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An Uncertainty Model Approach for Detection Of Power Quality Disturbances

Renuka Hiremath[1] , Swathi B Kocharekar[1] , Kaustub H. S[1], Harish Naik[1], Rashmi S[2]
[1]Students, EEE Department, VVCE, Mysuru, Karnataka, India
[2]Asst. Prof, EEE Department VVCE, Mysuru, Karnataka, India

ABSTRACT

Now a days, the analysis and detection of various power quality disturbances are widely required due to increasing use of sensitive control in most of the devices at all consumer levels. The various power quality disturbances that occur in distribution and transmission systems are voltage sag, voltage swell, harmonics, interruption, transients, spikes, notch etc. these disturbances can occur due to switching off large loads, use of solid state switching device, arc furnaces, transformer energization, capacitor switching, lightning strikes and use of electronically switched loads such as rectifiers or invertors. Poor power quality can cause malfunctioning of protective relays, can affect the accuracy of utility metering, loss of data and can result in equipment damage resulting in a loss of productivity. In order to improve power quality, these disturbances need to be identified before taking appropriate mitigating action. In this paper we have created the power quality disturbances using uncertainty model approach in MATLAB/SIMULINK. Then the detection of disturbances is one using RMS method.

Keywords: power quality, Disturbances, Detection, uncertainty model approach, RMS method.

I. INTRODUCTION

IEEE Standard 1100 (IEEE 1999) defines power quality as the concept of powering and grounding sensitive electronic equipment in a manner suitable for the equipment.

The Power Quality requirement is one of the most important issues for electrical utilities of consumers. The equipment used in modem industrial and

commercial plants such as process controllers, programmable logic controllers ,Adjustable speed drives ,robotics ,computers etc. are actually becoming more sensitive to PQ disturbances such as outages, voltage sag, voltage swell, harmonics, transients as the complexity of the equipment increases[1]. voltage notch. The causes and effects of other PQ disturbances are discussed in chapter

Occurrence of these power quality disturbances can lead to loss of information, can cause malfunctioning of data and protective relays, can damage sensitive equipments, cause problems with electromagnetic compatibility (EMC) and noise.

This gives rise to implementation of Power Quality analysis and detection methods. For analyzing various disturbances it is necessary to first generate the PQ disturbances which can give results similar to that of real time waveforms. This can be done either by using simulation blocks in SIMULINK or by programming mathematical equations for each and every fault in MATLAB/SIMULINK.

After creating the PQ disturbances the SIMULINK model should be able to detect the particular disturbance occurring in the system and should also classify it based on the conditions prescribed. For this purpose RMS technique, S transform, wavelet transform technique, etc can be used.

In this paper we have used numerical equations of uncertainty model approach for creating the disturbances like voltage sag, voltage swell, transients, harmonics, flicker and interruption. RMS technique has been used for detection and classification of disturbances in MATLAB/SIMULINK.

II. PQ DISTURBANCES

PQ disturbances can be described either in terms of voltage or current. These disturbances are characterized by system voltage and frequency. The various power quality disturbances are voltage sag or voltage dip, voltage swell or over voltage, harmonics, flickers, transients, voltage fluctuations, notch, spike, etc.

Faults taking place due to sudden switching of large loads on consumer side and the faults in transmission lines of network cause voltage sags and voltage swells. Lightning strikes on the network cause transients in the system which is a sudden momentary rise in voltage magnitude.

The simultaneous operation of switches in converter during commutation cause two phase short circuit which lead to voltage loss. This loss in voltage result in disturbances called

A. Voltage Sag

According to IEEE Standards 1159-1995 sag can be defined as a decrease to between 0.1 and 0.9 p.u in root mean square (RMS) voltage at the power frequency for durations of 0.5 cycles to 1 min.

Voltage sags can be caused in transmission systems due to weather, construction accidents, transportation accidents, due to nesting habits of birds which introduce phase to ground Faults.

Voltage sags in distribution systems are caused due to sudden opening and closing of circuit breaker contacts. These faults can be three phase, line-to-line, or single line-to-ground. These three phase faults are relatively unusual but can be most severe when occurred.

