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GENERATION OF SINGLE AND MULTIPLE POWER QUALITY DISTURBANCES USING MATLAB/SIMULINK

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Abstract

Due to increase in non-linear loads and sensitive equipments at distribution end, power quality (PQ) of the power signal is distorted. Monitoring of the power quality is essential because it is the primary step for the mitigation of PQ disturbance to save the electrical system. In this paper generation method of different types of PQ disturbances are presented. Parametric equations and Simulink model are given for disturbance generation. Single and multiple power quality disturbances like sag, swell, harmonics, interruption and sag with harmonics are presented. All this work has been carried out in MATLAB/Simulink.

Keywords:

Power Quality;
Disturbance;
Generation;
Simulation model;

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1. Introduction

The electrical power system is a very complex network. Electrical power system contains three main parts, i.e. generation, transmission and distribution of electricity. The generating units generate the electricity and the generated electricity is transported at high voltage through the transmission lines as the generating units are away from the load centers. After that the voltage is distributed to the industrial, commercial and domestic customers at different voltage levels.

The term power quality (PQ) has become the main concern in the field of electric power system engineering. With the increasing awareness of the customers about the quality of power and its consequences on the sensitive equipments, utilities also try to maintain the quality of the power. Power quality is defined as a fixed amplitude, frequency and phase of the voltage or current signal. Any deviation from these parameters is called distorted power quality or poor power quality.

At the distribution level, different customers have different kind of loads which affect the quality of power and generate disturbances like sag, swell, harmonics, transients, notch, interruption etc. and combination of these disturbances. The PQ disturbances are results of heavy load switching, use of power electronic devices, non-linear loads and line faults [1]. These PQ disturbances are responsible for misoperation or damage of sensitive equipments like computers, workstations, programmable logic controller (PLC), microprocessor based instruments, adjustable speed drives etc. [2]. To reduce such types of ill effects, the quality of power should be maintained for smooth operation of instruments.

Now, the demand of electric power is growing and it is difficult to meet the power demand. For increasing demand, there is need to enhance the generation and transmission facilities, which is a costlier approach as it needs a huge capital cost. With the global concern of the environmental issues, more stress on green and clean energy has been given. For this, renewable energy resources like wind, solar, fuel cell etc.

are used with the grid to fulfill the power demand. But the renewable resources are affected by weather conditions and cause power quality problems.

From past three decades, a lot of work has been carried out in the field of power quality. In this duration, mathematical models, Simulink models, application of soft computing and artificial intelligence techniques are widely used.

For the power quality analysis, detection and classification of the disturbances is very important. For this purpose, the different power quality disturbances are recorded and later used for the analysis purpose. So, the first step in PQ analysis is generation of disturbance signal. In this paper, different power quality disturbances are generated using Simulink model. The PQ disturbances are generated as per the definition and parameters defined by IEEE 1159 [3] and IEC 61000 standard [4]. Table 1 classifies different PQ disturbances.

Table 1.Power Quality disturbances[3,4]

Name of Disturbance	Category	Duration	Magnitude
Short Duration Sag	Instantaneous Momentary Temporary	0.5- 30 cycle 30cycle-3sec 3sec – 1 min	0.1pu-0.9 pu 0.1pu-0.9 pu 0.1pu-0.9 pu
Swell	Instantaneous Momentary Temporary	0.5- 30 cycle 30cycle-3sec 3sec – 1 min	1.1pu-1.8 pu 1.1pu-1.8 pu 1.1pu-1.8 pu
Interruption	Instantaneous Momentary	0.5- 3sec 3sec – 1 min	< 0.1pu < 0.1pu
Long duration Interruption,Sustained		> 1 min	0.0 pu
Under voltage		> 1 min	0.8 - 0.9 pu
Over voltage		> 1 min	1.1 - 1.2 pu
Transients (Impulsive)	Nanosecond Microsecond Millisecond	< 50 ns 50 ns -1 ms > 1 ms	
Transients (Oscillatory)	Low Frequency< 5 Khz Medium Frequency5 - 500 kHz High Frequency 0.5 - 5 MHz	03 – 50 ms 20 µs 5 µs	0 - 4 pu 0 - 8 pu 0 – 4 pu
Harmonics	0 – 100 harmonic		0-20 %

2. Power Quality Disturbances

Voltage Sag: Voltage sag is the most common type of disturbance occurring in power system. A sudden reduction in magnitude is called voltage sag or dip. Voltage sag is defined as reduction in current or voltage amplitude from 0.9p.u. to 0.1 p.u. Duration of voltage sag may be from half cycle to one minute. The main causes of voltage sag are switching on of heavy load, large induction motor starting or transformer energization. Different kinds of faults like line to ground, double line to ground etc. are also causes voltage sag.

