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Power Quality Event Generation in MATLAB/Simulink Environment

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ABSTRACT: Power quality(PQ) is a measure issue in power system. This is the measure of system reliability, equipment security, and power availability in power system to the industry or end user. The power quality events/problems are caused at generation, transmission and distribution level due to generation to load mismatch, short circuit faults, equipment failure, etc. A paper introducing the generation of power quality events and classification of these events using radial basis function neural network. The power quality events are generated by developing an electric power distribution model using SimPowersystem in MATLAB/Simulink. This creates power quality events such as sag, swell, interruption, harmonics, transient, noises etc. and these signals are validated by the virtual signals generated by parametric equations.

KEYWORDS: Power Quality, Power Quality Events, Parametric Equations,

I.INTRODUCTION

Electrical power system is a network of electrical components that supply power to the customer such as industry, home, etc. Power system generally divided into the generators that supply the power, the transmission system that carries the power from generating center to load center and the distribution system that supply the power to nearby industries and homes. Majority of power system rely on alternating current (AC) power and this AC power increase complexity to move from the point of generation to point of consumption combined with variation in generation, load, weather and other factors. In order to transferring power from generation to consumption, an interconnection system is required which used to interconnect transmission line to neighbouring utilities or distribution system which used to transferring power to the costumer that may be connected through underground or overhead cables with equipments. Industrial, residential, commercial are the category of power system load which consist large number of sensitive equipments [1-3]. Power quality (PQ) is a set of electrical limitations that allow a piece of equipment to function in its proposed manner without significant loss of performances or life expectancy. In recent days PQ is very sensitive issue and Customers at different level (Industry, end user etc) have become very particular about power quality disturbances. Because of these disturbances the performances and efficiency of equipment decreases day by day. The use of electrical devices might be electrical motor, transformer, sensitive electronic equipments, communication equipments or failure or malfunctioning of power system exposed to one or more PQ disturbances [1-4].

PQ disturbances or PQ events generated in power system are sag, swell, interruption, transient, harmonics, voltage imbalance etc and they having very wide range of magnitude, time, frequency so to resolve these PQ events or action taken to mitigate these PQ events, firstly source and cause of disturbance must be specified and this requires monitoring, identification and classification of disturbances, in fact the most important issue is how to detect and classify PQ events. PQ signals are generated through various tools like PSCAD/EMTDC, ATP/EMTP and MATLAB/Simulink. Amongst all tools MATLAB/Simulink is very powerful to generate PQ events. This provide a real time data for the further analysis of power quality [7].

II.POWER QUALITY EVENTS

Power quality events are generally identify in the system by a set of waveforms, these waveforms either observed, calculated or generated by test equipment. Power quality events are characterized by extracting information from various disturbances individually and generally classify according to voltage magnitude variation frequency variation and transients as shown in Table 1[4].

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Table 1 Classification of Power Quality Events

Sr. No.	category	Typical duration	Typical magnitude
1.Short duration magnitude			
Sag	Instantaneous	0.5- 30 cycle	– 0.9 pu
	Momentary	30cycle-3sec	– 0.9 pu
	Temporary	3sec – 1 min	– 0.9 pu
Swell	Instantaneous	0.5 - 30 cycle	1.1-1.8 pu
	Momentary	30cycle-3sec	1.1-1.8 pu
	Temporary	3sec-1min	1.1-1.8 pu
Interruption	Instantaneous	0.5-3sec	<0.1 pu
	Momentary	3sec-1min	<0.1 pu
2. Long duration magnitude	Interruption, sustained		
	Overvoltage	>1min	0.0 pu
	Under voltage	>1min	0.8-0.9 pu
		>1min	1.1-1.2 pu
3. Transients			
Oscillatory Transients	Low frequency	0.3-50ms	0-4 pu
	Medium frequency	20μs	0-8 pu
	High frequency	5μs	0-4 pu
Impulsive Transients	Nanosecond	<50ns	
	Microsecond	50ns-1ms	
	Milisecond	>1ms	
4 Voltage imbalance		Steady state	0.5-2%
5. Waveform distortion	Harmonics	Steady state	0-20%
	Notching	Steady state	
	Noise	Steady state	0-1%
6. Voltage fluctuation		Intermediate	0.1-7%
7. Power frequency variation		<10s	

A. Sag(dip)

A sag is an event where the line rms voltage to between 0.1 p.u. and 0.9 p.u. for time duration of 0.5cycle to 1 min. In the power quality community the term sag is describe as a short duration voltage decrease. The IEC definition for this phenomenon is dip. This is the most common type of power quality event which is generally associated with a short circuit fault such as single line to ground(SLG),line to line(LL), line to line to ground(LLG),three phase(LLL) and three phase to ground(LLLG) faults. Increased load demand and transitional events like large motor starting is also cause of voltage sag [2-3].

B. Swell

A swell is reverse of the sag and it is define as an increase in line rms voltage to between 1.1 p.u. and 1.8 p.u. for the time duration of 0.5 cycle to 1 min. This is also associated with the short circuit faults but this is much less common than voltage sag. The swell can caused by SLG faults, this caused in non fault phase. The swell can also be caused by switching-off a heavy load and switching-on or energizing a heavy capacitor bank[1-3].

