ANN Model for Automated Detection and Classification of Power Quality Disturbances

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***Abstract*— This study describes a method for detecting and classifying various power quality problems that combines discrete wavelet processing with artificial neural networks. There are different methods used to identify the same issue, including the Hilbert transform, Gabor transform, Gabor-Wigner transform, S transform, and Hilbert-Haung transform. The wavelet and ANN methods involve the creation of voltage waveforms with varying sampling rates and number of cycles, as well as the analysis of a large number of power quality events using MATLAB. The wavelet transformation and ANN techniques were used to obtain the needed coefficients. Collections of power quality events are tracked at each stage to categorize the specific occurrence. The study's steps lead to automated real-time power signal monitoring, detection, and categorization.**

***Keywords*— Hilbert transform, Gabor transform, Gabor-Wigner transform, S transform, Hilbert-Haung transform**

I. Introduction

Power quality is one of the most serious and widespread issues confronting all electric users and industrial societies alike. To avert serious difficulties, electric power monitoring, quality assessments, and describing the problems, as well as implementing solutions to limit their impact, can assist. However, in order to effectively minimize the problem, precise monitoring technology must identify, collect, and classify it. Fourier analysis is one of the procedures used to obtain precise measurements.

In this work, Fourier analysis and artificial neural networks (ANNs) are used to automatically identify the issue. The automated data gathering procedure that categorizes recorded events using artificial neural networks (ANNs). This approach solely relies on the wavelets' localization property and time-frequency monitoring. Wavelets and several ANNs are being used in this procedure, and the results are really good.

Power quality issues are classified based on the length of the interruption. Nonlinear loads induce harmonic distortion and flickering, which are examples of steady-state conditions that require long-term solutions. In other circumstances, such incidents may occur infrequently. Other phenomena, such as sagging, swelling, and notching, may occur temporarily. These problems can arise in a wide range of appearance, length, and timing of disruptions, making diagnosing power quality issues challenging.

A technique of categorizing disturbances using a mix of wavelet analysis and artificial neural networks (ANN) is suggested to address the problem of automated recognition of many events and different types of disturbances. The goal is to create a technique that might be used in a real-time power quality monitoring application where different kinds of power quality disruptions can occur.

II. POWER QUALITY CLASSIFICATION

To sustain dependability in an electrical power system, consumers must be provided with undistorted sinusoidal current and voltage at rated frequency on a continual basis. However, massive industrial machinery and individual generators, as well as capacitor banks, place additional strain on the power system network, while rising demand causes power quality issues.

The power quality can be described in a variety of ways. primarily from the perspectives of customers, equipment makers, and utilities. Customers need high-quality power to guarantee that operations, business, and procedures continue to function smoothly. From the perspective of system dependability, utilities need power quality. For their equipment to operate properly, manufacturers need power quality.

A power quality issue is described as "any power problem manifested in voltage, current, and/or frequency deviations that result in the failure or malfunction of customers or equipment." Power quality issues nowadays are produced by power system transients such as switching and lightning surges, induction furnaces, and loads. Also, interconnection and large-scale use of power electronic devices with sensitive and fast control schemes in electrical power networks have provided many technical and economic benefits, but they have also introduced power quality issues that have become new challenges in the power system.

To be competitive, utilities and other electric power suppliers must guarantee a high caliber of service. When it was discovered that transformers and spinning machinery were the primary causes of waveform distortion, power quality analysis was first conducted around the close of the 19th century. There are two main types of power quality issues.

A. Events or Disturbances

These forms of disturbances occur when an irregularity in the voltage or current is detected. Transient voltages can be recognized when the peak magnitude exceeds a predetermined threshold. RMS voltage changes, such as sags or interruptions, may be recognized when they surpass a certain level.

B. Steady-State Variations

Along with distortion and the degree of imbalance between the three phases, steady state variation is essentially a measurement of how much the voltage or current may deviate from the nominal value. Examples include harmonic and distortion, as well as typical rms voltage fluctuations.

Power quality disturbances can be further characterized according to the type of the distorted waveform. Table 3.1 shows the waveform information for each type of power quality problems, including duration and magnitude. The mentioned events in the Table can be specified using a variety of characteristics. For steady-state disturbances, the amplitude, frequency, spectrum, modulation, source impedance, notch depth, and notch area properties can be used. Other properties important for non-steady state disturbances include rate of ascent, rate of recurrence, and energy potential.

Table 3.1: Classification of different power quality instances.