Some of the effects of sag on equipment are malfunction of programmable logic controllers, disconnection of adjustable speed drives with subsequent shutdown and production losses, tripping of under voltage relays. The voltage dip condition can last until the large current demand decreases, or till the fault is cleared by any of the switchgear equipment [2].

B. Voltage Swell

According to IEEE Standards 1159 it is defined as an increase to between 1.1 pu and 1.8 pu in RMS voltage or current at the power frequency durations from 0.5 to 1 minute. The swell can be divided into three main classes namely; instantaneous swell, momentary swell and temporary swell.

Single line-to-ground faults lead to occurrence of voltage swell in system which can also result in a temporary rise in voltage in other unfaulted phases. Swells can also be caused due to switching on large capacitor banks, or by sudden decrease in load.

The occurrence of voltage sag can cause immediate or long-term breakdown of components because of overheating, can damage the different lightings, sensitive loads which in turn cause shut down of the equipment.

C. Harmonics

Harmonics are sinusoidal voltages or currents having frequencies that are integral multiples of the fundamental frequency. They are mainly caused by the non-linear loads such as rectifiers and other power conversion equipment.

Other sources of harmonics are rapid use of energy conversion devices such as electronic chokes for tube lights, supply system converters and tractions regulators for electronic fan, etc. These lead to occurrence of harmonics in domestic and industrial sectors. The major effects of harmonics are: heating effects in power handling equipment, disruption of operation of electronically controlled equipment [3].

D. Transients

Transients are undesirable and momentary events in power system. They can be classified as oscillatory and impulsive transients.

Impulsive transients are sudden non power frequency change in the steady state condition of voltage, current or both that is unidirectional in polarity. These have very fast rise and decaying time. Oscillator transients are sudden non power frequency change in the steady state condition of voltage, current or both that include both polarity values. The causes of these transients are lightning, load switching and capacitor switching.

These transients are of large voltage magnitude which may spoil the normal operation of sensitive electronic devices.

E. Flicker

Voltage fluctuations also called as flicker is much defined problem as it is related to human eye perception and luminous light bulbs.

The major causes of flicker in transmission and distribution systems are arc furnaces and welding machines. As human beings are very sensitive to flash caused by flickering, it is important to analyze this disturbance and use necessary methods for reducing it.

F. Interruption

A voltage interruption is defined as a large decrease in RMS voltage to less than a small percentile of the nominal voltage, or a complete loss of voltage.

Voltage interruptions may be caused due to accidents like faults and component malfunctions, improper maintenance and continuous operation of circuit breakers and fuses. They can also occur due to scheduled downtime. The power system faults, equipment failure, and control functions are the consequences of interruption.

III. UNCERTAINTY MODEL APPROACH

Modeling uncertainty conditions in utility calculations can be done using either of the two approaches. The first approach is a probabilistic approach and the second is called as "Unknown but Bounded". In probabilistic approach assumption of probability distributions is required whereas in the second approach assumption of upper and lower limits on the uncertainties without a probability structure is required [4].

In probabilistic method all the values are assumed to be equally distributed between given limits. This is assumed so, because no particular distribution is known.

Interval mathematics provides a tool for the practical implementation and extension of the unknown but bounded concept. Mathematical equations are used to generate Power Quality signals so that the real time signals are represented accurately [5]. The software programs for generation of PQ disturbances are governed by standard definitions for events as given in Table 1.

In this paper numerical models are used for creating various disturbances. The advantage of using this method is that the results obtained from this closely depict the real-time disturbances. These disturbances are characterized by their magnitude, duration and frequency and are simulated over the defined parameters range.

IV. DETECTION METHODS

After the disturbances are created using numerical models, a SIMULINK model should be created for classification and detection of these disturbances. RMS measurement, Peak Detection Method, Point to Point Comparison, Fast Fourier Transform, Wavelet Transform and S Transform techniques can be applied for the purpose of detection of PQ disturbances.

