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Power Quality Disturbaces Clasification And Automatic Detection Using Wavelet And ANN Techniques

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Abstract— In this paper a development method to detect and classify the several power quality problems using the discrete wavelet transformation and artificial neural networks combined. There are several other methods in use to detect the same problem like Hilbert transform, Gabor transform, Gabor-Wigner transform, S transform, and Hilbert-Haung transform. The method of using wavelet and ANN includes the development of voltage waveforms of sampling rate and number of cycles, and also large number of power quality events with help of MATLAB software. The wavelet transformation and ANN tools used to get required coefficients. The obtained events of power quality monitored in each step to classify the particular event. These steps of the paper lead towards the automatic real time monitoring, detection and classification of power signals.

Keywords—*Power quality problem detection; wavelet transform; Artificial Nural Network.*

I. INTRODUCTION

Power quality is one of the major and most common problems facing by all electric consumers and industrial societies etc. To avoid major problems the electric power monitoring, quality surveys and characterizing the problems and implementation of the solution to minimize the effect helps. But to effective minimization of the problem accurate monitoring equipments needed to recognize, captured and classified the problem. For the accurate measurement the methods like Fourier analysis is used.

In this paper the artificial neural networks **(ANNs)** have been combined with Fourier analysis to detect the problem automatically. The ANN used for the automated data collection process that classifies recorded events. This method is purely depending on the time-frequency monitoring and localization property of wavelets. This process of using wavelets and multiple **ANNs** are giving quite good results.

The power quality problems are described according to disturbance duration. Harmonic distortion and flickering caused by nonlinear loads, is an examples of a steady-state condition for which long-term solutions are applied. In some cases, such events may occur intermittently. Other events may occur momentarily example sag, swell, notches. These problems may occur in large variety in the appearance, duration, and timing of disturbances, so that these power quality problems are difficult to diagnose.

To classify the problem of automatic recognition of a variety of disturbance types, and multiple events, a method of classifying disturbances using a combination of wavelet analysis, and **ANN** is proposed**.** The objective is to develop a method that has potential in a real-time power quality monitoring application where the variant types of power quality disturbances occurred.

II. POWER QUALITY CLASSIFICATION

To maintain reliability in an electrical power system the undistorted sinusoidal with rated voltage and current at rated frequency has to be supplied to users continuously. However, the large industrial machines and individual generators, capacitor banks put more stress on the power system network and in other hand, the day by day increasing in the demand causes the power quality problems.

There are many ways to describe the power quality. Mainly from the views of utilities, equipment manufacturers and customers. Customers require good Power quality that ensures the continuous running of processes, operations, and business. Utilities require Power quality from the system reliability point of view. Equipment manufacturer require Power quality for proper operation of their equipment.

A Power quality problem can be defined as “any power problem manifested in voltage, current and/or frequency deviations that result in failure or mal-operation of customers or equipment”. Now a day’s power quality problems are caused from the power system transient arising due to switching and lightning surges, induction furnace and loads. And also interconnection, large scale usage of power electronic devices with sensitive and fast control schemes in electrical power networks have brought many advantages technically and economically, but these have also introduced power quality problems which are became new challenges in power system.

The utilities or other electric power providers have to ensure a high quality of their service to remain competitive. The power quality analysis was, first started at the end of 19th century, when rotating machinery and transformers were found to be main sources of the waveform distortion. Power quality problems fall into two basic categories.

A. *Events or Disturbances*

These types of Disturbances are caused by triggering on an abnormality in the voltage or the current. Transient voltages may be detected when the peak magnitude exceeds a specified threshold. RMS voltage variations examples like sags or interruptions may be detected when it exceeds a specified level.

B. *Steady-State Variations*

Steady state variation is basically a measure of the magnitude by which the voltage or current may vary from the nominal value, plus distortion and the degree of unbalance between the three phases. Examples like normal rms voltage variations, and harmonic and distortion.

The power quality disturbances can further be classified depends on the nature of the distorted waveform. The information of the waveform regarding duration and magnitude for each category of power quality disturbances are shown in Table 3.1. The listed events in the Table can be described by various attributes. For steady-state disturbances, the amplitude, frequency, spectrum, modulation, source impedance, notch depth and notch area attributes can be utilized. For non-steady state disturbances, other attributes such as rate of rise, rate of occurrence and energy potential are useful.

Few reasons for the interests in PQ are as follows:

• Modern world is fully equipped with power electronics devices like microprocessor and microcontroller. These devices introduce various types of PQ problems and themselves very sensitive to PQ problems.

• Industrial equipments such as high-efficiency, adjustable speed motor drives and shunt capacitors are now commonly used. This results in huge economic loss if equipment fails or malfunctions.

• Renewable energy sources create new power quality problems, such as voltage variations, flicker and waveform distortions.