S No	Categories	Duration	Voltage Magnitude
I	***Short Duration Variation***		
a)	**Sag Instantaneous**	**0.5-30 cycles**	**0.1-0.9pu**
	Momentary	**30cycles-3sec**	**0.1-0.9pu**
	Temporary	**3sec-1min**	**0.1-0.9pu**
b)	**Swell Instantaneous**	**0.5-30 cycles**	**1.1-1.8pu**
	Momentary	**30cycles-3sec**	**1.1-1.8pu**
	Temporary	**3sec-1min**	**1.1-1.8pu**
c)	**Interruption**		
	Momentary	**0.5-30 cycles**	**<0.1pu**
	Temporary	**3sec-1min**	**<0.1pu**
II	***Long Duration Variation***		
a)	**Interruption, sustained**	**>1min**	**0.1pu**
b)	**Under-voltage**	**>1min**	**0.8-0.9pu**
c)	**Over voltage**	**>1min**	**1.1-1.2pu**
III	***Transients***		
a)	**Impulsive Nano-sec**	**<50nsec**	
	Micro-sec	**50-1msec**	
	Milli-sec	**>1msec**	
b)	**Oscillatory Low freq**	**0.3-50msec**	**0-4pu**
	Medium freq	**20µsec**	**0-8pu**
	High Freq	**5µsec**	**0-4pu**
IV	**Voltage imbalance**	**Steady state**	**0.5-2%**
V	***Wave Distortion***		
a)	**Harmonics**	**Steady state**	
b)	**Notching**	**Steady state**	
c)	**Noise**	**Steady state**	

The following are a few explanations for the interest in PQ:

- Power electronics equipment like microprocessors and microcontrollers are ubiquitous in today's environment. These devices are highly sensitive to PQ issues and introduce a variety of PQ issues.
- Nowadays, industrial devices like shunt capacitors and high-efficiency, variable-speed motor drives are often utilized. If the equipment malfunctions or fails, there is a significant financial loss.
- Power quality issues including voltage fluctuations, flicker, and waveform distortions are brought about by renewable energy sources.

To reduce the power quality events listed in the table above, efficient detection and classification approaches are necessary in evolving power systems. Human operators must watch waveforms to classify power quality issues, which takes time. Furthermore, extracting useful information from basic monitoring waveforms is not always reliable. So it is a crucial responsibility for appropriate development and improvement. Various artificial intelligence algorithms for PQ event categorization are also in use. This work describes a mix of wavelet and ANN classification approaches for PQ events.

III. PROGRAMMING AND RESULTS

The creation of a wavelet-based neural network classifier for power system disturbance waveforms is described in this chapter. Power quality events may be used to train artificial neural networks to identify patterns. One popular method for identifying disturbance characteristics in pattern recognition tasks is the wavelet transform. Due to the large range of disturbance classes involved, power quality event detection is a challenging challenge. By taking into account a variety of disruptions in terms of amplitude and duration, this procedure is made simpler. And we carried out the necessary processes by calculating the Discrete Wavelet Transform (DWT) utilizing MATLAB@ Wavelet Toolbox algorithms.

A. Event detection

The identification of events in normal supply is necessary to ensure distortion-free supply. When disturbance data from the power system is monitored, artificial control cannot be applied to that data. The classifications, sampling rate, and types of disturbances are passed to the ANN, which then trains the corresponding events. Then, based on the arbitrary placements of disturbance and the number of cycles at any sample rate, the ANN could detect the observed event for fault categorization. Noise in power system data has been shown to be a barrier to the categorization of several events, including sag, swell, harmonics, transients, flickers, and notches. Etc.

