavelet transform (WT), Neural Network, Fuzzy logic, S-transform have been employed for study of power quality disturbance signals (PQDS) [2],[3]. The FT is a fast signal analysis method which only provides the information about the frequency component. Similarly, STFT gives the time frequency information [4]. But, it fails to analysis the transient signals perfectly [5]. Similarly, the S-transform requires large computation [6]. The beauty of wavelet transform is its multi-resolution property. MODWT is the upgradation of traditional wavelet transform (WT), Neural Network, Fuzzy logic, S-transform have been employed for study of power quality disturbance signals (PQDS) [2],[3]. The FT is a fast signal analysis method which only provides the information about the frequency component. Similarly, STFT gives the time frequency information [4]. But, it fails to analysis the transient signals perfectly [5]. Similar...
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The $n^{th}$ element of the 1st-stage wavelet and the scaling coefficients are

\[
\tilde{W}_{1,n} = \sum_{l=0}^{L_{1}-1} h_l X_{n-l \mod N} \tag{5}
\]
\[
\tilde{V}_{1,n} = \sum_{l=0}^{L_{1}-1} \tilde{g}_l X_{n-l \mod N} \tag{6}
\]

where $n = 1, 2, 3, \ldots$, $N$ and $N$ is the length of signal (sample). The approximations and details at stage-1 can be determined by the equations (5) and (6). The MODWT scaling coefficients $V_j$ and $W_j$ wavelet coefficients at $j^{th}$ stage are represented in equations (8) and (7)

\[
\tilde{A}_{1,n} = \sum_{l=0}^{L_{1}-1} \tilde{g}_l \tilde{X}_{1,n+l \mod N} \tag{7}
\]
\[
\tilde{D}_{1,n} = \sum_{l=0}^{L_{1}-1} \tilde{h}_l \tilde{W}_{1,n+l \mod N} \tag{8}
\]

Likewise, the $n^{th}$ element coefficients are represented by the equations (9) and (10).

\[
\tilde{A}_{j,n} = \sum_{l=0}^{L_{j}-1} \tilde{g}_{j,l} \tilde{V}_{1,n+l \mod N} \tag{9}
\]
\[
\tilde{D}_{j,n} = \sum_{l=0}^{L_{j}-1} \tilde{h}_{j,l} \tilde{W}_{1,n+l \mod N} \tag{10}
\]

The original signal can be written as follow

\[
X(n) = \sum_{j=0}^{J} \tilde{D}_j + \tilde{A}_j \tag{11}
\]

The details of the classifier is described below.

IV. APPROACH FOR CLASSIFICATION

The indices are normalized and nourish to the DT.

Decision Tree Classifier (DT)

The DT is a Data mining based approach. DT is easy to handle, faster and simpler than the traditional techniques [18] and [19]. It requires less time and memory as compare to the traditional methods. The features from the training patterns has been implemented to construct DT [20]. The algorithm for design of DT is under given [14], [21].

1. Initiate with single node called as root node.
2. Split node with optimal criteria into two subdivision called as child node.
3. Exit node referred as the leaf node. Otherwise, repeat step-2. These leaf nodes carries the ‘outcome’.

V. MODEL FOR POWER QUALITY DISTURBANCES

PQDS are decomposed with the MODWT up to forth finer levels. The PQD signals has been simulated with 3.2 kHz sampling frequency [22]. Allotted class labels of simulated signals is displayed in Table I.

<table>
<thead>
<tr>
<th>TABLE I: Class labels</th>
</tr>
</thead>
<tbody>
<tr>
<td>PQD events</td>
</tr>
<tr>
<td>Sag</td>
</tr>
<tr>
<td>Swell</td>
</tr>
<tr>
<td>Interruption</td>
</tr>
<tr>
<td>Oscillatory transient</td>
</tr>
<tr>
<td>Flicker</td>
</tr>
<tr>
<td>Harmonics</td>
</tr>
<tr>
<td>Sag and Harmonics</td>
</tr>
<tr>
<td>Swell and Harmonics</td>
</tr>
<tr>
<td>Notch</td>
</tr>
<tr>
<td>Spike</td>
</tr>
</tbody>
</table>
VI. DECOMPOSITION PQ SIGNALS

A. Pure sine wave with sag
Voltage with sag is considered for study. This signal break down upto forth levels is interpreted with Fig.2. The original sine wave is presented along with the decomposed levels.

![Fig. 2: Sine wave with sag](image)

The vertical axis is taken as amplitude axis. The amplitude in volt V p.u. Horizontal axis is considered here as the time (samples) axis. In Fig.2, sag localization has been realized at all levels shown in Fig. The 1st level waveform is at the same alignment with the considered signal. All other levels are drifted towards right. This shifting helps in prediction of further occurrence of PQD.

B. Pure sine wave with swell
The above operations is also followed in this case to analyze sine wave with swell. In Fig. 3, similar results are found. Decomposition levels other than the 1st, the initial point of the signal is also sifted along with the distortions. The inception and end point of interruption is proper localized at each decomposition levels. So, MODWT can be implemented to predict the occurrence of power quality distortions.