Table 1: Classification of various power quality events

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**	**0-4pu**
b)	**Oscillatory Low freq**	**0.3-50msec**	**0-8pu**
	Medium freq	**20μsec**	**0-4pu**
	High Freq	**5μsec**	
IV	**Voltage imbalance**	**Steady state**	**0.5-2%**
V	***Wave Distortion***		
a)	***Harmonics***	**Steady state**	
b)	***Notching***	**Steady state**	
c)	***Noise***	**Steady state**	

To minimize power quality events which mentioned in above table and efficient detection classification techniques are required in the emerging power systems. Classification of power quality disturbances based on the monitoring of waveforms by human operators is time consuming. In addition to that, it is not always accurate to extract important information from simple monitoring waveforms. So it is important task for proper developing and perfective measures. Various artificial intelligent techniques which are used in PQ event classification are also in use. In this paper, a combination of wavelet and ANN classifications techniques used for PQ events has been presented.

III. PROGRAMMING

This chapter explains the development of programming of a wavelet-based neural network classifier for power system disturbance waveforms. Artificial Neural networks can be trained to recognize patterns which are presented based on power quality events. The wavelet transform is a well known tool for extracting disturbance features in pattern recognition problems. Power quality event recognition is a difficult problem because it involves a wide range of disturbance classifications. This step is simplified by considering multiple number of disturbances in the view of amplitude and time. And using MATLAB@ Wavelet Toolbox functions to calculate the Discrete Wavelet Transform (DWT) we performed the required operations.

A. Event detection

The detection of events in normal supply is required to maintain distortion free supply. When disturbance data from power system is monitored, the artificial control cannot be applied over the monitored data. The classifications, sampled rate and types of disturbances given to the ANN and train the respective events. Then according to the arbitrary placements of disturbance and number of cycles at any sampling rate the ANN could detect the monitored event to the fault classification. Power system data also contain noise, which was found to be a barrier to classification of some events, such as Sag , swell , Harmonics , transients , flickers , notches . Etc.

B. Discret wavelet transform

Another step in the classification process is the discrete wavelet transform, which will produce coefficients of the disturbance signal. It also decreases the number of steps of the sampling rate which makes the detection simpler. The DWT is applied to that portion of the signal if no disturbance is detected in this step, or if the disturbance is suspected then the respective coefficients has been produced which represents the signal itself. One scale gives an overall view of the signal, another presents the disturbance in some detail, and the third captures high frequency content of the disturbance. The **DWT** will produce distinctive coefficients which can train by **ANNs.** The resulting set of DWT coefficients, representing some power system voltage waveform with or without a disturbance

C. Programming steps

The programming code for all the considered power quality problems and their respective variables are given bellow

```
%Pure Normal 50 Hz sine wave
 t=[0 :0.0001:0.4];
y=sin(314*t);
figure(1)
plot(t,y)
title('Pure 50 Hz Sine wave')

%Sag wave
%alpha ranges 0.1 to 0.9
 t=[0 :0.0001:0.4];
alpha=0.5;
y=(1-alpha*((heaviside(t-0.05)-heaviside(t-0.15)))).*sin(314*t);
figure(2)
plot(t,y);
title('Sag disturbance');

%swell wave
%alpha ranges 0.1 to 0.8
```

```
t=[0 :0.0001:0.4];
alpha=0.5;
y=(1+ alpha*((heaviside(t-0.05)-heaviside(t-0.15)))).*sin(314*t);
figure(3)
plot(t,y);
title('Swell disturbance');

%Interruption
%alpha ranges 0.9 to 1
t=[0 :0.0001:0.4];
alpha=0.95;
y=(1-alpha*((heaviside(t-0.05)-heaviside(t-0.15)))).*sin(314*t);
figure(4)
plot(t,y);
title('Interruption');

%Harmonics
%alpha3,aplha5, alpha7 range from 0.05 to 0.15
t=[0 :0.0001:0.4];
alpha3=0.15;
alpha5=0.15;
alpha7=0.15;
alpha1= sqrt(1- alpha3^2-alpha5^2-alpha7^2);
y= alpha1* sin(314*t)+ alpha3*sin(3*314*t)+ alpha5*sin(5*314*t)+
alpha7*sin(7*314*t) ;
figure(5)
plot(t,y)
title('Harmonics');


%Transient
%t1 start duration
%t2 end duration
%ampllitude
%fn goes from 300 to 900
fn=500;
amp= 1;
t1=0.06; t2=0.058;
ty= (t1+t2)/2;

t=[0 :0.0001:0.4];
amp= 5;
t1=0.06; t2=0.058;
ty= (t1+t2)/2;

t=[0 :0.0001:0.4];
y= sin(2*pi*50*t)+ amp*(heaviside(t-t2)-heaviside(t-t1)).*exp(-
t/ty).*sin(2*3.14*fn*t);
figure(6)
plot(t,y)
title('Transient');

%sag+harmonic
t=[0 :0.0001:0.4];
alpha=0.5;
alpha3=0.15;
alpha5=0.15;
alpha7=0.15;
alpha1= sqrt(1- alpha3^2-alpha5^2-alpha7^2);
```

```
y=(1-alpha*((heaviside(t-0.05)-heaviside(t-0.15)))).*(alpha1* sin(314*t)+ alpha3*sin(3*314*t)+ alpha5*sin(5*314*t)+ alpha7*sin(7*314*t));
figure(7)
plot(t,y)
title('Sag+Harmonics');

%swell+ harmonics
t=[0 :0.0001:0.4];
alpha=0.5;
alpha3=0.15;
alpha5=0.15;
alpha7=0.15;
alpha1= sqrt(1-alpha3^2-alpha5^2-alpha7^2);
y=(1+alpha*((heaviside(t-0.05)-heaviside(t-0.15)))).*(alpha1* sin(314*t)+ alpha3*sin(3*314*t)+ alpha5*sin(5*314*t)+ alpha7*sin(7*314*t));
figure(8)
plot(t,y)
title('Swell+Harmonics');

%Flicker
%alpha ranges 0.1 to 2
%beta ranges 5 to 10
t=[0 :0.0001:0.4];
alpha=0.15;
beta=7.5;
y=(1+alpha*sin(beta*314*t)).*sin(314*t);
figure(9)
plot(t,y)
title('Flicker');
```

