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Classification and Identification of Power System Disturbances Using Wavalet and Artificial Neural Network Technique

Noraliza Hamzah, W. Norainin W. Abdullah & Pauziah Mohd Arsad

Faculty of Electrical Engineering
Universiti Teknologi MARA (UiTM), Malaysia

ABSTRACT

Power Quality disturbances problems have gained widespread interest worldwide due to the proliferation of power electronic load such as adjustable speed drives, computer, industrial drives, communication and medical equipments. This paper presents a technique based on wavelet and probabilistic neural network to detect and classify power quality disturbances, which are harmonic, voltage sag, swell and oscillatory transient. The power quality disturbances are obtained from the waveform data collected from premises, which include the UiTM Sarawak, Faculty of Science Computer in Shah Alam, Jati College, Menara UiTM, PP Seksyen 18 and Putra LRT. Reliable Power Meter is used for data monitoring and the data is further processed using the Microsoft Excel software. From the processed data, power quality disturbances are detected using the wavelet technique. After the disturbances being detected, it is then classified using the Probabilistic Neural Network. Sixty data has been chosen for the training of the Probabilistic Neural Network and ten data has been used for the testing of the neural network. The results are further interfaced using matlab script code. Results from the research have been very promising which proved that the wavelet technique and Probabilistic Neural Network is capable to be used for power quality disturbances detection and classification.

***Keywords**: Power Quality Disturbances, wavelet, artificial neural network*

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Introduction

The rise in power quality problem is due to the proliferation of power electronic loads and also nonlinear loads which are more sensitive to power quality disturbances such as harmonic, voltage sag, swell and oscillatory transient. The power quality issues have gained great attention from the utility, customer and the manufacturer side. As a result numerous power quality assessment methodologies and diagnostic equipment for the detection, measurements and analysis are becoming commonplace in power system industry. Power quality can be defined as "any power problem manifested in voltage, current, or frequency deviations that result in failure or disoperation of customer equipment" [1]. Major power quality problems are related to voltage sag, transient and harmonics. In [2] discrete wavelet transform (DWTs) and neural system have been used to detect and classify power quality disturbances. The DWT (Daubechies family, Db4) is used to detect the disturbances and the data is compressed and a learning vector quantization (LQV) neural network is employed to classify the disturbances. References [3-4] also used the wavelet transform and LQV network to detect and extract power quality disturbances. Another technique to classify power quality disturbances is based on Fourier Linear Combiner and a fuzzy expert system [5].

The aim of this paper is to present the application of wavelet technique based on Daubechies family (Db7) decomposition coefficient to detect the power quality disturbances. The neural network based on Probabilistic Neural Networks is further employed to classify the disturbances. Real data from power quality monitoring has been used to justify the proposed method.

Theories

The theories used in the proposed method to detect and classify the power quality disturbances are explained in the following sections.

Oscillatory Transition, Harmonics, Voltage Sags and Swell [1]

An oscillatory transient is a sudden, non-power frequency change in the steady state of Voltage, current or both that includes both positive and negative polarity values. An oscillatory transient with a primary frequency component between 5 kHz and 500 kHz measured in the tens of microseconds (or several cycles of the principal frequency) is termed a medium frequency transient. A transient with a fundamental frequency less than 5 kHz and duration from 0.3 ms to 50 ms is considered as a low frequency transient. The oscillatory transient can be caused by capacitor energization and cable switching. The most frequent oscillatory transient is capacitor bank energization, which typically results in an oscillatory voltage transient with a voltage frequency between 300 Hz and 900 Hz. The peak magnitude can approach 2.0 pu but it is typically 1.3-1.5 pu with duration of between 0.5 and 3 cycles.

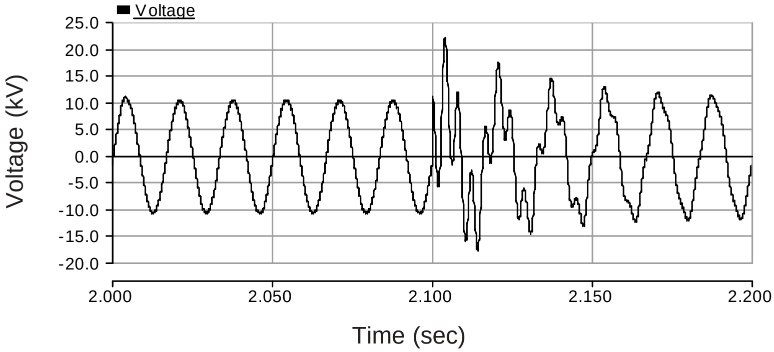
Harmonics are sinusoidal voltages or currents having frequencies that are multiples of the fundamental frequencies. The source of harmonics includes power electronic device, adjustable speed drives, converter, saturated transformer and arc furnace. Harmonic can cause overheating of the device and telecommunication interference.

