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Power Quality Disturbance Classification Using Adaptive Linear Neural Network (ADALINE) and Feed Forward Neural Network (FFNN)

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Abstract: This paper presents a dual neural network based technique for detecting and classifying the power quality disturbances. In the proposed method, Adaptive Linear Neural Network is used to extract the rms voltage for harmonics and Interharmonics estimations. With the help of these indices, PQ disturbances such as Sag, Swell, Outages are detected and classified, Harmonics and Interharmonics alongwith horizontal and vertical histograms for a specified voltage waveform and Feed Forward Neural Networks are used for pattern recognition in order to classify Spikes, Notches, Flicker and Oscillatory transients. Synthetic disturbance waveforms are generated using the MATLAB parametric equations.

Key words: Power quality · Power quality disturbances · Neural Network · Adaptive Linear Neural Network · Feed Forward Neural Network

INTRODUCTION

Power Quality: Power quality has become a very important issue over the past few decades. In order to improve power quality, the sources and causes of such disturbances must be known before the appropriate mitigating actions can be taken. The windowed FFT which is the time windowed version of discrete Fourier transform has been applied for power quality analysis to classify a variety of disturbances in [1].Wavelet based neural network classifier has been presented in [2] for the learning vector quantization network and a decision making scheme. A combination of wavelet packet energy entropy features and weighted support vector machines has been used to diagnose the Power quality faults in [3] and also identify the real time classification of power quality disturbances has been presented in [4]. A hybrid techniques of DWT and ANN has been discussed for better performance in the classification of power quality events in [5]. and a wavelet packet based algorithm has been illustrated in [6], which is used to analysis the harmonics in the power supply. The DWT combine with PIC hardware has been used to detect the voltage sag in the test system in [7]. In order to identify the type of disturbance present in the power signal, the S-transform based PNN. The S-transform extract important information from a disturbance signal and trained by PNN to determine the type of disturbance that caused power quality (PQ) problem to occur has been presented in [8]. Wavelet based genetic algorithms has been used to monitor the PQ disturbances and their characters in [9]. Multiresolution S-transform has been used to distinguish the different types of PQ disturbances The classification and characterization of the disturbances are discussed in [10] based on Parseval's Theorem. A real time standard multifunction instrument has been used to measure the PQ disturbances in [5].

An S-transform based SVM has been discussed for identifying the power quality disturbances in the test system [11]. A Hilbert transform shows greater immunity towards noise, it has been used for the detection and classification of power quality events along with RBF network in [12]. An S-transform based fuzzy and Particle swarm optimization has been presented in [13] and this combines to identify the time series PQ disturbance data and also classified it. A rule based technique along with S-transform has been discussed in [14] An ADALINE and FFNN based power quality analyzer in which features are extracted using ADALINE and disturbances are classified using an FFNN and histogram is presented in this paper.

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Proposed System: The proposed methodology for disturbance waveform classification and detection are Performed by evaluating the value of the THD and RMS value using ADALINE NN and classifying the disturbance using Feed Forward NN based neural classifier according to the evaluated values.

Features Extraction

Adaline (and) FFNN: An Adaline is a multi-input, single-output, single layer linear neural element and its characteristics are Train on-line based on the changing inputs and the target response; Self adaptive algorithm can be applied to the weights training; Simple structure makes it easily implemented on hardware. A feed forward neural network has one or more layers between input and output layer. Except for the input nodes, each node is a neuron with a nonlinear activation function. FFNN utilizes a supervised learning technique called back propagation for training the network.

Classification Stage: In this stage, Adaptive Linear Neural Network extracted features such as RMS voltage. The horizontal and vertical histograms were extracted through Feed Forward Neural Network, which has been applied for classifying the disturbances.

Simulation Results:

The case study of the Pure sine wave is shown in Figures 1(a) to 1(d).

The case study of the Voltage sag is shown in Figures 2(a) to 2(d).

The case study of the Voltage swell is shown in Figures 5(a) to 5(d).

The case study of the Voltage Outages is shown in Figures 6(a) to 6(d).

The case study of the Sag with Harmonics is shown in Figures 8(a) to 8(d).

The case study of the Swell with Harmonics is shown in Figures 9(a) to 9(d).

