International Journal on Future Revolution in Computer Science & Communication Engineering
Volume: 4 Issue: 2
ISSN: 2454-4248
213– 216

Review of Detection and Classification Techniques for Power Quality Events

Rajender Kumar Beniwal
Department of Electrical Engineering
DCR University of Science & Technology
Sonepat, India
Email: mail.rajender@gmail.com

Rinku Kumar
Department of Electrical Engineering
DCR University of Science & Technology
Sonepat, India
Email: rinkukumar721@gmail.com

Rohit Saini
Department of Electronics & Comm. Engg.
Hindu College of Engineering
Sonepat, India
Email: rohitsaini2010@gmail.com

***Abstract*—** This paper presents a short review on the field of power quality. Power quality is directly related to the performance of the electric equipment. The accurate and reliable operation and life of equipment based on the quality of input power. So the main concern on the power quality is for satisfactory operation of each connected equipment. Detection, classification and mitigation are the main steps used in the power quality analysis. Accurate detection and classification gives effective mitigation solutions. A number of research papers are reviewed and presented here which gives some knowledge about power quality field.

Keywords- *power quality; signal processing; artificial intelligence*

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I. INTRODUCTION

The term Power Quality (PQ) deals with electromagnetic behaviour of the power system network and the electrical equipments connected. With the advancement in technology the equipments are more prominent to the supply and more sensitive. Use of power electronics equipments is common now a days and the non-linear behaviour of these equipment destroy the quality of the supply.

Institute of Electrical and Electronics Engineers (IEEE), defines PQ as "the concept of powering and grounding electronic equipment in a manner that is suitable to the operation of that equipment and compatible with the premise wiring system and other connected equipment."

The word power quality is related with the quality of the electric power supplied by the utilities. From last two decades, it is a major research area for the power systems. Every equipment is designed to operate on the specified power supply, any deviation from these specification results in misoperation and may damage the equipment. In present scenario electric equipments are more sensitive to the supply and the use of non-linear equipments create distortion in the supply. Hence, the thrust on the power quality research is increased.

The power quality disturbances like sag, swell, transients, interruptions, harmonics, notch etc. are occurs in transmission and distributions networks. For the desired functioning of the equipments these disturbances must be mitigated. For the mitigation purpose detection and classification of these disturbances is very important. A plenty of work has been done in this area and some of the work has been presented in this paper.

II. LITERATURE REVIEW

For the detection and classification of PQ disturbances or events, signal processing and artificial techniques are used by the researchers. Some of the PQ disturbances are due to environmental factors like storm, lightning etc. and due to improper connections for theft [1-5] which also causes PQ distortion. The electricity reforms [7,12] create competitions among different companies and customer stratification [6,10] is one of the major challenge for these companies. So the demand of steady and clean power i.e., service quality [8,9,11,13,14] to the customer is also priority of the companies. Some of the researches are presented in this section.

Eristi et al. [15] have presents classification of PQ events by using S-Transform (ST) and Extreme Learning Machine (ELM) technique. In this proposed method, the different features have been extracted by S-Transform and extracted features are fed to the ELM classifier for classification of various PQ events. The real and synthetic power quality events are generated in MATLAB/SIMULINK with added noises of 20, 30 and 50 db. An analysis of power system generation and distribution system has been presented in [16-17].

Authors in [18] have analyzed voltage sag and voltage swell in power system networks by using ellipse parameters of voltage. The authors have used the instantaneous magnitude information of three phase voltages in three axis, separated by 1200. Veena et al. [19] proposed a Time/ Frequency domain approach. Using extracted features, PQ disturbances like sag, swell, transients outage and harmonics are classified. In the proposed method, the models are simulated from parametric equations, which are given the 100% classification efficiency. Smart distribution sytems are also under development phase [20-21].

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Deokar et al. [22] have proposed an integrated approach of Discrete Wavelet Transform and Fast Fourier Transform. Total sixteen type disturbances are simulated using parametric equations in MATLAB. Rule based approach is used for classification of PQ disturbances. Hence, from present study we found that the proposed DWT-FFT approach gives effective. Authors in [23] have proposed a Sparse Signal Decomposition technique. By this method PQ signals are decomposed into detail and approximation signals containing impulse and sinusoidal waveforms. Features have been extracted from these waveforms and then the signals are classified by hierarchical decision-tree algorithm. Both synthetic and micro grid simulated power quality disturbances are tested.