Voltage sag is a decrease to between 0.1 and 0.9 pu in rms voltage at the power frequency for durations from 0.5 cycle to 1 min. The cause of voltage sag can be power system faults, energization of heavy loads and starting of large motors. Voltage swell is defined as an increase to between 1.1 and 1.8 pu in rms voltage at the power frequency for durations from 0.5 cycle to 1 min.

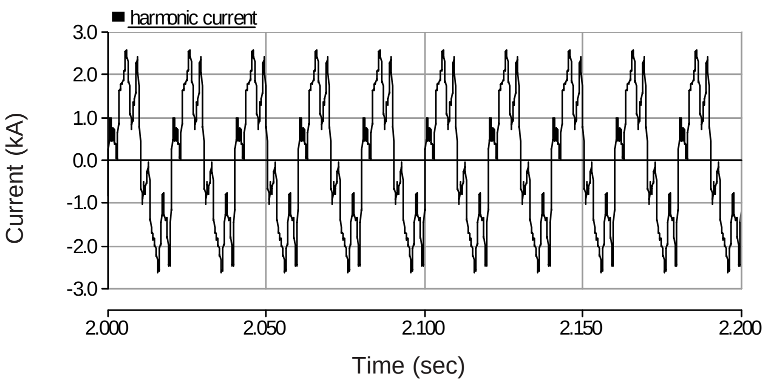
Figures 1(a) and (b) show the waveform of transient voltage caused by capacitor switching and harmonic current generated by adjustable speed drives respectively. Figure 1(c) shows the voltage sag caused by fault.

Wavelet [6]

Wavelet is a windowing technique with variable-sized regions. Wavelet analysis is the breaking up of a signal shifted and scaled versions of the original (or mother) wavelet. A continuous wavelet transform (CWT) is defined as the sum over all time of the signal multiplied by scaled, shifted version of the wavelet function. The results of the CWT are many wavelet coefficients C, which are a function by the appropriately scaled and shifted wavelet yields the constituent of the original. In wavelet analysis, a signal is split into an approximation and detail. The approximation is then split into a second-level approximation and detail, and the process is repeated. Figure 2 shows the wavelet decomposition tree for signal S. Figure 3 shows a signal after decomposition step A3 and details step $D_{1,}$ D_2 and D_3.



(a)



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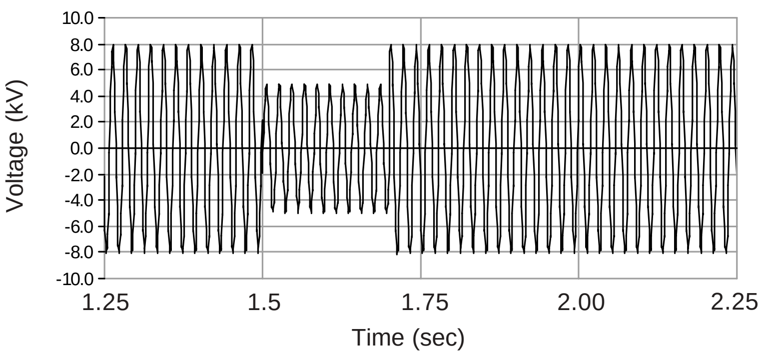
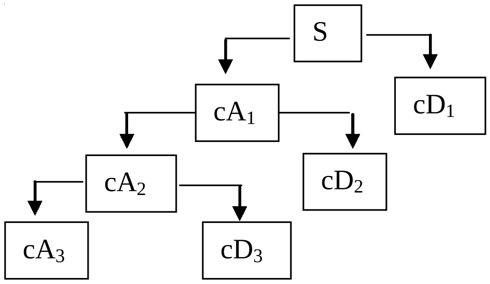


(c)