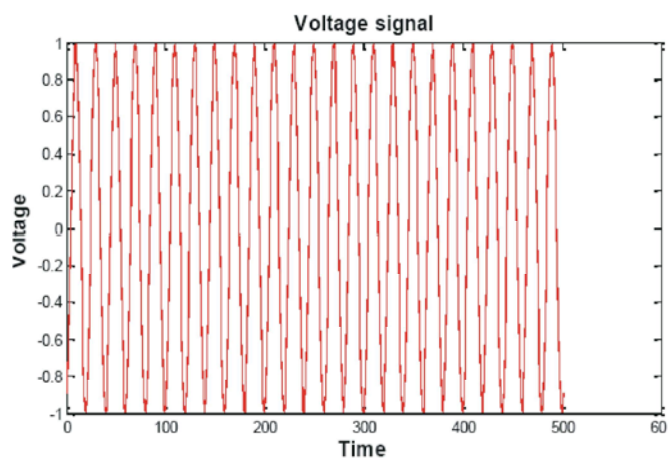


Fig. 1(a): Voltage Signal

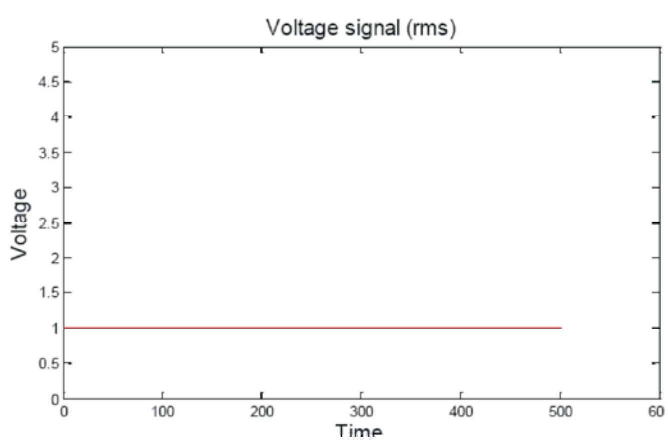


Fig. 1(b): RMS Voltage

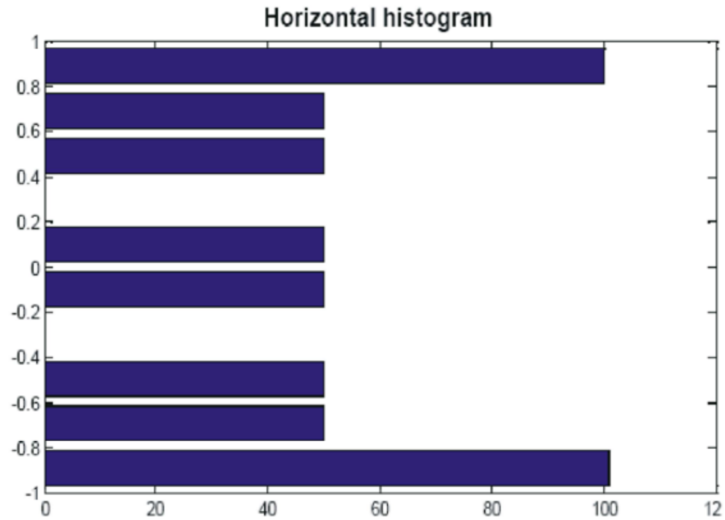


Fig. 1(c): Horizontal histogram

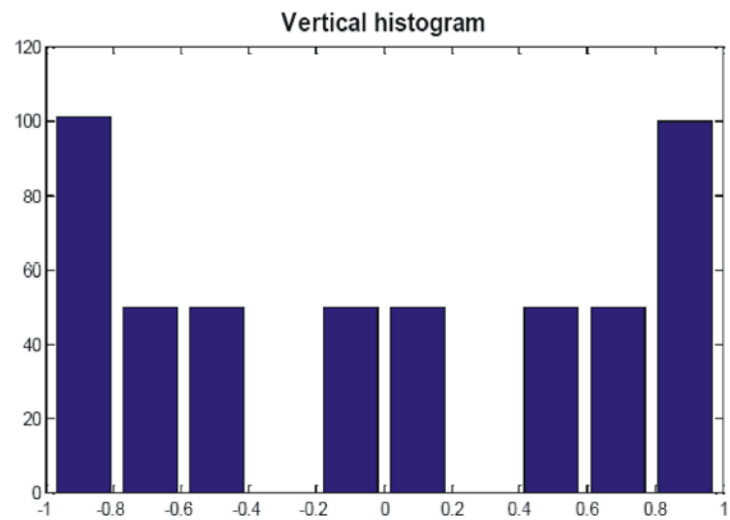


Fig. 1(d): Vertical histogram

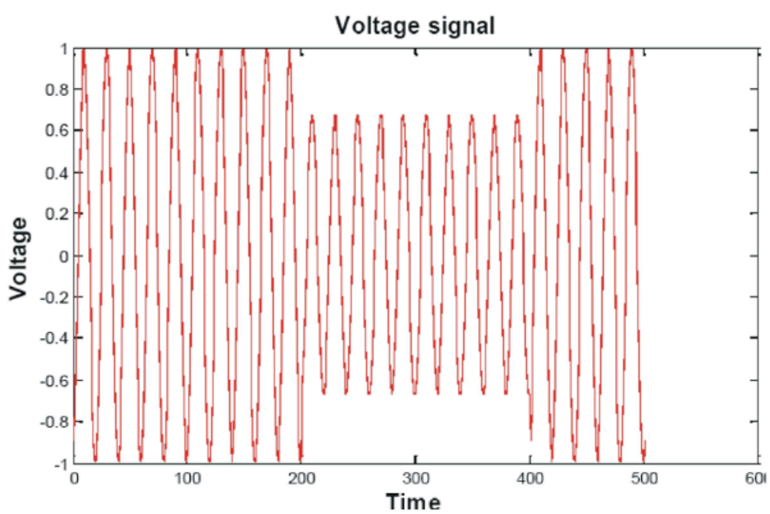


Fig. 2(a): Voltage Sag

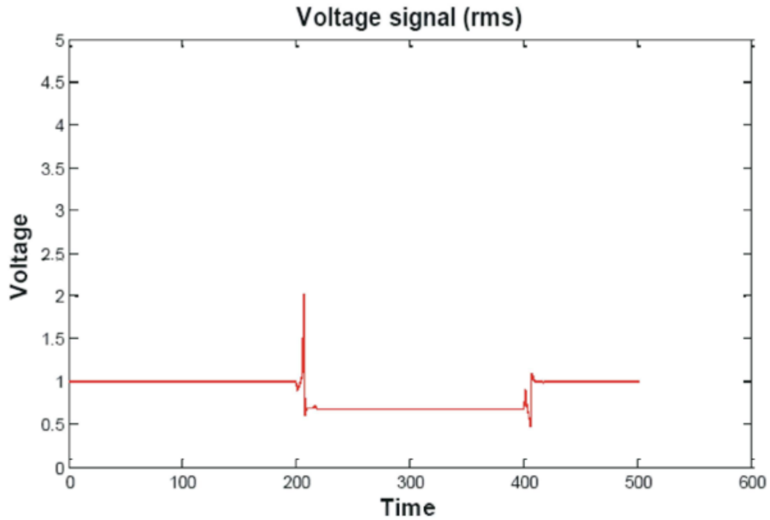