Voltage Swell: Voltage swell is rise in voltage magnitude. It is defined as rise in current or voltage amplitude from 1.1 p.u. to 1.8 p.u. and remains from half cycle to one minute. The rise in magnitude is due to switching off heavy load, due to large capacitor bank or due to asymmetrical faults.

Over voltage and Under voltage: These disturbances are similar to voltage swell and voltage sag but the time duration is longer than one minute.

Transients: These are momentary disturbances which have very short time duration. These are mainly due to switching events or due to environmental effects. These are further classified as impulsive or oscillatory transients.

Interruption: Interruption is just complete loss of power. If the amplitude of voltage or current goes below 0.1 p.u., for half cycle to one minute duration, this is called interruption. Failure of control relay or protection technique, equipment failure or any other system fault can cause the interruption.

Voltage Notch: It is a steady state phenomenon. Notch is a periodic supply voltage which is caused by power electronic devices like converters, rectifiers or universal bridges. This happens due to current commutation from one phase to another.

Harmonics: Harmonics are distortion in sinusoidal frequency which is integral multiple of a fundamental signal frequency. Power electronics devices or non-linear loads are the main cause of harmonics.

Complex (Multiple) Power Quality Disturbances: These disturbances are generated by combining two or more disturbances like sag with harmonics, swell with harmonics, sag with transients, swell with transients etc.

3. Generation of PQ Disturbances

3.1 Parametric Equation

The power quality disturbances are generated by using mathematical (parametric) equations [5] or by using MATLAB/Simulink models [6]. The signals which are generated by parametric equations are in wide range and controlled easily using parameters. These equations give accurate wave shapes because there is no effect of load conditions so these are somewhat different to real life signals. Signals generated from Simulink models are closer to real life signals because these are modeled by practical situations. Different PQ disturbance generation equations are shown in Table 2.

Table2.Parametric equations used for signal generation [5]

PQ Disturbances	Parametric Equations	Parameters
Normal signal	$s(t) = sin(wt)$	$w = 2\pi * 50$
Voltage Sag	$s(t) = A_m\left(1-\alpha\left(u(t-t_1)-u(t-t_2)\right)\right)sin(wt)$	$0.1 \le \alpha \le 0.9$, $T \le t_2 - t_1 \le 9T$
Voltage Swell	$s(t) = A_m\left(1+\alpha\left(u(t-t_1)-u(t-t_2)\right)\right)sin(wt)$	$0.1 \le \alpha \le 0.9$, $T \le t_2 - t_1 \le 9T$
Harmonics	$s(t) = A_m(\alpha_1\, sin(wt) + \alpha_3\, sin(3wt) + \alpha_5\, sin(5wt))$	$\alpha_1 = 1, \alpha_3 = 0.2 - 0.02$, $\alpha_5 = 0.08 - 0.008$
Transient	$s(t) = A\left(1+\alpha\left(u(t-t_1)-u(t-t_2)\right)\right)sin(wt)$	$A = 5 - 10$, $0.05T \le t_2 - t_1 \le 0.06T$
Sag with Harmonics	$s(t) = A_m\left(1-\alpha\left(u(t-t_1)-u(t-t_2)\right)\right)(\alpha_1\, sin(wt) + \alpha_3\, sin(3wt) + \alpha_5\, sin(5wt))$	Sag and Harmonics
Swell with Harmonics	$s(t) = A_m\left(1+\alpha\left(u(t-t_1)-u(t-t_2)\right)\right)(\alpha_1\, sin(wt) + \alpha_3\, sin(3wt) + \alpha_5\, sin(5wt))$	Swell and Harmonics

3.2 Simulink Model

All the PQ disturbances are also simulated using simpower system toolbox in MATLAB/Simulink as shown in Figure1. In this model, a 25kV source with source impedance 8+j 0.5 has been used. Three buses, one transmission line with length 30 kmand a step down transformer are used for modeling the distribution system. Heavy load, non-linear load, capacitor bank and fault block are used with circuit breakers to generate different types of power quality disturbances with sampling frequency 10 kHz.