C. Interruption

Interruption is defined as reduction in supply voltage, or load current to a level of 0.1 p.u. or complete loss of supply voltage for a period of time not exceeding 1 min. Interruption can be caused by system faults, control and protection malfunction or system equipment failure[1][2].

D. Overvoltage and under voltage

An overvoltage (Long duration swell as defined by IEEE) is a increase in ac rms voltage greater than 1.1 p.u. for a duration longer than 1 min, typical values are 1,1 p.u. to 1.2 p.u. similarly an under voltage(long duration sag as defined by IEEE) is a decrease in ac rms voltage less than 0.9 p.u.for a duration longer than 1 min. typical values are

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between 0.8 p.u to 0.9 p.u. Overvoltage caused by the load switching(switching off a heavy load) and under voltage are the result of events that are the opposite of the events that cause overvoltage [3][4].

E. Transients/surge

A transient is an undesirable and momentary type of events which usually initiated by some type of switching event such as energizing of capacitor bank or electric motor. Transient are much less than full cycle oftentimes a full second or less, they come and go intermittently and may or may not impact on equipment.Transient are generally classified into two catogeries: oscillatory(caused by switching on/off a heavy load, capacitor bank energization) and impulsive(caused by lightning strokes) [1][2][4].

F. Voltage imbalance

Voltage imbalance or unbalance is defined as the deviation in the magnitude of negative sequence component to the magnitude of positive sequence component in phase of one or more of the phase or of the three phase supply. This expressed as percentage, Mathematically, the voltage imbalance is represented by equation 1 [1-2].

$$\%\ Imbalance = \frac{|V_{neg}|}{|V_{pos}|} \times 100 \qquad (1)$$

G. Harmonics

Harmonics are periodic sinusoidal distortion in supply voltage and load current having frequencies that are integral multiples of the fundamental supply frequency (50 Hz or 60 Hz) at which system is designed to operate. Harmonics are mainly caused by power electronics-based equipments such as rectifiers and inverters and static power conversion equipments in power system [1-3].

III. GENERATION OF PQ EVENTS

Analysis or diagnosis of PQ signals for detection of various events in power system is a major challenge and the first step towards PQ analysis or diagnosis is generation of PQ events. In this thesis an effort has been made to generate PQ signals using software controlled scheme and electrical power distribution system models in MATLAB/SIMULINK environment utilize various type of faults, switching devices and non linear loads [2][5].

SOFTWARE CONTROLLED SCHEME

A software controlled scheme is basically the parametric equation mode which is generated using software program in order to represent the artificial real time signal accurately. These artificial signals are possible to vary in wide range and in a controlled manner. The signal generated by controlling the parameters of the parametric equation as shown in table 2.

Table 2 Parametric equation model

Disturbance	Parametric Equation	Parameter
Pure sine wave	$v(t) = \sin(\omega t)$	$\omega = 2\pi * 50\ rad/sec$
Sag signal	$v(t) = [1 - \alpha(u(t - t_1) - u(t - t_2))]\sin(\omega t)$	$0.1 \le \alpha \le 0.9, \quad T \le t_2 - t_1 \le 9T$
Swell signal	$v(t) = [1 + \alpha(u(t - t_1) - u(t - t_2))]\sin(\omega t)$	$0.1 \le \alpha \le 0.9, \quad T \le t_2 - t_1 \le 9T$
Interruption	$v(t) = [1 - \alpha(u(t - t_1) - u(t - t_2))]\sin(\omega t)$	$0.1 \le \alpha \le 0.9, \quad T \le t_2 - t_1 \le 9T$
Harmonics	$v(t) = (\alpha_1 \sin(\omega t) + \alpha_2 \sin(3\omega t) + \alpha_3 \sin(5\omega t) + \alpha_4 \sin(7\omega t))$	α_1=1, α_2=0.6-0.06, α_3=0.2-0.02, α_4=0.08-0.008
Transient	$v(t) = A[1 + \alpha(u(t - t_1) - u(t - t_2))]\sin(\omega t)$	$A = 5 - 10$, $0.05\,T \le t_2 - t_1 \le 0.06T$
Noise	$v(t) = \sin(\omega t) + A(randn(\text{size}(\omega t)))$	A=0.1

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REAL TIME ELECTRICAL DISTRIBUTION MODEL

Real time electrical distribution model is designed in MATLAB/SIMULINK by using simpower toolbox. This model represent a three phase distribution network which consist 50MVA, 25KV generator with source impedance of Z_s , Z_s= 5+j0.314, connected with 20KM distribution line, a delta/star step down transformer with normal RL load of 1MVA as shown in one line diagram Figure 1. In Figure 1 there are three buses which are connected to get voltage and current values when different type of loads such as heavy load, non linear load and different type of faults like SLG, LL, LLG, LLL, LLLG are connected [2][6][7].