Fig. 2(b): RMS Voltage

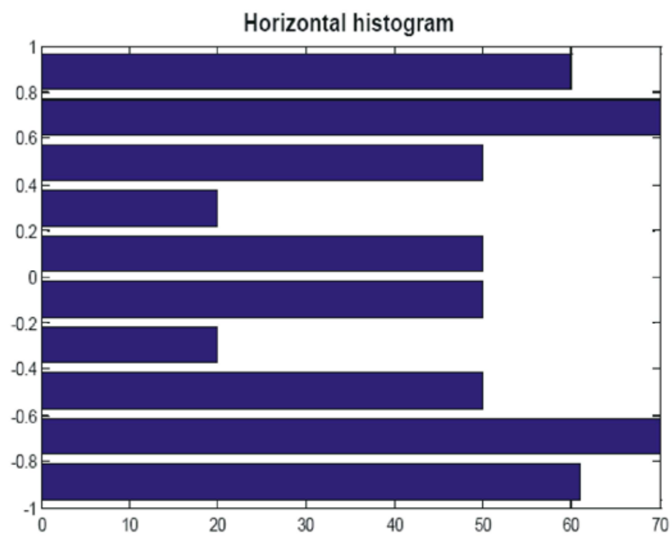


Fig. 2(c): Horizontal histogram

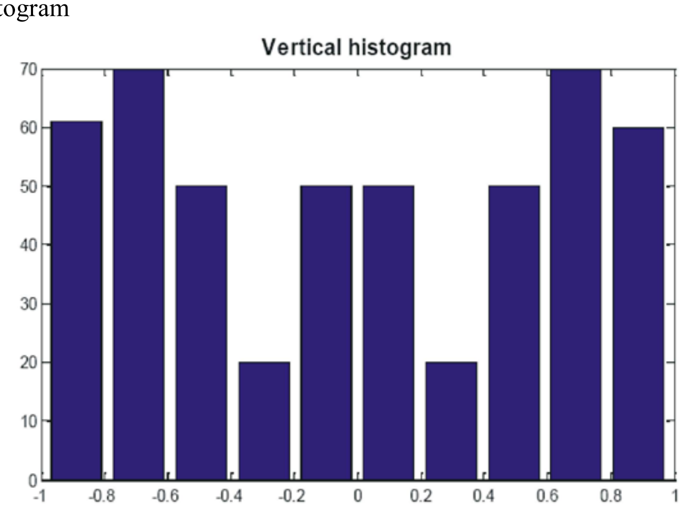


Fig. 4(d): Vertical histogram

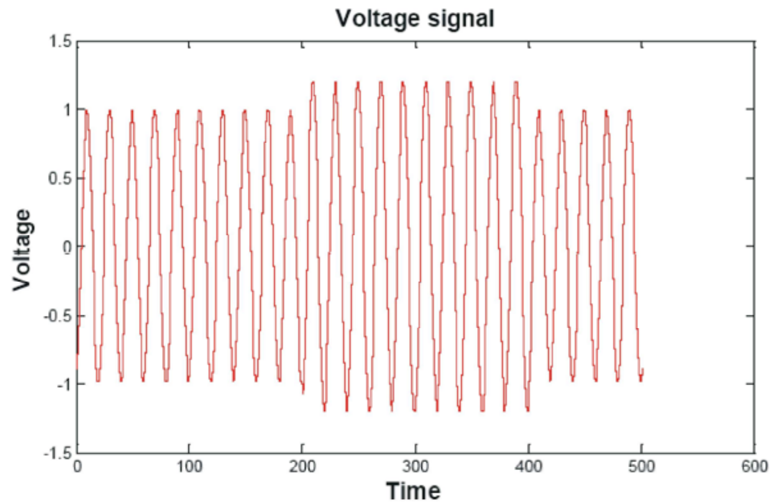


Fig. 5(a): Voltage Swell

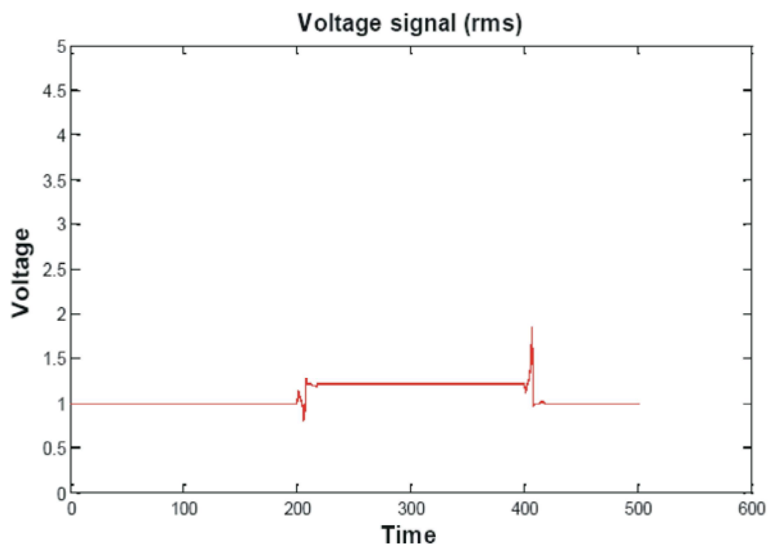


Fig. 5(b): RMS Voltage

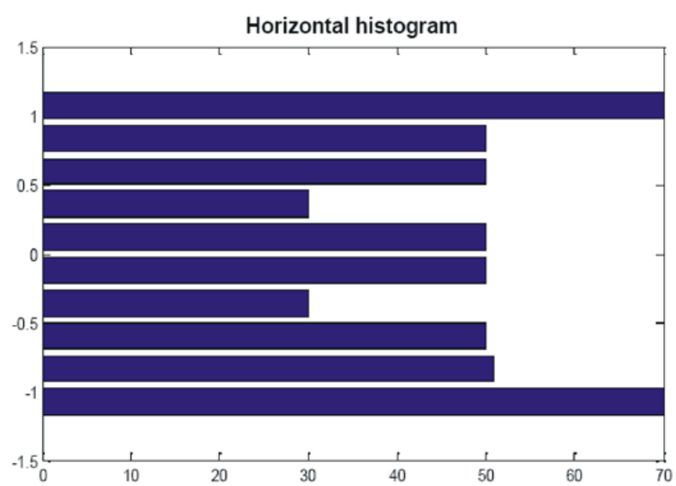


Fig. 5(c): Hortizontal histogram

