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Generation of Mathematical Models for various PQ Signals using MATLAB

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ABSTRACT
Analysis of PQ (Power Quality) signals for detecting PQ disturbances is one of the major challenging techniques are being explored by many researchers. It becomes important to understand the causes of electronic equipment being damaged due to power disturbances, for this purpose there is need for reliable algorithm that can work for PQ analysis. First step towards PQ analysis is generation of PQ disturbances. In this work, mathematical models for PQ disturbances are developed. The software reference models for various PQ signals are generated and their parameters are studied.
Keywords – Power Quality, PQ disturbances, mathematical models, simulation, Matlab

I. INTRODUCTION

In recent years, Power Quality (PQ) is a problem makes interest to both electric utilities & customers. The disturbance in power quality is primarily due to increase in using switching devices, unbalanced power system, nonlinear loads, computers and data processing. PQ disturbances such as sag, swell, interruption, harmonics, noise, flicker, transients are most common types of issues that occur in power line. Electronic equipment connected to power line get damaged due to the disturbances present in PQ signal for short duration occur randomly. Thus it is necessary to estimate the presence of disturbances and parameter related to the same. In order to perform the process of analysis of PQ signals, it is required to understand the basic properties of Power Quality events and their parameters. In these section PQ disturbances like sag, swell, interruption, harmonics, noise, flicker, transients are studied and their parameters are summarized.

II. GRAPHICAL REPRESENTATION OF PQ SIGNALS AND THEIR PARAMETERS

Power Quality signals such as sag, swell, interruption, harmonics, transients, flicker, noise have their basic parameters related to the amplitude and frequency as defined by standards i.e. 220V and 50HZ signal. Deviation of amplitude and frequency from their normal value leads disturbances in power signal. Frequency variation in power signal leads harmonics and variation in amplitude introduces sag, swell, interruption, transients. Figure 1 Shows different types of disturbances in power signal.

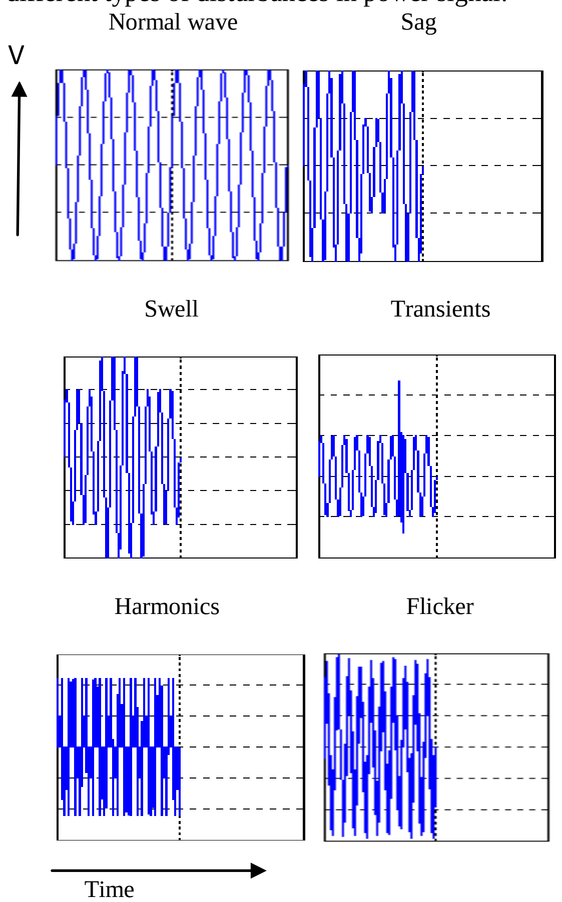

Fig.1 Graphical representation of PQ disturbances

From Figure 1 we can define PQ disturbances as follows: Voltage variation: increase or decrease in the amplitude of voltage caused by variation in load. Voltage variation can be named as sag or swell.

Voltage sag: sudden decrease in rms voltage. The decreased value is between 0.9 p.u. and 1 p.u. and duration between 10ms and 1min.
Voltage swells: sudden increase in rms voltage. The increased value is between 1.1 p.u. and 1.8 p.u. with maximum duration of several milliseconds.
Transients: sudden change in voltage amplitude with very small duration.
Flicker: intensity of nuisance caused by flicker.
Harmonics: sinusoidal voltage with a frequency which is a multiple of fundamental frequency and caused by nonlinear loads.