Fast Fourier transform (FFT) technique can correctly identify the magnitudes and phase of harmonic components present in the voltage signal. But the disadvantage of this technique is that it does not give the time information of the harmonics in the signal. RMS value technique is applied to overcome this drawback. But measuring of RMS of the signals is affected by the instant at which the disturbances occur thus introducing an error in the calculated duration of disturbance.

Wavelet Transform (WT) and S-Transform (ST) techniques can detect these disturbances accurately with accurate magnitude and time information. Depending on the types of signal, continuous wavelet transform (CWT) and discrete wavelet transform (DWT) can be employed. For simplicity, RMS value technique is used for detection and classification of the PQ disturbances in MATLAB/SIMULINK.

Root mean square (RMS) is commonly used in power systems as it is an easy way of accessing and describing variables like voltage, current, etc. The discrete RMS voltage within a window is calculated as:

$$= \sqrt{\frac{1}{N} \sum_{i=1}^{N} x_i^2}$$

Where, Xi sample value at i^{th} instant and N is the number of sample per window length. The window length is generally a cycle or half a cycle.

The RMS values can be continuous type or discrete type. If the values are updated every time a new sample is obtained, then the series is called continuous RMS series. If the values are updated with certain time interval, then the obtained RMS series is called discrete. Advantage of RMS value method is its simplicity, speed of calculation and less requirement of memory, therefore it is the most commonly used tool. The RMS values can be stored periodically instead of sample per sample. Dependence on window length is the disadvantage of this method [6].

V. MATHEMATICAL MODELLING

Real-time PQ disturbances are difficult to capture. Usually, signals of these disturbances are produced by simulation for analyzing them. In this paper six types of PQ disturbances are produced by using mathematical modelling i.e. by using uncertainty equations. The advantages of using uncertainty equations are we can vary signal parameters over a wide range in a controlled manner.

Also it is very easy to obtain the samples in a large extent. All uncertainty equations are numerically solved and an algorithm is developed to solve the problem by making use of MATLAB programming. These disturbances can be modeled by considering either transmission system or distribution system. In this paper we have considered distribution system of 230V corresponding to 1 pu for duration of 500 to 700ms.

The numerical models and range of parameters used for creating disturbances are given below:

Table 1. Numerical Modelling Of Pq Disturbances

PQ Disturbance	Numerical Model	Parameters
Pure Sine	$V(t)=A \sin(\omega t)$	$A=1$(pu);$\omega=2\pi 50$ rad/sec
Voltage Sag	$V(t)=(1-\alpha(u(t-t1)-u(t-t2)))\sin\omega t$	$0.1 \le \alpha \le 0.9$, $T \le t2-t1 \le 9T$
Voltage Swell	$V(t)=(1+\alpha(u(t-t1)-u(t-t2)))\sin\omega t$	$0.1 \le \alpha \le 0.8$, $T \le t2-t1 \le 9T$
Harmonics	$V(t)=\alpha 1\sin(\omega t)+\alpha 3\sin(3\omega t)+\alpha 5 \sin(5\omega t)+\alpha 7\sin(7\omega t)$	$0.05 \le \alpha 3$, $\alpha 5$, $\alpha 7 \le 0.15$, $\Sigma\alpha i^2$-1
Flicker	$V(t)=(1+\alpha\sin(\beta\omega t))\sin \omega t$	$0.1 \le \alpha \le 0.2$, $5 \le \beta \le 20$ Hz
Interruption	$V(t)=(1-\alpha(u(t-t1)-u(t-t2)))\sin\omega t$	$0.9 \le \alpha \le 1.0$, $T \le t2-t1 \le 9T$
Transients	V(t)=0.5*((1-A1*(u(t-t1)-u(t-t2))).*sin(2*pi*f/Fs*t)+(1-A2*(u(t-t3)-u(t-t4))).*sin(2*pi*f/Fs*t))	$0.1 \le \alpha \le 0.8$, $0.5T \le t2-t1 \le 3T$, 8ms ≤ ≤ 40ms, 300 ≤ fm ≤ 900 Hz

VI. SIMULINK MODEL

As mentioned above, simulation is necessary for the detection and classification of PQ disturbances like sag, swell, transients, flicker, harmonics and interruption. In this paper RMS value technique is employed for this purpose. It

is implemented in MATLAB/SIMULINK by interconnecting if else blocks, if else subsystems and RMS blocks. This makes the implementation of RMS method simple and can be understood easily.