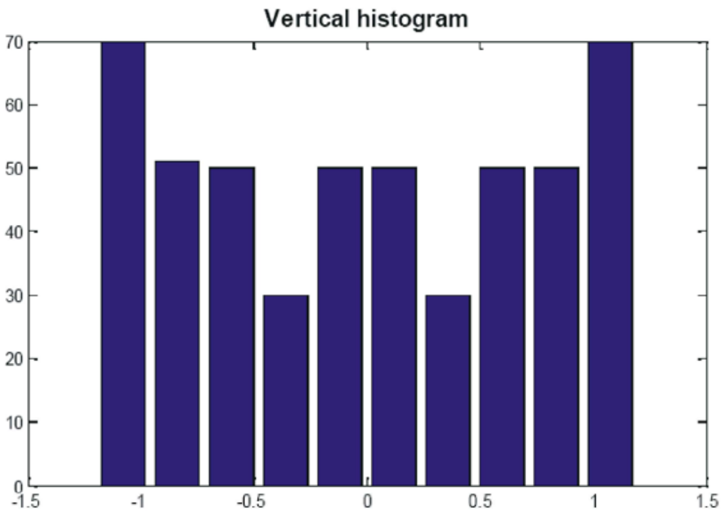


Fig. 5(d): Vertical histogram

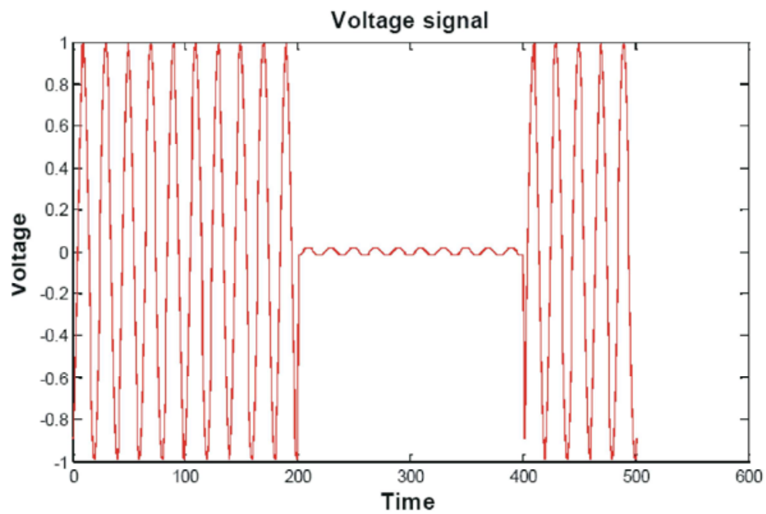


Fig. 6(a): Voltage Outages

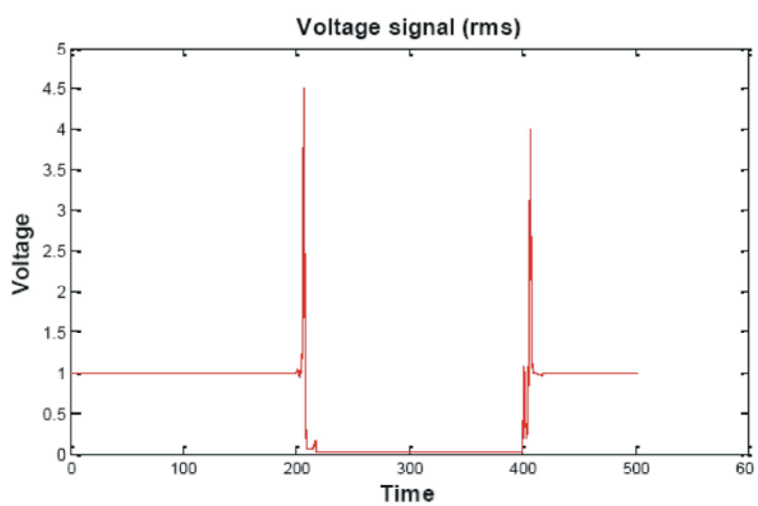


Fig. 6(b): RMS Voltage

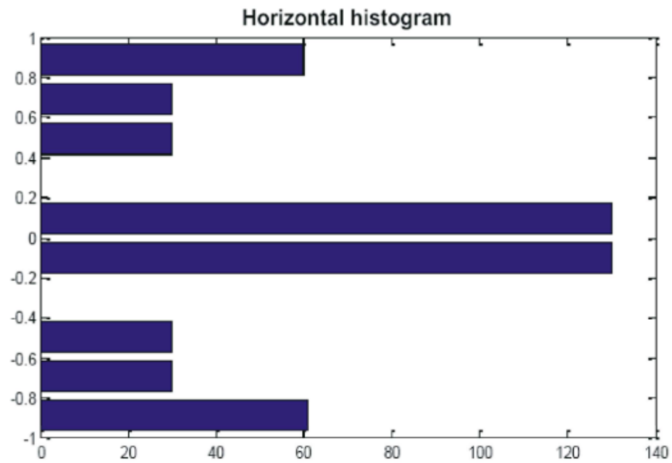


Fig. 6(c): Hortizontal histogram

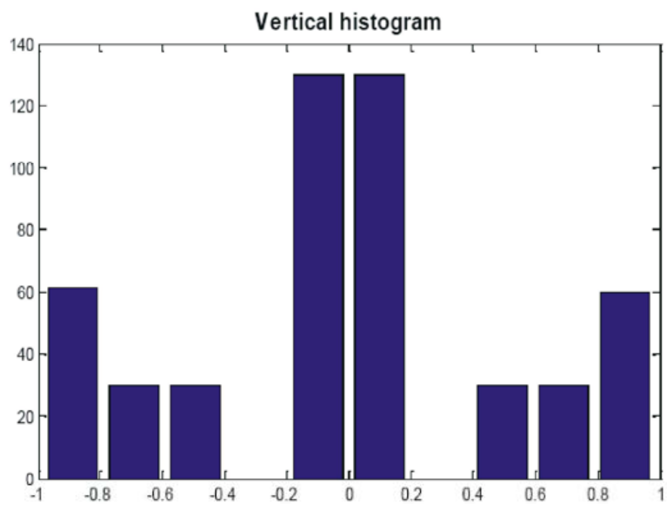


Fig. 6(d): Vertical histogram

