Training of the Naïve Bayes Classifier for the Detection of the Power Quality Events (Voltage Dip, Voltage Swell and Voltage Interruption)

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Abstract—The effect of the Power Quality events can be devastating if not properly managed. To manage such PQ events effective detection and classification techniques must be developed. There are various mathematical models that can be used in the detection and classification of the events which could vary from Dip, Swell, Interruption, and Harmonic distortion. The paper is based on the classification of Voltage Dip, Voltage Swell and Voltage Interruption using the STFT as the method of the detection of the triggering point and using such synthetic signal to train the Naïve Bayes classifier to develop a classifier that is capable of classifying waveform signals that has such disturbances in them.

Index Terms—Matlab, Naïve Bayes, Power Quality events, STFT.

I. INTRODUCTION

Efficient power delivery is the concern of every electric power provider all over the world, hence the term Power Quality (PQ) analysis cannot be over emphasized. The electrical power system is expected to deliver undistorted sinusoidal rated voltage and current continuously at rated frequency to the consumers. Power Quality problem is defined as any power problem manifested in voltage, current, or frequency deviation that results in failure or malfunction of customer equipment [3] [5] [13]. Power Quality is something both the supplier of utility, the equipment manufacturer, and the end user has to deal with as it has to deal with the quality of the power supplied and how it is been used. To the Utility suppliers, Power Quality initially refers to the quality of the service delivered that is its reliability. To the end users it centres on their ability to use the delivered energy in the desired manner. The equipment manufacturer views PQ as the level of supply that ensure efficient running of their equipment [9]. The correct classification of power quality disturbance is the premise and the basis of governance and control of power quality events, and the usual approach is primarily based on the transformation and reconstruction of the original waveform, extracting classification features, impelling a large number of signal processing methods applied to the detection of the power quality events. Commonly used feature extraction methods is Wavelet Transform (WT), Fourier Transform (FT), Hilbert Hung Transform (HHT), and S-Transform. When the feature extraction has been done, the classification is carried out by

mathematical classifiers which includes Artificial Neural Network (ANN), Fuzzy Logic, Support Vector Machine (SVM) and Bayesian classifier [7] [15]. One of the visible sign of a power quality problem is a distortion in the waveform of the voltage of the power sine wave or from the amplitude established reference level or a complete interruption. The disruptions can go for a fraction of a cycle (milliseconds) to great durations (seconds to hours) in the supplied voltage which could start from either the power plants or the transmission lines or the distribution substations or the service equipment and building wiring [1] [2] [4] [6] [8] [10] [14]. Synthetic signals was generated using the Short Time Fourier Transform for the purposes of the training of the Naïve Bayes classifier. Short Time Fourier Transform (STFT) is another form of the Fourier Transform known as the sliding window version of the Fast Fourier Transform which shows a better results in terms of resolutions and frequency sensitivity [12]. Bayesian classification and decision making is based on probability theory and the principle of choosing the most probable or the lowest risk (expected cost) option [11].

II. METHODOLOGY

The synthetic signal is to determine the feature extraction points of the PQ events waveform which will be used in the training of the Bayes classifier. The following input parameters were used in the generation of the synthetic signals. The input parameters are set which are

- i. rms Nominal Voltage (V) = 220volts
- ii. Fundamental Frequency (f_0) in Hz = 50Hz
- iii. Sampling rate (f_s) in samples per second (KHz) = 6.4×10^3
- iv. Samples per 50Hz cycle (N_{cycle}) = f_s/f_0
- v. Window Width = 1500 – 3000

The cosine sinusoidal signal with the nominal voltage used as amplitude was generated and the Power Quality events was introduced between the signal waveform sample at the window width. The PQ events introduced in this project was Voltage Dip, Voltage Swell, and Voltage Interruption. Each of the PQ event waveform signal was passed through the STFT. The maximum frequency which are the points of the fundamental magnitudes(triggering point) are located and the waveform was segmented based on this triggering points. The signal energy was computed using

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the Parseval's theorem and the Total Harmonic Distortion (THD) was also computed. To generated various signal energy and THD the PQ events are introduced at different percentages.

The data gotten from the signal energy and the THD was used to train the Naive Bayes function in the Matlab to train it. The created classifier is the trained classifier.