In figure 2, all the disturbances are shown from 2200 to 3800 samples. Each PQ disturbance start at 2520th sample and ends at 3420th sample.

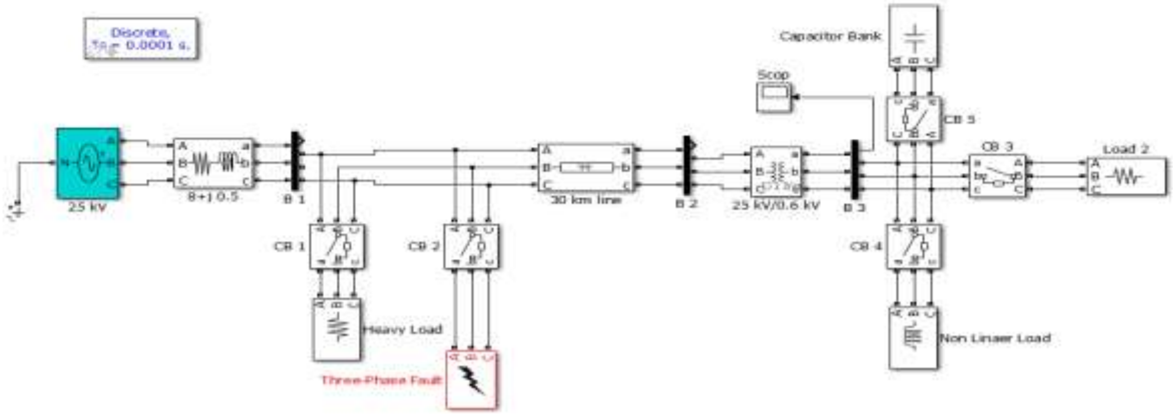
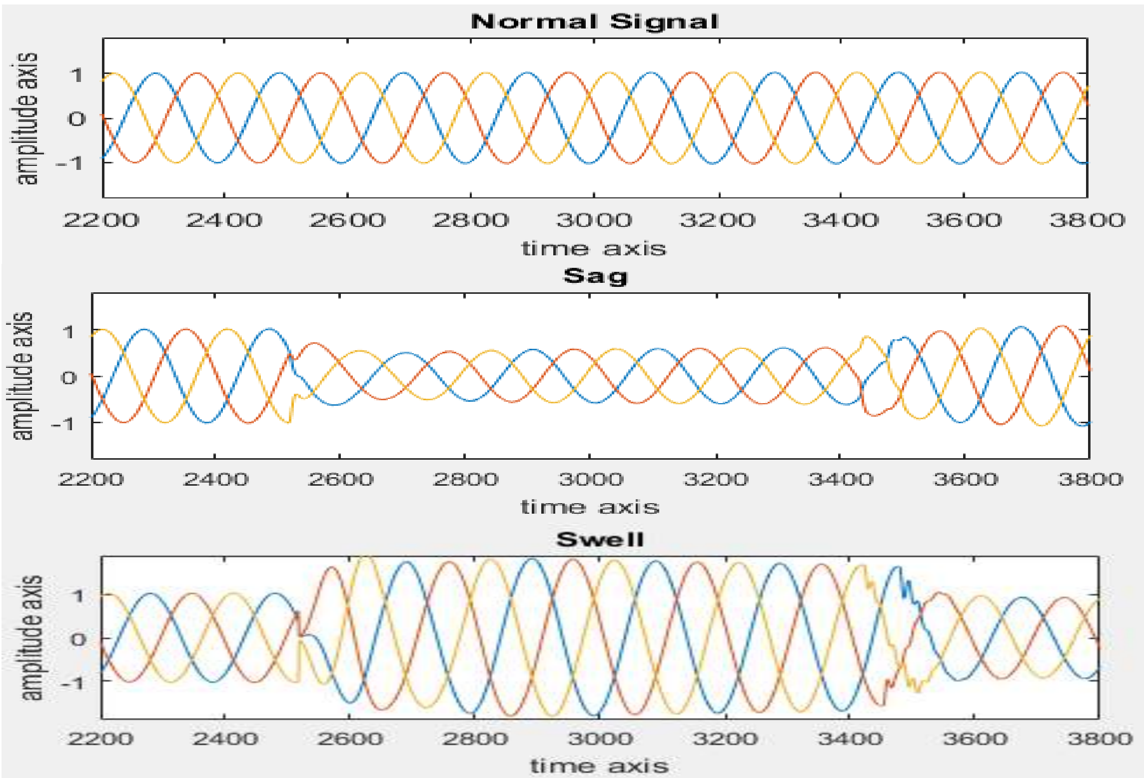