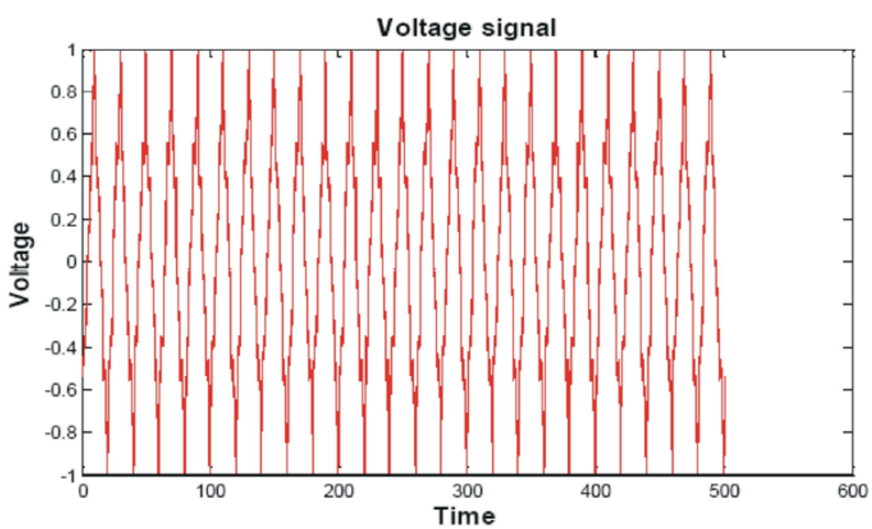


Fig. 7(a): Harmonics

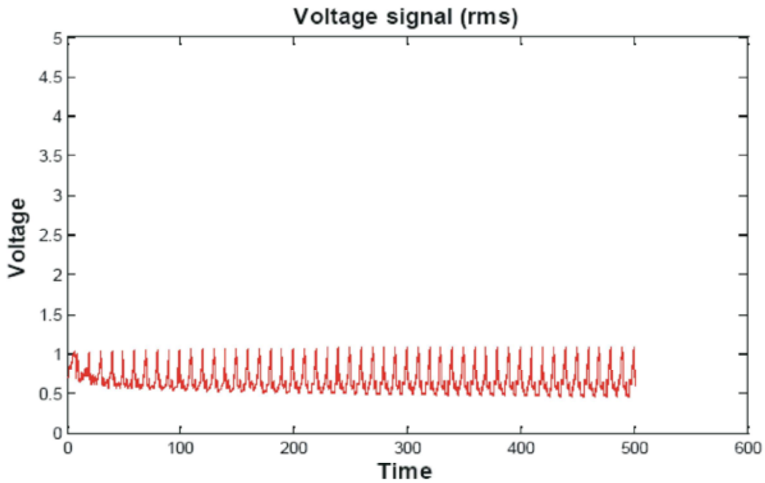


Fig. 7(b): RMS Voltage

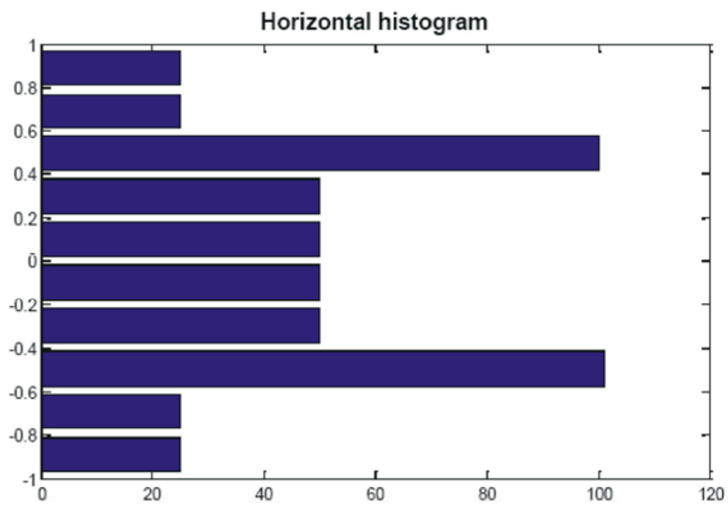


Fig. 7(c): Hortizontal histogram

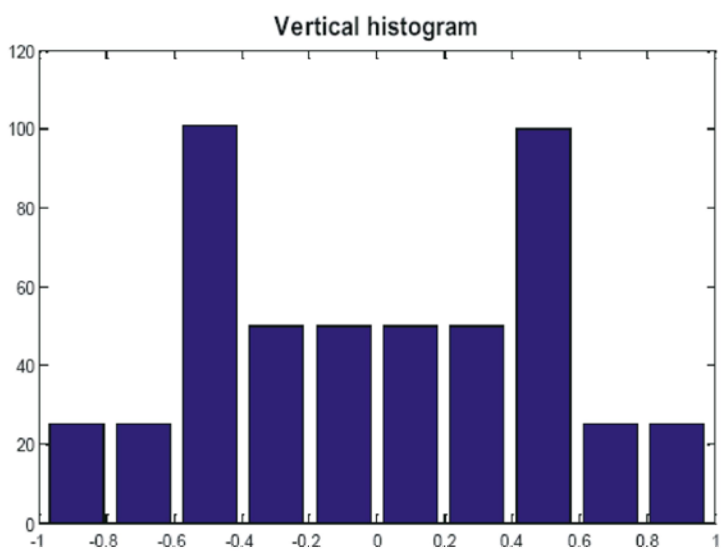


Fig. 7(d): Vertical histogram

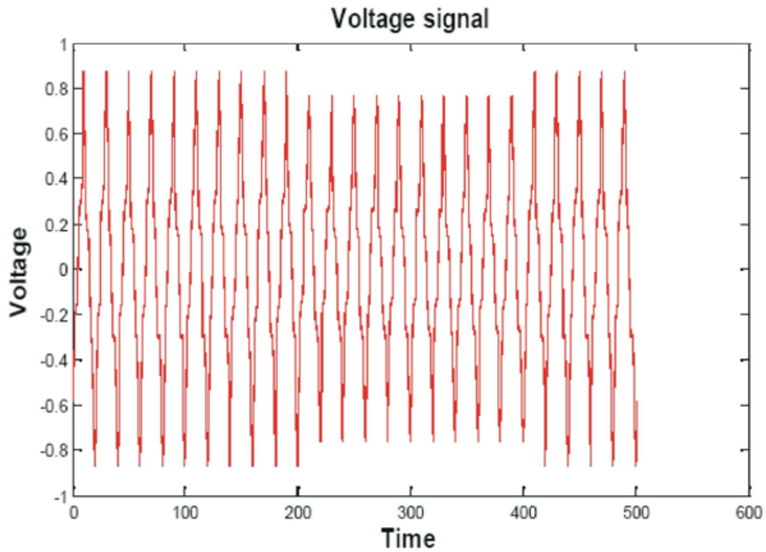


Fig. 8(a): Sag with Harmonics

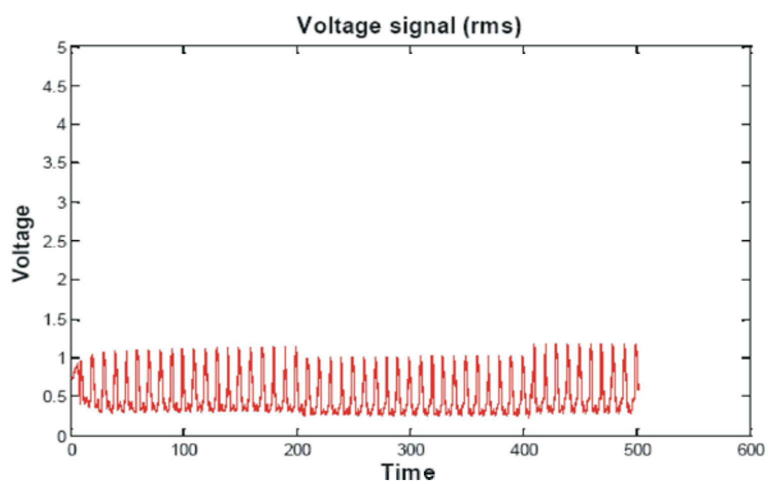