![Fig. 3: Sine wave with swell](image)

C. Pure sine wave with interruption
Voltage signal with interruption has interpreted in Fig.4. Similar to that of the previous cases, the 1st decomposition level is at same position with the considered signal. The waveform of other levels are shifted towards right due to the circular shifting property.

![Fig. 4: Sine wave with interruption](image)

The inception and end point of interruption is proper localized at each decomposition levels. Finer levels are more shifted which is the main beauty of this MODWT.

D. Sag and harmonics
Considering voltage signal with the sag and harmonic interpreted in Fig.5. From the inspection of 1st two levels of Fig. 2 and Fig. 5, it is observed that the magnitude of these levels of pure sinusoidal voltage are almost zero except inception and end point of sag. Whereas for harmonic signal, there are some magnitude for 1st two levels. Similar to that of other cases, the origin point of signals are shifted along with the distortion in MODWT operations.

![Fig. 5: Sag and harmonic](image)

E. Swell and harmonics
Considering voltage signal with the swell and harmonic. From the inspection of 1st two levels of Fig. 2 and Fig.6, like the previous case it is observed that for pure sinusoidal voltage signal, the magnitude of these levels are almost zero except inception and end point of swell. Whereas for harmonic signal, there are some magnitude for 1st two levels.
Similar to that of other cases, the origin point of signals are shifted along with the distortions. Other PQDS are processed similarly.

VII. RESULT S AND DISCUSSIONS

The PQDS are discriminated in terms of classification accuracy. %CA is determined with employment of classifier named as DT. Total 32000 signals has been simulated. For construction of classification data set, signals have been resolved up to seventh levels. For each dataset classification, 30% of input are reserve as the testing sets. With 70% of data, training model is built.

White Gaussian noise is incorporated with pure PQDS. The considered signal set is doped with 20 dB noise. The Table II provides %CA of all considered classes in the noise free environment using MODWT and DT. The end row of the Table II carries the average %CA. Similar procedure has been realized for noisy data set.

**TABLE II: Pure Signals**

<table>
<thead>
<tr>
<th>Class</th>
<th>%CA</th>
</tr>
</thead>
<tbody>
<tr>
<td>CL1</td>
<td>99.52</td>
</tr>
<tr>
<td>CL2</td>
<td>100</td>
</tr>
<tr>
<td>CL3</td>
<td>99.34</td>
</tr>
<tr>
<td>CL4</td>
<td>100</td>
</tr>
<tr>
<td>CL5</td>
<td>100</td>
</tr>
<tr>
<td>CL6</td>
<td>99.23</td>
</tr>
<tr>
<td>CL7</td>
<td>100</td>
</tr>
<tr>
<td>CL8</td>
<td>100</td>
</tr>
<tr>
<td>CL9</td>
<td>100</td>
</tr>
<tr>
<td>CL10</td>
<td>100</td>
</tr>
<tr>
<td>Total % CA</td>
<td>99.14</td>
</tr>
</tbody>
</table>

**TABLE III: 20 dB noise signal**

<table>
<thead>
<tr>
<th>Class</th>
<th>%CA</th>
</tr>
</thead>
<tbody>
<tr>
<td>CL1</td>
<td>98.13</td>
</tr>
<tr>
<td>CL2</td>
<td>98.11</td>
</tr>
<tr>
<td>CL3</td>
<td>99.01</td>
</tr>
<tr>
<td>CL4</td>
<td>100</td>
</tr>
</tbody>
</table>

Table II and Table III, have interpreted with the %CA of the PQDS. From Tables, it is interpreted that classification accuracy of DT slightly decreased with presence of noise.

**Real PQDS classification**

Eight different class of three phase PQDS have been captured from 380 kV transmission line panel. The length of line is 360 km. Fig 7 is the representation of experimental set up. The natural load of this demo panel is 600 MW. The applied voltage is 380 V. With variation of load and creating faults, the various distortions have been inserted in to pure sine wave signal. These three phase real signal data set have been fed to DT. The %CA of three phase PQD have been shown in Table IV.

**Fig. 7: Setup for signal generation**

(a) 

(b)
From Table IV, it is analyzed that the aforementioned techniques are performed satisfactorily for the classification of real data. The DT classifier has provided good results. %CA of MODWT based data set is identical to synthesized signal.

VIII. CONCLUSION

The distortions have been properly localized with proper shifting in finer levels of MODWT. The %CA of simulated and the real signals have been obtained by MODWT with the combination of DT. The unresponsive to commencement of time series enhances suitability of MODWT. So MODWT is a good candidate for real time environment application. The decision has better classification rate. DT also perform satisfactorily on real time signal.

REFERENCES


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AUTHORS PROFILE

Swarnabala Upadhya, received her Ph.D from National Institute of Technology, Rourkela. At present, she is working as an Asst. Professor in Electrical and Electronics Engineering at Sambalpur University Institute of Information Technology, Burla. Her area of interest is Power quality disturbance detection and classification, utilization of wavelet transform and data mining for analysis of power quality.

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