III. DEVELOPMENT OF MATHEMATICAL MODEL OF PQ SIGNALS

Analysis of PQ disturbances requires software reference model of these signals and these signals are generated through the software program written in software called Matlab. Mathematical equations are used to generate artificial signals. These artificial signals need to have all properties as that of real time signals so that, the performance of the signals can be appreciated as real-time analysis done. The development of software programs to generate PQ disturbances are created by mathematical equations are given in table 1

TABLE 1

Mathematical Models of PQ Signals

PQ disturbances	Model	Parameters
Normal	x = amp*sin(2*pi*f/Fs*t)	amp=1
Sag	v=(1-A*(u(t-t1)-u(t t2))).*sin(2*pi*f/Fs*t)	A=0.5 t1=500; t2=700
Swell	z=(1+A*(u(t-t1)-u(t-t2))).*sin(2*pi*f/Fs*t)	A=0.5; t1=300; t2=700
Interruption	k=(1-A*(u(t-t1)-u(t-t2))).*sin(2*pi*f/Fs*t)	A=1; t1=400; t2=700
Harmonics	x1=amp*sin(3*2*pi*f/Fs *t) x2=amp*sin(5*2*pi*f/Fs *t) y=x+x1+x2	
Notch	n= x + awgn(x,25)	
Transients	r=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))	A1=10; t1=690; t2=700 ;A2=5;t3 =710; t4=720
Flicker	f= x + rand([1 length(x)])	

The events like sag, swell, transients are modeled using the product of step functions and sinusoidal wave. Step function is defined for the period between t1 and t2. Amplitudes of the events can be controlled by using amplitude of step function is defined by A as shown in table 1. In PQ signals the harmonics disturbances have more than three frequency components and odd multiple of fundamental frequency, odd harmonics have voltage variation and thus fundamental frequency get affected.

3.1 Block diagram for signal generation using mathematical models

As discussed above, the mathematical equations can be generated by using programs written in software named MATLAB. This program is obtained by simulating the mathematical equations in MATLAB. The variation in disturbances can be controlled by controlling the parameters of the signals as shown in table 1. Graphical representation helps verification of PQ disturbances. The block diagram for generating PQ signals in MATLAB is shown in Figure 2

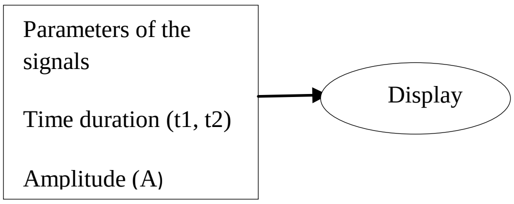

Fig. 2 block diagram for generating PQ signals

3.2 Flow chart for generating PQ disturbances using MATLAB

Figure 3 shows flow chart for generating PQ disturbances. PQ signals are generated with 50 Hz with sampling frequency of 1KSPS. For various PQ signals 400,000 samples are generated. Before generation of the signals, the normal PQ signal is normalised hence the amplitude of the signal is 1p.u.(per unit).