Fig. 8(b): RMS Voltage

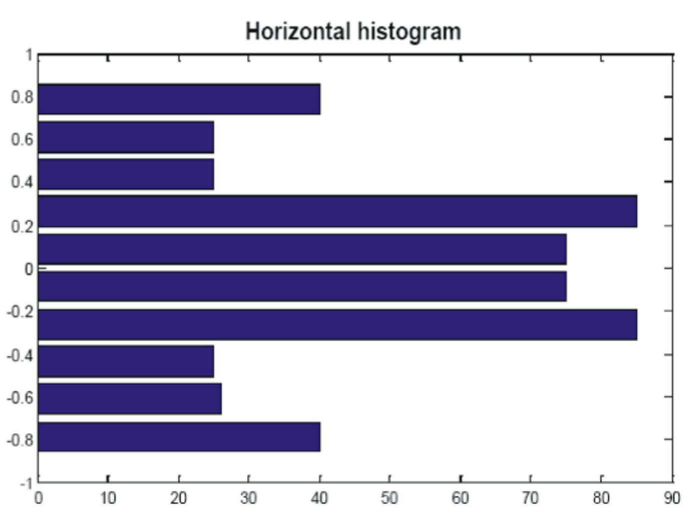


Fig. 8(c): Hortizontal histogram

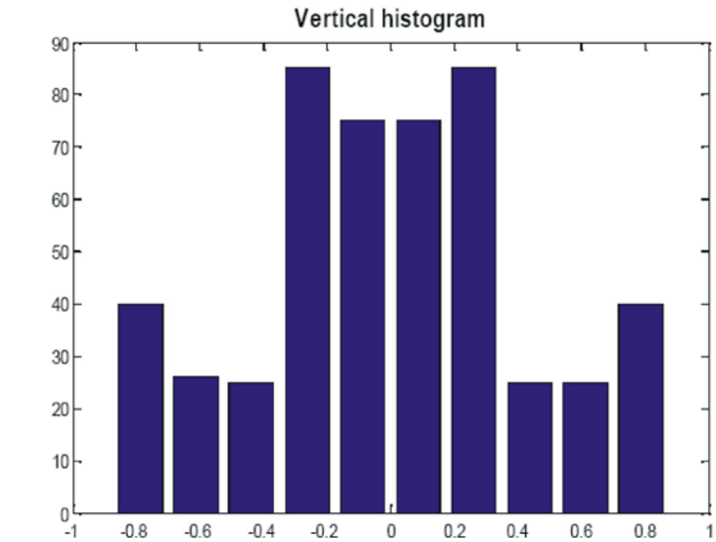


Fig. 8(d): Vertical histogram

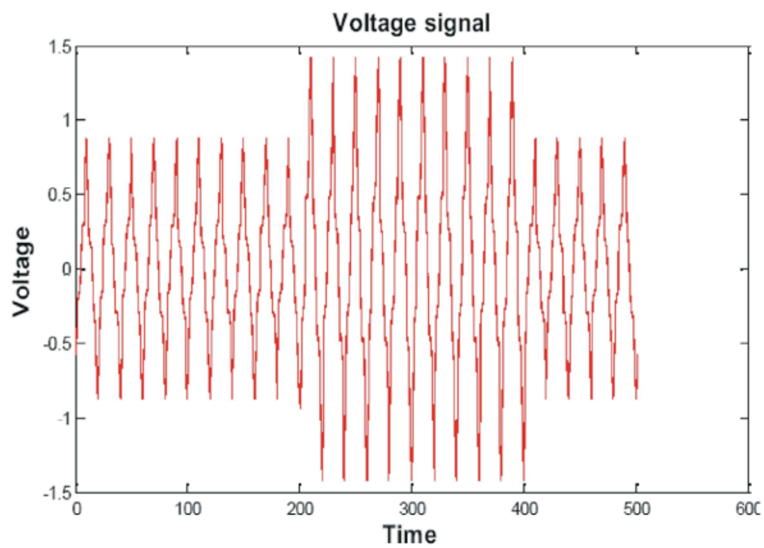


Fig. 9(a): Swell with Harmonics

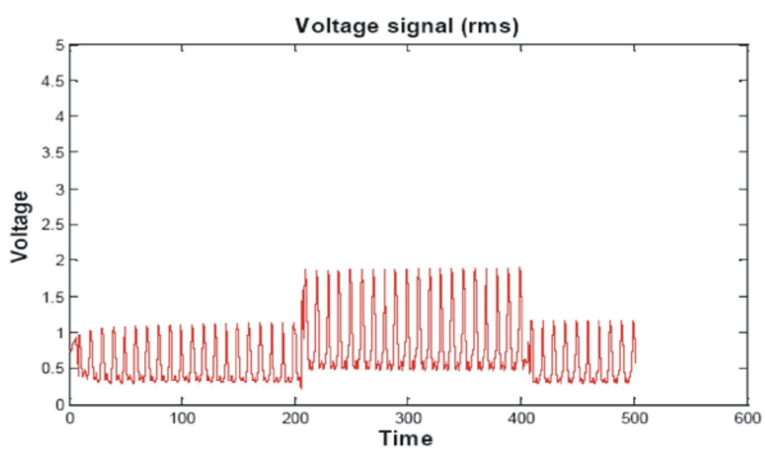


Fig. 9(b): RMS Voltage

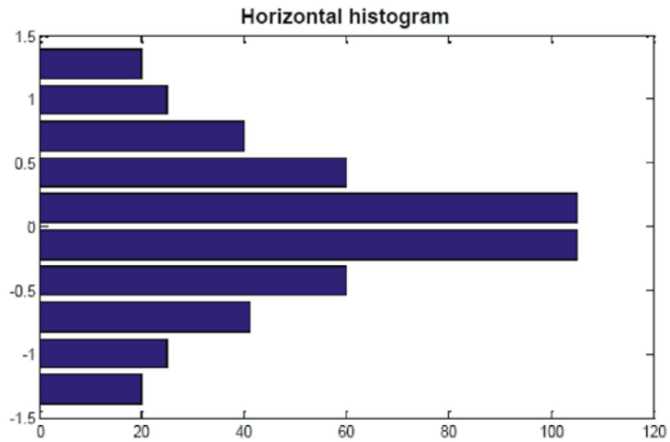