If block, along with If Action Subsystem blocks containing an Action Port block, implements if-else logic to control subsystem execution. Logical operands should be given to input port and the output should be connected to action port of If Action Subsystem block.

The RMS block computes the true root mean square (RMS) value of the input signal and the value is calculated over a running average window of one cycle of the specified fundamental frequency. The initial RMS value is assumed to be zero.

At first, the if else block is fed with two input values one of which is the RMS value of sine wave that is 0.707 and the RMS value of any disturbance obtained for a duration of to 700 msec is given as the second input. The blocks mentioned above are interconnected in such a manner that they perform continuous, iterative looping thus comparing the reference RMS value with the input values continuously.

At the end of this iterative comparison the disturbances are classified based on their RMS values and the RMS value of the disturbance occurring in the system will be displayed in the display unit. The Display block shows the value of its input and the display format can be short, long, short_e , long_e or bank. The SIMULINK model is as shown in fig 1

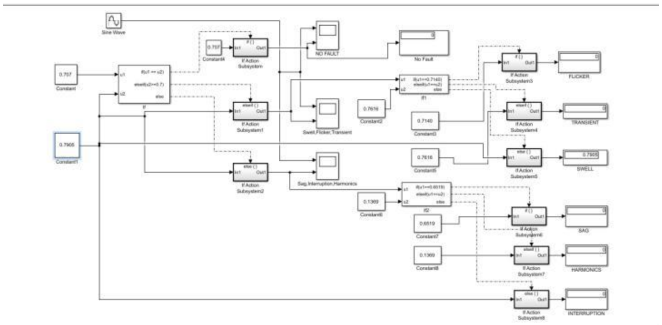

Figure 1. Model for classification of PQ disturbances using RMS values

VII. RESULTS

The resulting waveforms of the PQ disturbances obtained by using numerical modeled equations in MATLAB/SIMULINK are shown in below. The disturbances are modeled for duration of 500 to 700ms