The above 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. That same program code has DWT transformation in order to produce coefficients of the produced power quality disturbed waveform.

```
[ca0 cd0]=dwt(y1,'db2');
[ca1 cd1]=dwt(ca0,'db2');
[ca2 cd2]=dwt(ca1,'db2');
[ca3 cd3]=dwt(ca2,'db2');
[ca4 cd4]=dwt(ca3,'db2');
y1=ca4;
```

Those coefficients will be formed into one individual matrix. In this paper the obtained matrix have 8*1890 order matrix.

D. Neural programming

After getting a Matrix Neural program implemented as follows.

```
load y
y=y';
P=.0001*y;
d1=ones(8,1);
  T=[d1 2*d1 3*d1 4*d1 5*d1 6*d1 7*d1 8*d1];
 [netnw,tr] = newrb(P,T,0.0,10.0,70,10)
       Y = round(sim(netnw,P));
save netnw
```

This program will generate the netnw file and this file will help in testing the waveform. The test program as follows.

```
function D=test(y)
load netnw;
D=round(sim(netnw,y));
```

The value of D will store the knowledge of the entire Power Quality problems related waveforms. To perform Final step a testing signal will be given and tested. By doing so given testing signal will be classified into one of the power quality problems.

The test signal program code is as follows.

```
clear
clc
t=[0 :0.0001:1];
alpha=0.1;
y=(1+alpha*((heaviside(t-0.1)-heaviside(t-0.3)))).*sin(314*t);
D=test(y)

if D==0
   disp('There is sag');
else
    end
if D==1
   disp('There is swell');
else
end
if D==2
   disp('There is intruption');
else
end
if D==3
   disp('The is LL harmonics');
else
end
    if D==4
   disp('The is LLG transiants');
else
end
    if D==5
   disp('The is sag+harmonics');
else
end
    if D==6
         disp('There is swell+harmonics');
else
end
   if D==7
         disp('There is flicker');
else
end
```

IV. CONCLUSION

Power system events may be classified by quantity and duration of power quality disturbances. This paper has presented a method to detect and classify disturbed voltage waveforms of arbitrary sampling rate and number of cycles. The classification scheme uses multiple filtering, DWT, and ANN steps, with DWT coefficients as inputs to the ANNs. This novel combination of methods shows promise for future development of fully automated monitoring systems with classification ability.

Input waveforms are classified according to type of disturbance and number of disturbances in the number of cycles presented, and whether the disturbance is ongoing, repeating, or a solitary case. This distinction is useful because multiple disturbances may suggest a different scenario to the power engineer than a single occurrence, and this additional information provides much more information about events which led to the disturbances. Power system monitoring augmented by the ability to automatically characterize disturbed signals is a powerful tool for the power system engineer to use in addressing power quality issues.

FUTURE WORK*:* In this paper Wavelet transforms and fuzzy control offer same efficiency in the detection criteria is discussed. Various manipulations and sheer innovativeness can yield robust techniques better suited for real time application involving various other transforms. The method of Phase shifting is one of the mediocre manipulations of the transform technique for the detection of the faults.

More work can be undertaken in employing the same techniques to suitably detect, characterize and filter the disturbances. The algorithm is suitable for all types of disturbances and gives accurate results without any disparity as it is based purely on the input signals and frequency of the system. But real time execution of the evaluation algorithm may turn out to be a time consuming process. Hence further work can be undertaken in improving the runtime of the algorithm. Inclusion of Wavelet Transform and other means would surely help the algorithm on this level.

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