Fig. 9(c): Hortizontal histogram

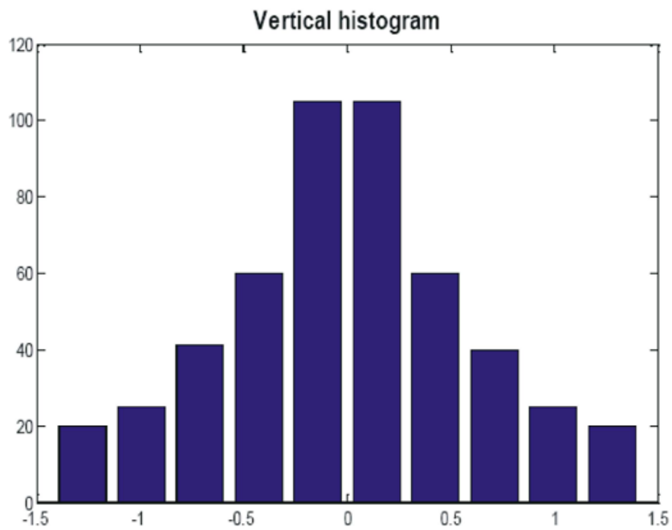


Fig. 9(d): Vertical histogram

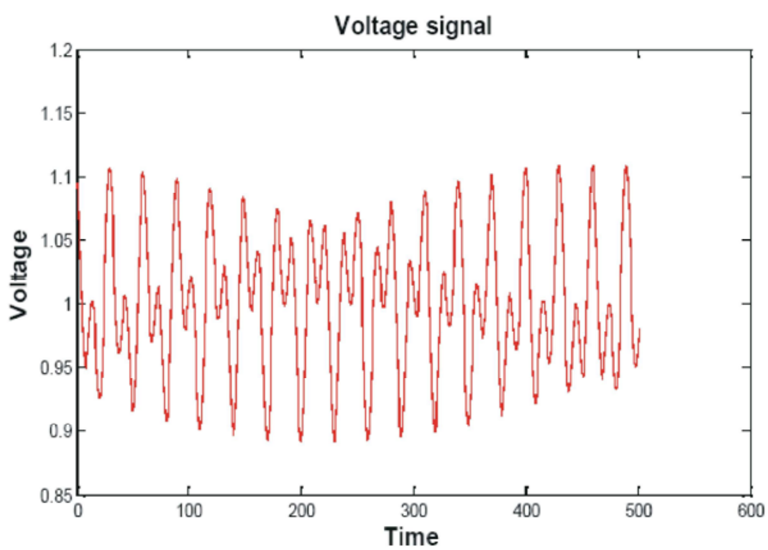


Fig. 10(a): Flicker

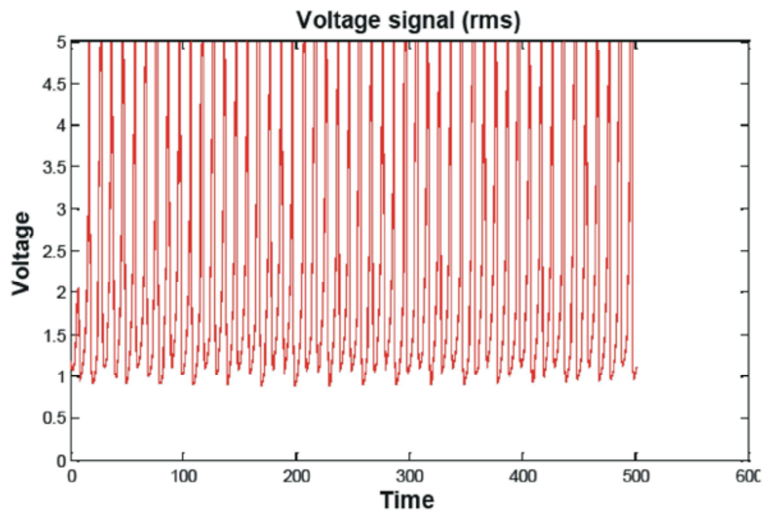


Fig. 10(b): RMS Voltage

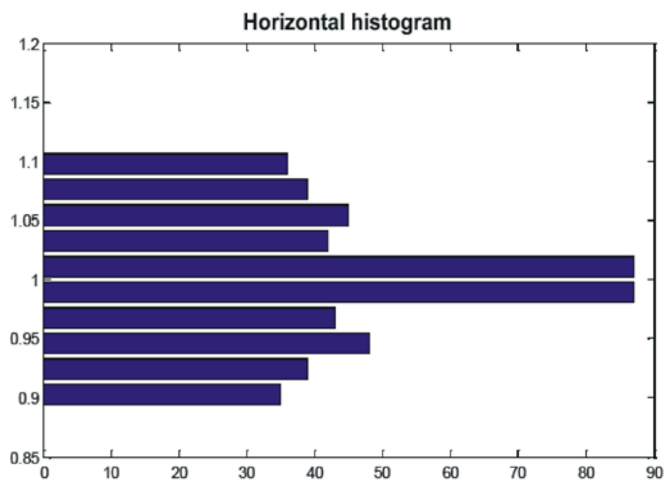


Fig. 10(c): Hortizontal histogram

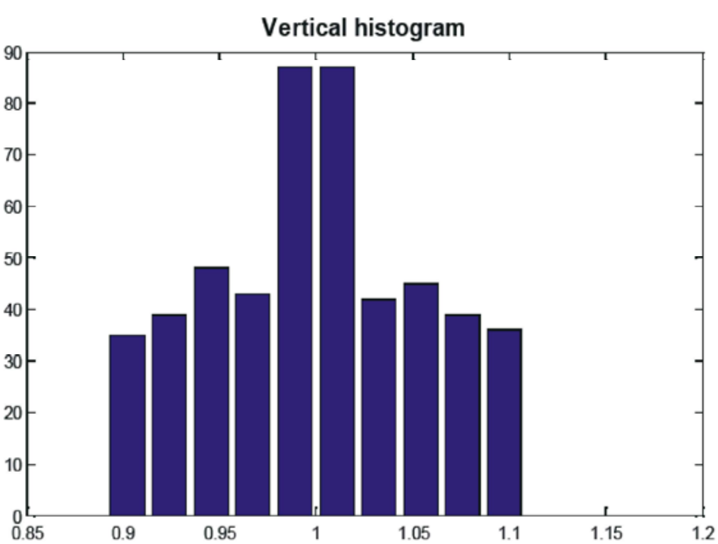
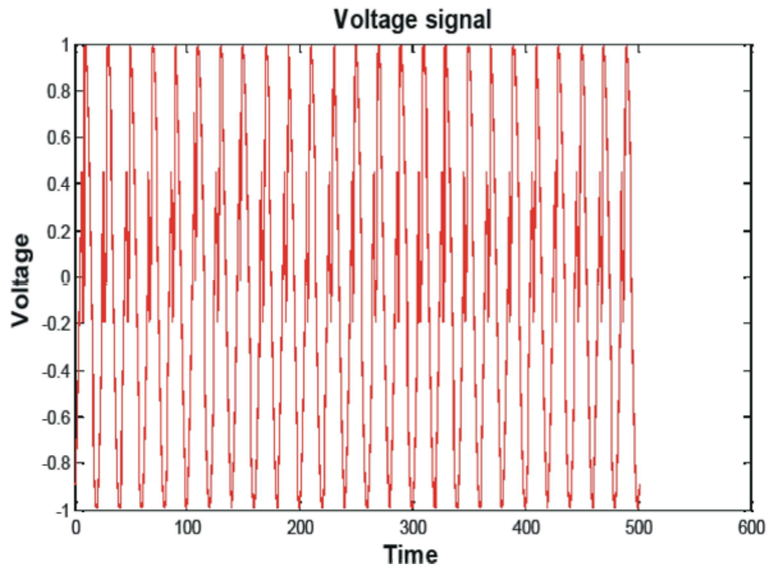


