A Soft Computing approach for Detection of the Voltage Flicker Source

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Abstract

The presence of heavy loads in the electric power network create lot of fluctuations in supply voltage which in fact give rise to one of the power quality issue called as voltage flicker. Nowadays utilities as well as consumers have become more attentive to this issue. The detection of flicker is necessary in order to mitigate it. A soft computing method for identification of flicker source is presented in this paper. This method is based upon Discrete Wavelet Transform and Artificial Neural Network. The wavelet transform is used for extracting features of voltage signal with flicker. A multilayer feed forward neural network with back propagation algorithm is then trained with these features. The trained network is tested by applying a new input signal from a flicker source. The flicker source used is an arc furnace. The accuracy of proposed technique has been validated by performing simulation in MATLAB/Simulink environment.

Key Words and Phrases: Voltage Flicker, Discrete Wavelet Transform (DWT), Artificial Neural Network (ANN).

1 Introduction

The intensity of voltage fluctuations increases due to the operation of heavy loads such as an arc furnaces, rolling mill drivers, main winders etc. and due to small loads like induction motors, welders, electric
saws and hammers, cranes, elevators etc. Also there are fluctuations caused by wind turbines and interharmonic sources like adjustable speed drives [1]. If these voltage fluctuations are frequent with a small frequency, then the phenomenon called as voltage flicker occurs. The main factors that cause irritating flicker are the supply system, type of load and frequency of fluctuation. The frequency range for observable flicker is from 0.5 to 30 Hz [2]. The flicker measurements are done by using the IEC flicker meter. This meter gives information regarding only level of flicker [3]. It fails to give any information regarding the direction of flicker source. The several methods have been introduced by researchers so far, for detection of the flicker sources. Dahai et al. 2005 [4] describe method based upon interharmonic power. A V-I slope method is elaborated by Edwin et al. 2005 [5]. A method based on the flicker power measurement has been presented by Axelberg et al. 2006 [6]. The flicker energy measurement method is given by Payam et al. 2007[7]. The correlation between envelopes of current and voltage have been studied to calculate flicker power by Axelberg et al. 2008[8]. A look up method has been presented by Moaddabi et al. 2008 [9] to detect the flicker source from a network containing several flicker sources. The method presented by Altintas et al. 2010 [10] focuses on individual flicker contribution of each load from a network with multiple flicker sources. A method to identify the flicker source in a distribution system is given by Eghtedarpour et al. 2010 [11], which uses Multi Resolution S-transform along with Artificial Neural Network (ANN). The calculation of flicker power is done by using a coherent detector by Poormonfaredazimi et al. 2012 [12]. A Discrete Fourier Transform (DFT) method for flicker power calculation has been presented by Jalal Khodaparast & Dastfan 2012b [13]. The benefit of this method is that, the number of measuring devices gets reduced. The detection of all flicker tones is carried out by computing phase angle for each tone with the help of d-q transformation is presented by Jalal Khodaparast and Dastfan 2012 [14]. A method given by J. Khodaparast & Dastfan 2012 [15] uses ANN to reduce number of measuring points. The use of Fast Fourier Transform demodulation technique to calculate the flicker power is explained by Jamaludin & Abidin 2013,2014 [16, 17]. The calculation of flicker power by using an Enhanced Phase Locked Loop [EPLL] is improved by Dejamkhooy et al. 2016 [18]. In this paper a method for detecting flicker producing load is proposed by combining Discrete Wavelet Transform (DWT) along with Artificial Neural Network (ANN). The feasibility of proposed work is checked in Matlab Simulink.

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2 Proposed Identification Based on DWT and ANN

The DWT is used for extracting features of the signal [19, 20] while ANN is used for prediction of output. The block diagram of the method is shown in Fig. 1. Initially a voltage signal with flicker is given as input to first block. The DWT based feature extraction is carried out by Wavelet Tool in Matlab Simulink. The features like standard deviation, amplitude, mean absolute deviation, median absolute deviation and energy are obtained by multi signal analysis [21]. These features are extracted for 10 different signals with different magnitudes and frequencies within the standard range for the flicker i.e. magnitude varies from 0.9 p.u. to 1.1 p.u. while frequency have range of 1 Hz to 30 Hz. These features are then passed to ANN with the target values. The target values are the values for a standard 50 Hz signal with unity magnitude.

Figure 1: Block diagram of DWT-ANN method for identification

Actual extracted features are normalized to per unit values so that the ANN can work satisfactorily. Table 1 shows normalized values of the features extracted.
### Table 1. Normalized values for extracted features.