Figure 1: Power Quality Disturbance (a) Transient Caused by Capacitor Switching (b) Harmonic Generated by Adjustable Speed Drives (c) Voltage Sag



$$S = A_1+D_1$$
$$= A_2+D_2+D_1$$
$$= A_3+D_3+D_2+D_1$$

Figure 2: Wavelet Decomposition Tree

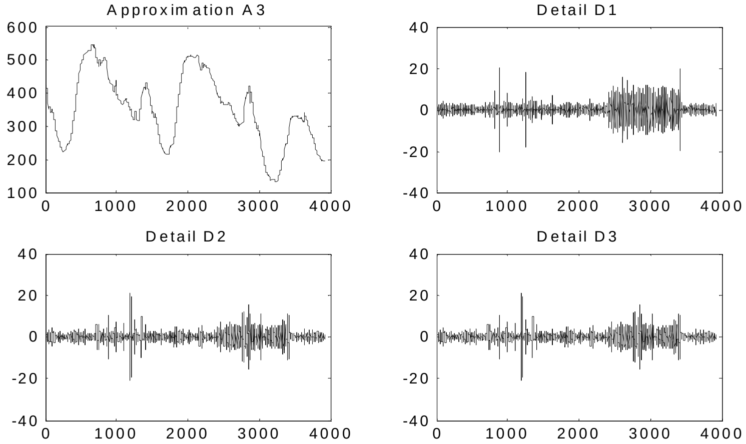


Figure 3: Approximation and Detail Signal after Decomposition Process

Probabilistic Neural Network [7]

Probabilistic Neural Networks can be used for classification problems. When an input is presented, the first layer computes distance from the input to the training input vectors and produces a vector whose elements indicate how close the input is to training input. The second layer sums these contributions for each class of inputs to produce as its net output a vector of probabilities. Finally, a competitive transfer function on the output of the second layer picks the maximum of these probabilities and produce a 1 for that class and a 0 for the other class. The network architecture of the Probabilistic Neural Network (PNN) is shown in Figure 4.

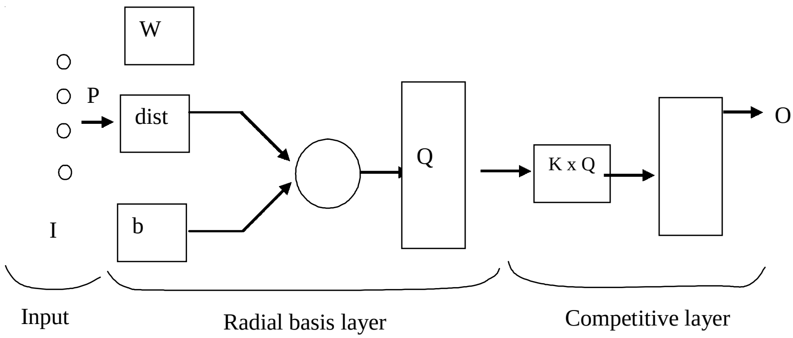


Figure 4: Probabilistic Neural Network Architecture

I = input elements, W = input weight , b = bias neuron
Q = no. of input pairs, K = no. of classes of input data,
O = output element
P = training input vectors pairs , dist = produce an input vector

Methodology

This project can be divided into two parts, the first one is to detect any disturbance from the original waveform using the wavelet technique. The second part is to classify the events using the probabilistic neural network. Using the wavelet technique, the waveform signal will be decomposed using Daubechies family (Db7) decomposition coefficient. After detection is done then, the classification of the wavelet is taken place using Probabilistic Neural Network (PNN). There are 60 training data used in this project. The oscillatory transient will have magnitude and duration whilst the other disturbance will display empty. The disturbances is then detected based on its duration and magnitude. Data used in this project is taken from UiTM Sarawak, Faculty of Science Computer in Shah Alam, Jati College, Putra LRT, Menara UiTM and PP Seksyen 18. The flowchart of this project is presented in Figure 5.

For the PNN application, the inputs are the magnitude and duration of the event. The output is the oscillatory transient and undefined waveform. The output of this project is display using the graphic user interface (GUI) in the matlab.