Fig. 10(d): Vertical histogram



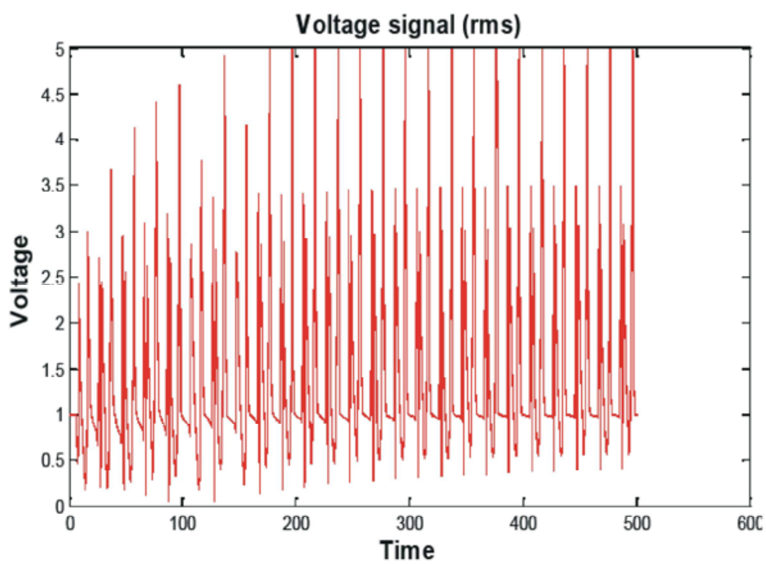


Fig. 11(a) and 11(b): Flicker and RMS Voltage

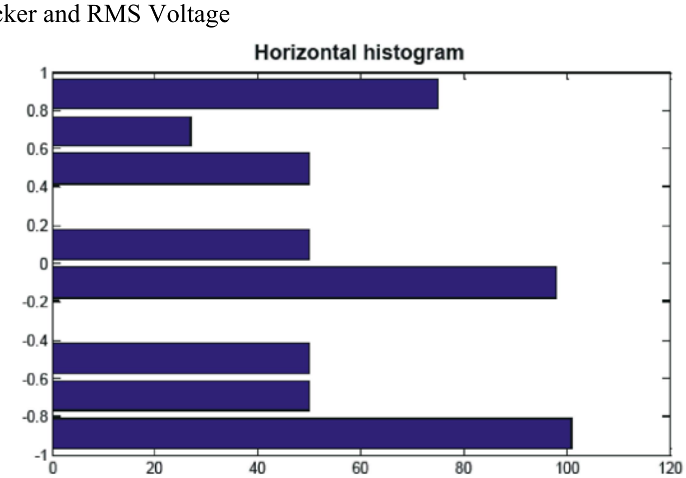


Fig. 11(c): Hortizontal histogram

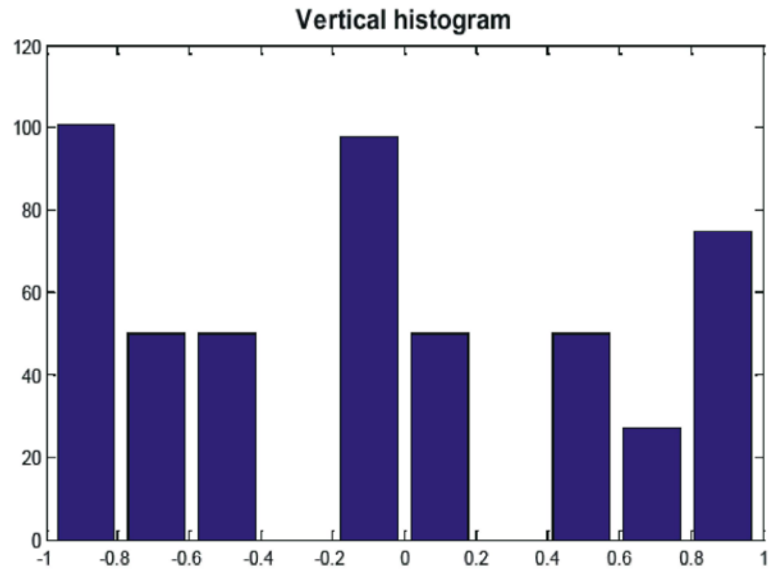


Fig. 11(d): Vertical histogram

The case study of the Flicker is shown in Figures 10(a) to 10(d).

The case study of the Harmonics is shown in Figures 7(a) to 7(d).

The case study of the Notch is shown in Figures 11(a) to 11(d).

RESULTS AND DISCUSSION

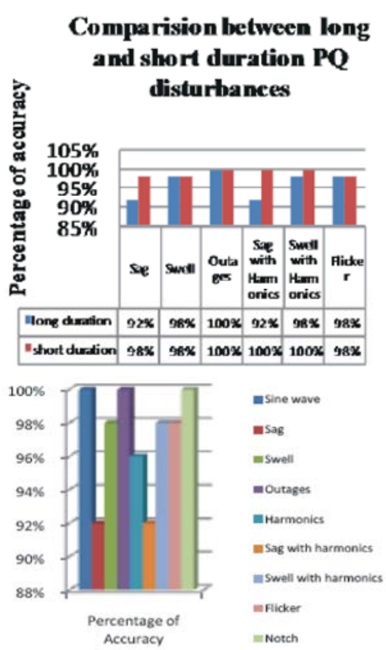


Fig. 12: Bar diagram for the percentage of accuracy of the proposed method

Table 3: Classification accuracy

Sno	Power Quality Disturbances	Input features	Percentageofaccuracy
1	Pure Voltage signal	100	100
2	Voltage Sag	100	92
3	Voltage Swell	100	98
4	Outages	100	100
5	Harmonics	100	96
6	Sag with Harmonics	100	92
7	Swell with Harmonics	100	98
8	Flicker	100	98
9	Notch	100	100
	Overall accuracy		97.11

CONCLUSION

Detection and classification of the power quality disturbances has been done by the proposed Adaptive Linear Neural Network and Feed Forward Neural Network based technique. The disturbance waveforms were generated through parametric equations. Features such as RMS voltage, horizontal and vertical histogram were extracted through Adaptive Linear Neural Network and Feed Forward Neural Network has been applied for classifying the disturbances. It has also been found that all the nine disturbances were classified accurately by the proposed method and it is well suitable for real world applications were the classifier is applied over the data captured in field. Neural Network is a versatile classifier that can be trained for any input combination and its application makes the suggested technique particularly suitable for classification of disturbances of varying nature.

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