<table>
<thead>
<tr>
<th>Input Signal with flicker (pu)</th>
<th>Amplitude (positive Peak) (pu)</th>
<th>Standard Deviation(pu)</th>
<th>Mean Absolute Deviation(pu)</th>
<th>Median Absolute Deviation(pu)</th>
<th>Energy (pu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>f1</td>
<td>0.9991</td>
<td>0.7108</td>
<td>0.6382</td>
<td>0.704</td>
<td>0.9882</td>
</tr>
<tr>
<td>f2</td>
<td>0.9818</td>
<td>0.7095</td>
<td>0.6376</td>
<td>0.705</td>
<td>0.9475</td>
</tr>
<tr>
<td>f3</td>
<td>0.9545</td>
<td>0.7082</td>
<td>0.6370</td>
<td>0.7068</td>
<td>0.9001</td>
</tr>
<tr>
<td>f4</td>
<td>0.9727</td>
<td>0.7090</td>
<td>0.6374</td>
<td>0.7054</td>
<td>0.9346</td>
</tr>
<tr>
<td>f5</td>
<td>0.9273</td>
<td>0.7074</td>
<td>0.6386</td>
<td>0.7071</td>
<td>0.8727</td>
</tr>
<tr>
<td>f6</td>
<td>1.0000</td>
<td>0.7108</td>
<td>0.6382</td>
<td>0.705</td>
<td>0.9582</td>
</tr>
<tr>
<td>f7</td>
<td>0.9818</td>
<td>0.7095</td>
<td>0.6376</td>
<td>0.705</td>
<td>0.9157</td>
</tr>
<tr>
<td>f8</td>
<td>0.9545</td>
<td>0.7082</td>
<td>0.6370</td>
<td>0.7038</td>
<td>0.8750</td>
</tr>
<tr>
<td>f9</td>
<td>0.9727</td>
<td>0.7090</td>
<td>0.6374</td>
<td>0.7049</td>
<td>0.8910</td>
</tr>
<tr>
<td>f10</td>
<td>0.9909</td>
<td>0.7101</td>
<td>0.6379</td>
<td>0.7049</td>
<td>1.0000</td>
</tr>
<tr>
<td>Target</td>
<td>0.9091</td>
<td>0.7073</td>
<td>0.6366</td>
<td>0.7073</td>
<td>0.8636</td>
</tr>
</tbody>
</table>

### 3 ANN training

The multi-layer perceptron architecture of the neural network is used to predict the output for a flicker producing source. The NNtool in Matlab is used to create, train and simulate the neural network. Table II gives details about the architecture and the training parameters. The training parameters are used by referring [22].

<table>
<thead>
<tr>
<th>Architecture</th>
<th>Training parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network Type: Feed Forward</td>
<td>Learning rule: Levenberg–Marquardt</td>
</tr>
<tr>
<td>Backpropagation</td>
<td>Performance: Mean-squared error (MSE)</td>
</tr>
<tr>
<td>The number of layers: 2</td>
<td>Training Function: TRAINLM</td>
</tr>
<tr>
<td>The number of neuron on the</td>
<td>Adaption learning function: LEARNGDM</td>
</tr>
<tr>
<td>layers</td>
<td></td>
</tr>
<tr>
<td>Input: 20, hidden: 20, output: 1</td>
<td></td>
</tr>
<tr>
<td>The initial weights and biases:</td>
<td></td>
</tr>
<tr>
<td>Random</td>
<td></td>
</tr>
<tr>
<td>Activation functions: Tangent</td>
<td></td>
</tr>
<tr>
<td>sigmoid</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. MLP Architecture and Training Parameters

The neural network is trained with the inputs and the targets from Table 1 and with the training parameters from Table 2. For achieving optimality the various parameters like the regression and the mean square error are selected. The network is trained till the value of regression reaches near to 1 and until minimum magnitudes of the
MSE is obtained. Fig. 2 shows performance plot which shows best validation performance at epoch 2 with the mean squared error equal to that $6.59773 \times 10^{-6}$. Fig. 3 shows regression plot obtained with value of regression as 0.99889.

![Figure 2: Plot of performance](image1.png)

![Figure 3: Plot of regression (R=0.99889)](image2.png)

4 Validation of proposed method

The validity of proposed method is checked by using test data. For obtaining the test data the flicker producing load selected is an arc furnace. The arc furnace model is simulated using mathematical equations given in [23]. Fig.4 shows the diagram of the network with load.

![Figure 4: Simplified diagram of a network with Load.](image3.png)
The proposed algorithm is applied to the output for single phase. The similar features are extracted. These features are the new inputs to the trained ANN. Table 3 shows the results obtained.

<table>
<thead>
<tr>
<th>Type of Data</th>
<th>Amplitude (positive Peak) (pu)</th>
<th>Standard Deviation (pu)</th>
<th>Mean Absolute Deviation (pu)</th>
<th>Median Absolute Deviation (pu)</th>
<th>Energy (pu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input</td>
<td>0.9273</td>
<td>0.627</td>
<td>0.494</td>
<td>0.747</td>
<td>1.3118</td>
</tr>
<tr>
<td>Output</td>
<td>0.9118</td>
<td>0.6366</td>
<td>0.6366</td>
<td>0.9079</td>
<td>0.9118</td>
</tr>
</tbody>
</table>

Table 3. Results Obtained From Arc Furnace Model

From Table 1 and Table 3, it is observed that the outputs with new data are well matched with the targets. Therefore it is noteworthy to say that the new input to ANN has same features as that of original training inputs which are flicker signals. Hence it can be said that the test input resembles to the flicker signal.

5 Conclusion

This paper has introduced a technique for detection of the flicker source. The strategy used is a combination of the discrete wavelet transform and the feed forward back propagation neural network. The DWT is used primarily for extracting features of contaminated source voltage due to presence of the voltage flicker. The ANN serves purpose of identification of the flicker source which causes the distortion of the source voltage. The validation of the methodology presented is done in MATLAB/Simulink environment. From the simulation results it is clear that the anticipated output parameters are well converged with target assigned to ANN. Therefore the test signal is a flicker signal and the source from which it is coming is a flicker source. Further it is observed that there is error in the actual output and target value though the ANN is trained for optimum condition. This error can be minimized by combining ANN with any of the various optimization techniques available.

References