For detection and classification of PQ events various signal processing tools have been proposed by the researchers in [24-26]. Further intelligent techniques used for classification were also discussed along with some optimization techniques. Different strategies for analysis of non-stationary signals have been compared such as STFT, GT, ST, WT, KF etc. [27]. These techniques have been compared on the basis of frequency and time resolution, convergence, signal-to-noise

Table 1. Important works on fault detection and classification of voltage sag

Authors	Signal Processing Techniques	Classifiers	Faults	Signal Used
Iovan et al. [32]	Virtual technology	---	3-phase Voltage dip	Real
Kumar et al. [33]	S-Transform	ANN and RBDT	Harmonic with Sag, Swell, Interruptions	Real
Latran et al. [34]	Wavelet Transform	---	Sag	Synthetic
Kanirajan et al. [35]	Wavelet Transform	RBFNN-PSO	Sag, Swell, Harmonics etc.	Synthetic
Babu et al. [41]	EMD, HHT	SVM	L-L, D-L-L	Synthetic
Eristi et al. [15]	S-Transform	ELM	L-L	Real and Synthetic
Biswal et al. [42]	EMD, HHT	BNT	Sag, Flicker etc.	Synthetic
Deokar rt al. [22]	DWT, FFT	MRA Curves	Sag, Swell, Interruptions, Harmonics	Synthetic
Manikandan et al. [23]	Sparse-Signal Decomposition	HDT Algorithm	Sag, Swell etc.	Synthetic

ratio. Similarly, the algorithms used for classifying power disturbances were compared such as ANN, SVM, FL, BC, MLP, k-NN and BPNN. These classifiers have been compared on the basis of classification accuracy, flexibility and time consumed. Some more techniques other than traditional techniques as discussed above are also used by the researchers in some of the reported articles such as empirical mode decomposition (EMD) with Hilbert transform (HT) i.e., HHT [28], demodulation concept [29] and TT-transform [30] based for analyzing of PQ events.

Iovan et al. [31] have studied power quality events like three phase voltage dips through virtual laboratory. Virtual laboratory exhibits various kinds of voltage sag having different properties. They have analyzed different signals to get the information generated for different users. In [32], a significant work on PQ disturbances by using Stock well's transform (ST) and artificial neural network based classifier and rule based decision tree. The proposed algorithm indicates the different multiple power quality disturbances in which harmonics with sag, swell, interruptions etc. are considered. This algorithm summarizes various features of power quality disturbances by applying S-transform, which are used as an input to the hybrid classifier for different power quality disturbance classification.

Latran et al. [33] have proposed an algorithm for voltage sag based on Db2 and Db8 wavelets, which are used to detect voltage sag with or without phase jumps for good competitive results between other methods like dq-transform, fast Fourier transform and EPLL. Authors in [34], have presented wavelet transform technique based on radial basis function neural network (RBFNN) classifier, proposed algorithm indicates the different types of power quality disturbances in which various features extracted by using wavelet transform were used for training RBFNN for the classification of events. Other researches using multiwavelet [35-37], Legendre wavelet [38] and modified potential function [39] are also presented.

Babu et al. [40] depict classification of power system faults by using Empirical mode decomposition and support vector machine. A multiple SVM model was used for classifying the fault conditions in various power system faults. Biswal et al. [41] have proposed a method for the power quality events classification which is based on Empirical mode decomposition and Hilbert transform. In this paper, EMD with HT has shown a better time-frequency localization for non-stationary signal patterns. In the proposed method, for event classification the extracted features are given to a balanced neural tree (BNT). Hence, from present study we found that the proposed method gives better result in comparison to ST.

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Naik et al. [42] have studied the analysis of short duration PQ disturbances such as sag, swell, harmonics, oscillatory transients etc. by using Wavelet Packet Transform (WPT). The proposed method has used Wavelet packet transform decomposition levels which are used to extract the parameters for the identification of power quality disturbances. Analysis of non-linear power quality disturbances has been presented in [43] and classification using fuzzy logic is presented in [44]. In [45], an Embedded system based distributed private cloud (EBDPC) is presented. Single channel independent component analysis (ICA) approach is presented in [46]. By proposed method, the independent components of the power system signal have been classified by classifier. The qualitative and quantitative analysis acknowledge the efficiency. Fractionally delay wavelets [47] and frequency management has been presented in [48].

Moreno et al. [49] have proposed an algorithm for detection and isolation of power quality monitoring from other disturbances based on power quality analyzer (PQA). In this algorithm, various kinds of disturbances have been programmed in PQA.

In [50-51], the authors present an approach for detection and analysis of sag and transients present in the supply voltage. Continuous wavelet transform has been used as signal processing technique which presents the signal under study in time-frequency domain. This gives correct time localization and amplitude of the sag and transient signal.

III. Comprehensive Analysis

Various signal processing techniques used in the works are mentioned in the Table 1 along with the type of faults being considered, different types of signal being operated upon and various classifiers used for classification of different type of fault. Consequently, ANN based RBDT has been used in reported work as in [33]. SVM using kernel function for better performance has been used in reported work as in Babu et al. [41]. EMD, a signal processing technique, has been used with one or more improved form Hilbert Huang Transform, as in Babu et al. [41], Biswal et al. [42].

IV. Conclusion

The literature of the power quality is very vast; it shows the importance of the power quality. A plenty of work has been done in this field. Different researchers present different approaches. Some of the approaches are presented in this paper, which gives an introductory idea about power quality and different problems in this field. By analyzing this review it is concluded that power quality disturbancces are cause of huge financial losses. For proper solution of these problems effective detection and classification is main key for mitigation.

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