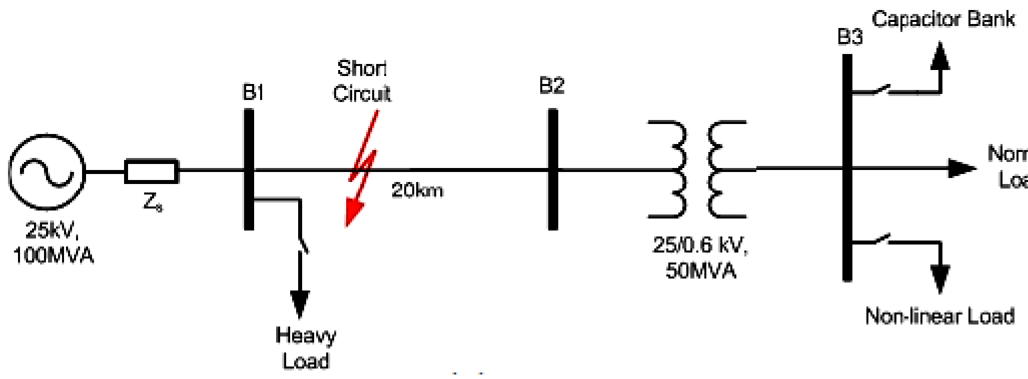

Fig 1. One line diagram of the electrical power distribution model

IV.SIMULATION RESULT

For simulation purpose electrical power distribution model is designed and one line diagram of the distribution model is shown in Figure 1 using SimPowerSystem Simulink model by applying various type of loads and faults like short circuit fault, heavy load, normal load, non linear load, capacitor bank switching off/on. The electrical power distribution model consist 25 kV voltage source and 50 Hz fundamental frequency. Each power quality events simulate for 10 cycles and a sampling frequency of 10 kHz. When single line to ground fault is applied at bus 1 then, voltage sag and interruption cause on faulty phase and voltage swell caused on healthy phase. Voltage sag swell and interruption also caused due to switching on a heavy load. When capacitor bank is applied to the Simulink model, an oscillatory transient is produced in supply voltage due to the operation of a capacitor bank. The frequency of the oscillatory transient depends upon the size of capacitor bank [6-7].

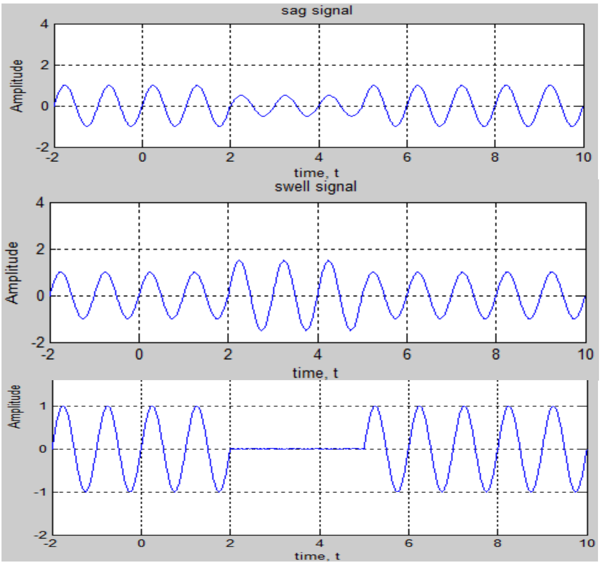

Fig 2. Sag, swell and interruption events by parametric model

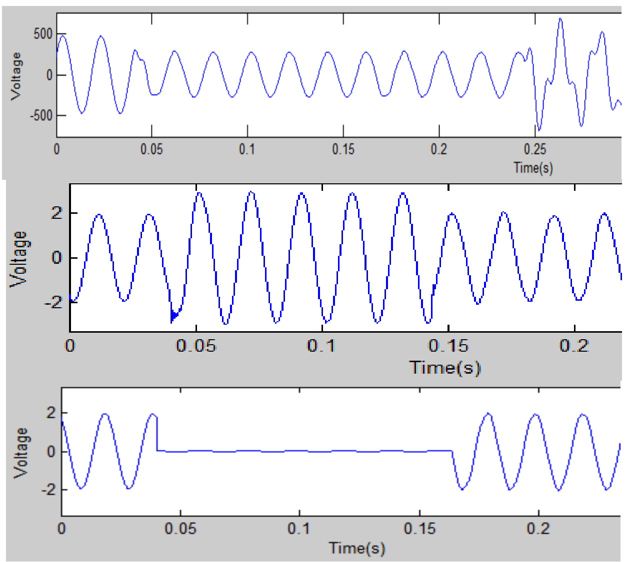

Fig 3. Sag, Swell, and interruption by electrical distribution model

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Fig 2 shows the artificial generated signals, which resembles the signal generated by the electrical power distribution model. There are various advantages of the parametric equation model signals. This is very flexible to modify and advantageous according to application point of view. Its range of variation is very similar to the actual PQ signals

V. CONCLUSION

PQ events can be created in MATLAB environment with actual electrical power distribution model and using parametric equation model or mathematical model. The signals produced by both models are quite similar and very near about the actual PQ signal. These models are very useful to produce PQ events which are further taken in application for the classification or analysis of PQ signals in industry or power system.

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