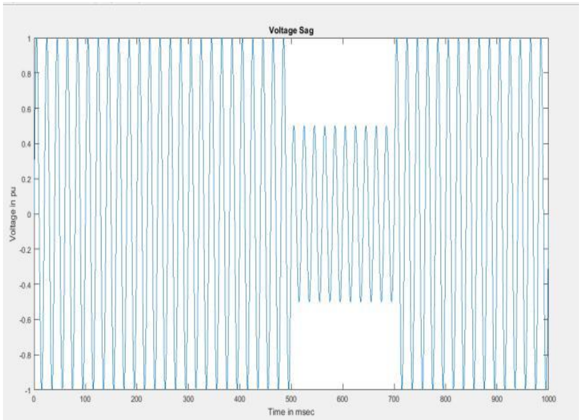

Figure 2. Voltage Sag

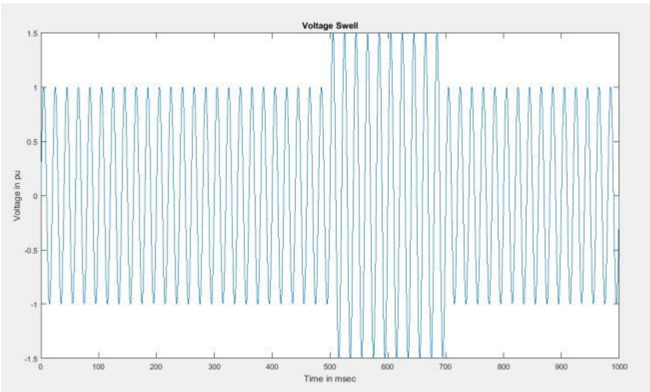

Figure 3. Voltage Swell

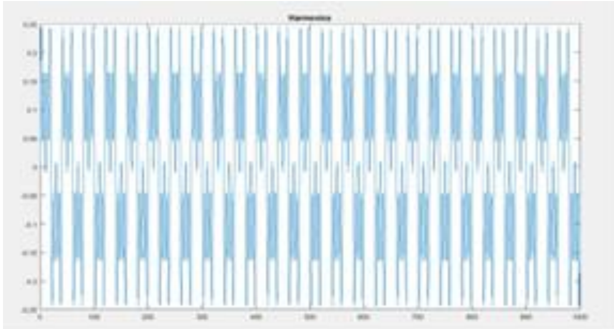

Figure 4. Harmonics

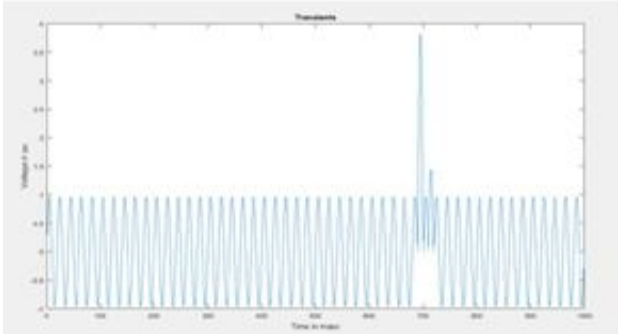

Figure 5. Transient

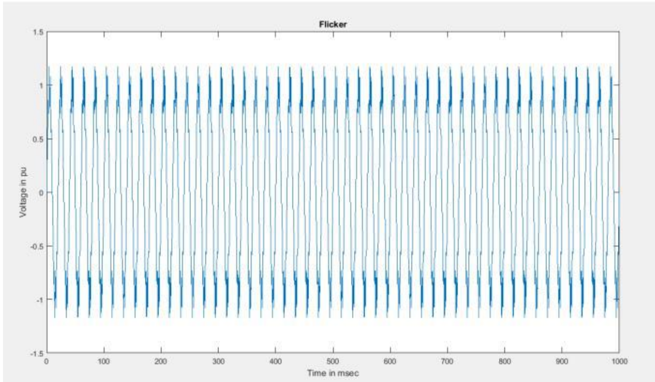

Figure 6. Flicker

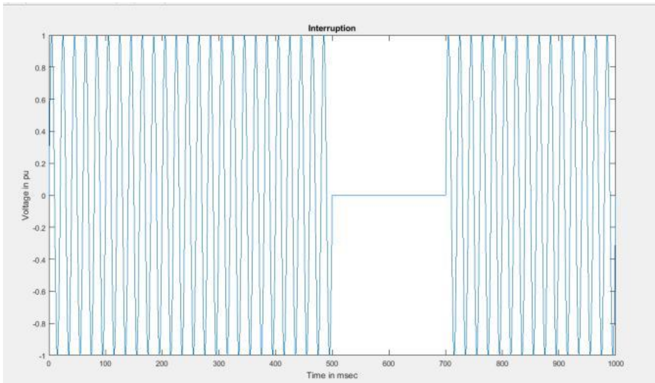

Figure 7. Interruption

VIII. CONCLUSION

Due to increasing use of sensitive electronic equipment in almost all applications, the necessity of analyzing and detecting the various Power Quality disturbances has gained more importance.

Faults occurring in transmission line due to natural calamities like lightning, felling of trees, nesting of large birds etc introduce certain PQ disturbances like interruption, voltage flicker, etc. Faults in distribution systems are caused due to sudden switching on large loads, continuous opening and closing of circuit breaker contacts, etc.

These PQ disturbances are uncertain and can occur anytime at any location in the power grid and can lead to severe damage to equipment and loss of data. Therefore, it is important to use different methods for analyzing and detecting the disturbances based on which corresponding mitigation techniques can be applied. For better accuracy in detection of PQ disturbances other techniques like s-transform and wavelet transform can be used

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