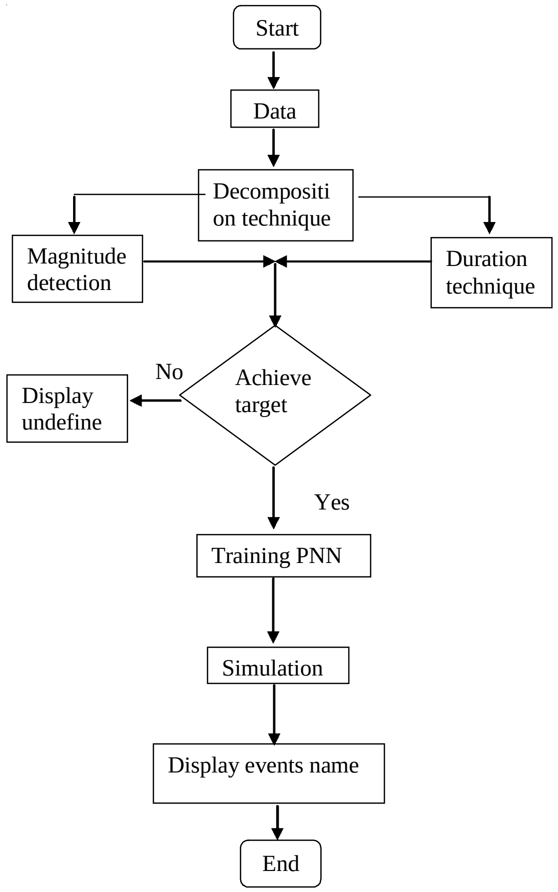


Figure 5: Flowchart for Detection and Classification Technique

Results and Discussion

Data for power quality disturbances such as harmonic, voltage sags, swell waveform and oscillatory transient have been used in this project. There are nine testing data used for verification of the result. Table 1 shows the result of the testing data.

Table 1: Testing with Wavelet

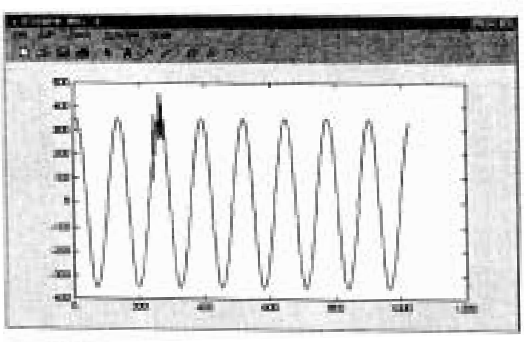
Data	Events	Is 'magnitude' empty?	Is 'duration' empty?
Data 1	Harmonic	Yes	Yes
Data 2	Voltage Sag	Yes	Yes
Data 3	Voltage Sag	Yes	Yes
Data 4	Voltage Swell	Yes	Yes
Data 5	Voltage Swell	Yes	Yes
Data 6	Oscillatory Transient	No	No
Data 7	Oscillatory Transient	No	No
Data 8	Oscillatory Transient	No	No
Data 9	Oscillatory Transient	No	No

From Table 1, data 1 until data 5 is a non-oscillatory transient event. Therefore when applying the wavelet technique, it shows empty cell which means it cannot recognize the waveform. Since, the technique is only programmed to recognize the oscillatory transient event, other than this event is classified as empty cell. Sample of the original waveform for the oscillatory transient event and its detail waveform after wavelet decomposition is shown in Figures 6(a) and 6(b) respectively after wavelet decomposition wavelet.

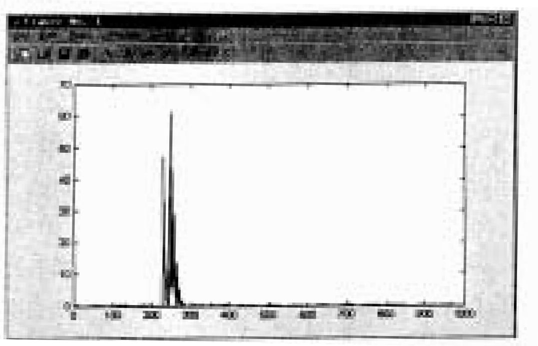
Table 2 shows the results from the PNN. From the table it is shown that PNN can classify the oscillatory transient event compared to the other events.

Conclusion

This paper has proved that the wavelet signal decomposition can be used to classify the power quality disturbances using the Daubechies decomposition. The PNN has been proved to be able to detect power quality disturbances as the oscillatory transient event or non-oscillatory transient event. The technique is simple and is possible to be used as on-line application. The work can be improved so that the other events can also be classified.



(a)



(b)

Figure 6: (a) Original Oscillatory Transient (b) Oscillatory Transient after Decomposition

Table 2: Results from PNN

Data	Events	Magnitude	Duration
Data 1	Harmonic	UW	UW
Data 2	Voltage Sag	UW	UW
Data 3	Voltage Sag	UW	UW
Data 4	Voltage Swell	UW	UW
Data 5	Voltage Swell	UW	UW
Data 6	Oscillatory Transient	OT	OT
Data 7	Oscillatory Transient	OT	OT
Data 8	Oscillatory Transient	OT	OT
Data 9	Oscillatory Transient	OT	OT

OT = Oscillatory Transient UW = Undefined Waveform

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[6] Matlab wavelet toolbox, Math Works Inc ™.

[7] Matlab Neural Network toolbox" Math Works Inc ™.