Figure 1. Simulink Model for PQ disturbance generation



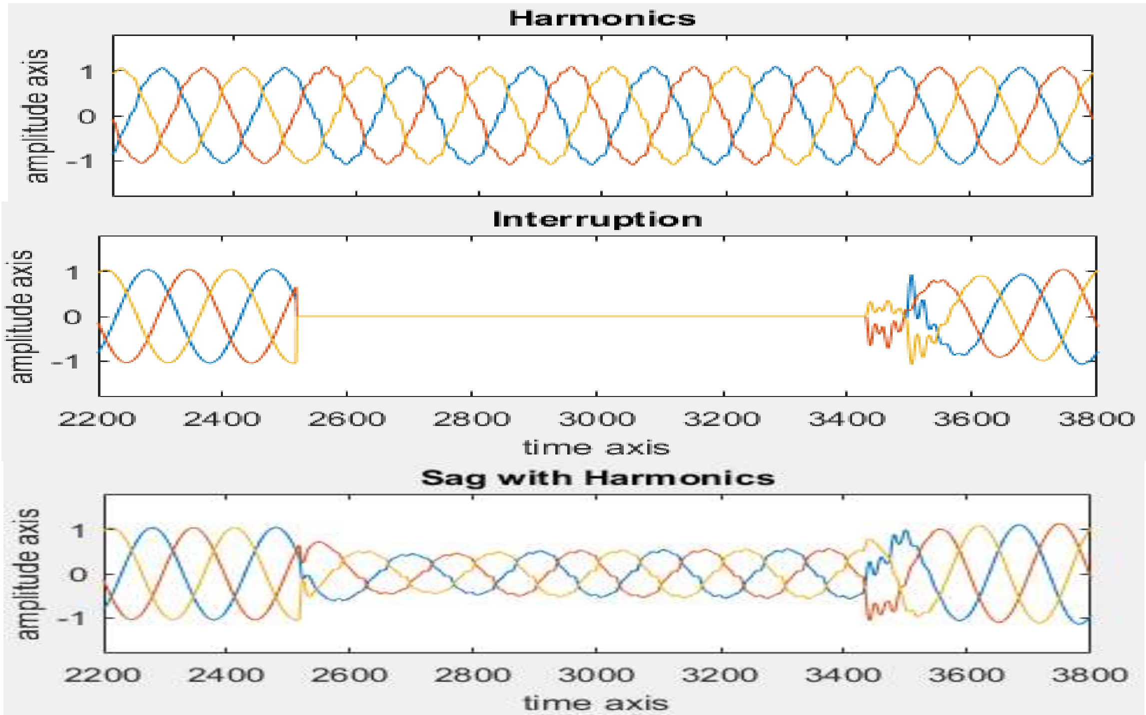


Figure 2. Waveform of different types of power quality disturbance

4. Conclusion

In the field of power quality monitoring, automatic detection and classification of disturbances is a necessary task. The work presented in this paper is helpful for the PQ disturbance analysis. Parametric equations and Simulink model are given in paper to generate different types of disturbances. These disturbances are created in MATLAB/Simulink.

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