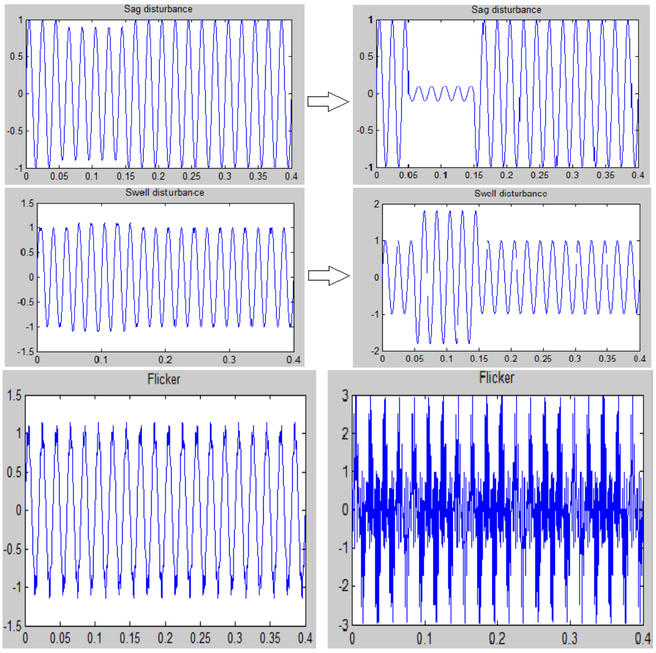
B. Discret wavelet transform

The discrete wavelet transform is another stage in the classification process that generates the disturbance signal's coefficients. Additionally, it reduces the sample rate's number of steps, which simplifies detection. If no disturbance is found in this stage, the DWT is applied to that part of the signal; if a disturbance is suspected, the corresponding coefficients that represent the signal itself are generated. An overview of the signal is provided by one scale, the disturbance is shown in more depth by another, and the high frequency content of the disturbance is captured by the third. The DWT will generate unique coefficients that ANNs can train. A power system voltage waveform with or without a disturbance is represented by the resultant set of DWT coefficients.

C. Programming steps

The programming code that generates all of the power quality problems and their corresponding variables.

For example, the sag and swell events are developed as from their minimum value to maximum according to the IEEE standard classification table. The waveforms are given below. To generate coefficients of the generated power quality disrupted waveform, the same computer code uses DWT transformation.



Similarly, the programming is developed such as the all variables meet their minimum to maximum to obtain a proper estimated wave in order to develop a final matrix which includes all power quality disturbances.

	1	2	3	4	5	6	7	8	9
1	0.0485	-0.0501	3.6198	5.5736	2.3580	-3.0447	-5.6234	-2.9865	2.4
2	0.0485	-0.0501	3.6198	5.5736	2.3580	-3.0447	-5.6234	-2.9865	2.4
3	0.0485	-0.0501	3.6198	5.5736	2.3580	-3.0447	-5.6234	-2.9865	2.4
4	0.1187	0.1219	3.7125	5.4034	2.5670	-3.1901	-5.4322	-3.2198	2.6
5	0.0485	-0.0501	3.6214	5.5729	2.3508	-3.0536	-5.6232	-2.9726	2.4
6	0.1187	0.1219	3.7125	5.4034	2.5670	-3.1901	-5.4322	-3.2198	2.6
7	0.1187	0.1219	3.7125	5.4034	2.5670	-3.1901	-5.4322	-3.2198	2.6
8	0.0460	0.0384	3.4473	5.6512	2.4278	-3.2134	-5.4778	-3.0024	2.2

These coefficients will be formed into one individual matrix. In this paper the obtained matrix have **8*1890** order matrix. The y matrix is given to a neural network as the reference. Which will generate a net file and the neural program internally have both target matrix and y matrix. It will create a T matrix in order to classify the given types of the events. After the running the neural program the net file will be saved in dictionary.

The test program will test the signal obtained from the y matrix and save it to the dictionary as well. Now finally for testing program we create a event randomly and give it to the test program along with test program we will given codes for the each possibility of the even classification. It is named as D.

After executing the final program, the value of D will contain the knowledge of all Power Quality problems-related waveforms. By doing so, the supplied testing signal will be classed as one of the power quality concerns.

IV. CONCLUSION

The number and duration of power quality disruptions can be used to categorize power system incidents. A technique to identify and categorize disturbed voltage waveforms with any sampling rate and cycle count has been given in this research. Multiple filtering, DWT, and ANN phases are used in the classification scheme; the ANNs get the DWT coefficients as inputs. This innovative set of techniques holds potential for the creation of completely automated monitoring systems with categorization capabilities in the future.

Input waveforms are characterized based on the kind of disturbance, the number of disturbances in the number of cycles provided, and whether the disturbance is continuous, repeated, or a single case. This distinction is significant because several disturbances may indicate a different situation to the power engineer than a single occurrence, and this additional information offers far more information about the events that caused the disturbances. Power system monitoring, enhanced by the capacity to automatically classify disrupted signals, is an effective tool for power system engineers to handle power quality concerns.

UPCOMING WORK: This study discusses how fuzzy control and wavelet transformations provide the same level of efficiency in the detection criteria. Robust solutions that are more suited for real-time application including numerous additional transformations can be produced by a variety of manipulations and sheer inventiveness. One of the poor transform technique alterations for defect identification is phase shifting.

More work may be done using the same approaches to identify, characterize, and filter disturbances. The method is suited for all forms of disturbances and produces accurate results with no discrepancy because it is based only on the system's input signals and frequency. However, real-time execution of the evaluation technique may prove to be time-consuming. As a result, more work may be done to improve the algorithm's performance. The use of Wavelet Transform and other methods would undoubtedly benefit the algorithm on this level.

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