III. RESULTS

The normal waveform without any PQ event are displayed in Fig. 1. The generated synthetic waveform signal of the Voltage Interruption, Voltage Swell, and Voltage Dip are displayed in the figures below. In Fig. 2 the PQ event which was Voltage Dip was introduced in the signal at window width of 1500 – 3000 samples and the STFT was able to detect it showing the fundamental magnitude which is the point of triggering point allowing it to be successfully located on the indicator. In Fig. 3 the PQ event which was Voltage Swell was introduced in the signal at window width of 1500 – 3000 samples and the STFT was able to detect it showing the fundamental magnitude which is the point of triggering point allowing it to be successfully located on the indicator. In Fig. 4 the PQ event which was Voltage Interruption was introduced in the signal at window width of 1500 – 3000 samples and the STFT was able to detect it showing the fundamental magnitude which is the point of triggering point allowing it to be successfully located on the indicator. In the training of the Naïve Bayes classifier, it was notice that the prediction and the actual PQ event tallies for all the PQ events tested as shown in the Table 1 and for the 50 samples carried for each event the trained classifier gives 100% accuracy as shown in Table 2. The Fig. 5 and Fig. 6 shows the relationship between the signal energy and Total Harmonic Distortion with respect to the increase in the percentages of PQ event introduced. It was observed that the Signal Energy for the Voltage Swell increases while that of the Voltage Dip decreases and Voltage Interruption is constant for increase in the percentage of each PQ event introduced. And the THD for the Voltage Swell slightly decreases while that of the Voltage Dip increases and Voltage Interruption is constant for increase in the percentage of each PQ event introduced.

IV. FIGURES

Fig. 1. Signal waveform without any PQ event

(a)

(b)

Fig. 2. Signal waveform with Voltage Dip (a) fundamental magnitude (b) indicator

(a)

(a)

(b)

(b)

Fig. 3. Signal waveform with Voltage Swell (a) fundamental magnitude (b) indicator

Fig. 4. Signal waveform with Voltage Interruption (a) fundamental magnitude (b) indicator

V. TABLES

TABLE I: TESTING OF THE CREATED NAÏVE BAYES MODEL

Testing samples		Predicted PQ Event	Actual PQ Event	Remark
Signal Energy	THD			
5.28E+07	6.87E-06	'swell '	Swell	Correct
6.19E+07	6.34E-06	'swell '	Swell	Correct
6.20E+07	6.35E-06	'swell '	Swell	Correct
9.38E+07	5.16E-06	'swell '	Swell	Correct
9.38E+07	5.15E-06	'swell '	Swell	Correct
1.32E+08	4.35E-06	'swell '	Swell	Correct
1.32E+08	4.34E-06	'swell '	Swell	Correct
2.35E+07	1.03E-05	'dip '	Dip	Correct
1.80E+07	1.17E-05	'dip '	Dip	Correct
5.87E+06	2.04E-05	'dip '	Dip	Correct
3.73E+05	7.25E-05	'dip '	Dip	Correct
1.80E+07	1.17E-05	'dip '	Dip	Correct
5.86E+06	2.04E-05	'dip '	Dip	Correct
3.66E+05	7.22E-05	'dip '	Dip	Correct
7.12E+03	1.48E-04	'interruption'	Interruption	Correct
7.12E+03	1.48E-04	'interruption'	Interruption	Correct
7.12E+03	1.48E-04	'interruption'	interruption	Correct
7.12E+03	1.48E-04	'interruption'	interruption	Correct
36.6337	1.47E-04	'interruption'	interruption	Correct
36.6337	1.47E-04	'interruption'	interruption	Correct
36.6337	1.47E-04	'interruption'	interruption	Correct

TABLE 2: CLASSIFICATION RESULTS OF STFT-BAYES ON SYNTHETIC VOLTAGE SIGNALS

PQ Event	Swell	Dip	Interruption	Classification Rate
Swell	50	0	0	100%
Dip	0	50	0	100%
Interruption	0	0	50	100%

Fig. 5. Graph showing the distribution of the PQ events (Swell, Dip, and interruption) using the signal energy

Fig. 6. Graph showing the distribution of the PQ events (Swell, Dip, and interruption) using the THD

VI. CONCLUSION

This paper utilize the STFT to determine the triggering point which is the point of disturbances to make the Naïve Bayes classifier train itself to classifier the PQ event which has been identified in the generation of the synthetic signals as the Voltage Swell, Voltage Dip, and Voltage Interruption. This classifier is useful for any classification of the triggering point detected by any of the detection classification model.

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