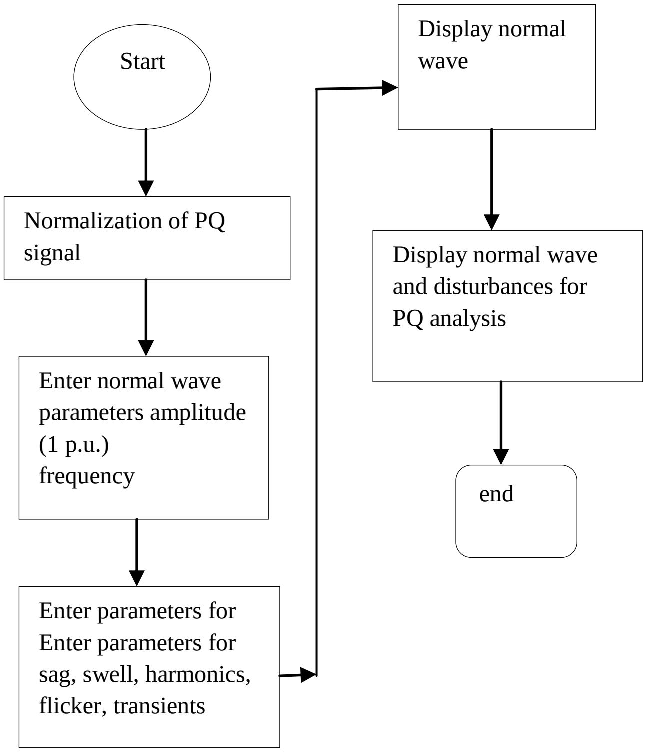

Fig. 3 flow chart of PQ signal generation

IV. SIMULATION RESULTS OF PQ SIGNALS USING MATLAB

Software programs are written using the mathematical equations of the PQ disturbances. These mathematical equations are simulated in MATLAB. The result of the programs are presented here. The normalised sine wave having 50 Hz frequency with disturbances like sag, swell, interruption, harmonics, transients, flicker, noise are generated as shown in Figure 4(a-h).

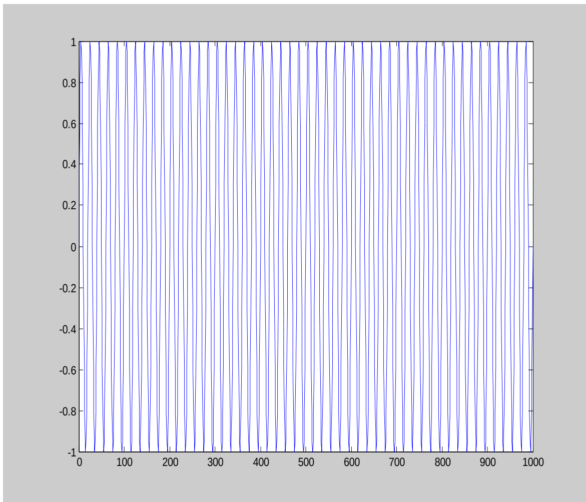

Fig. 4(a) sine wave

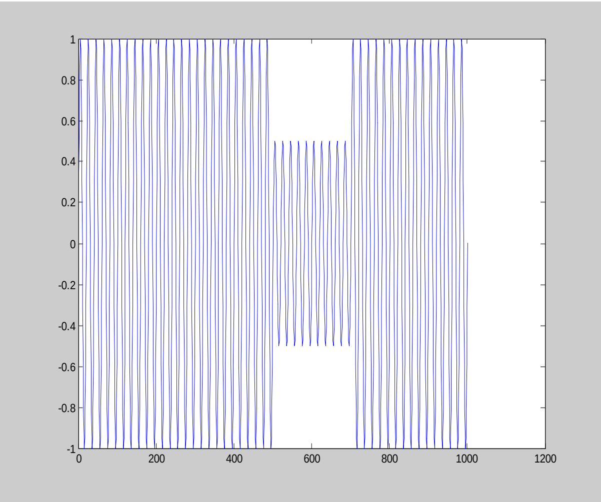

Fig. 4(b) sag wave

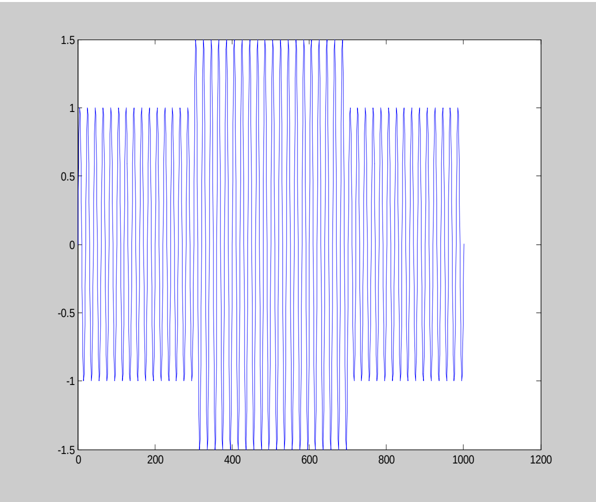

Fig. 4(c) swell wave

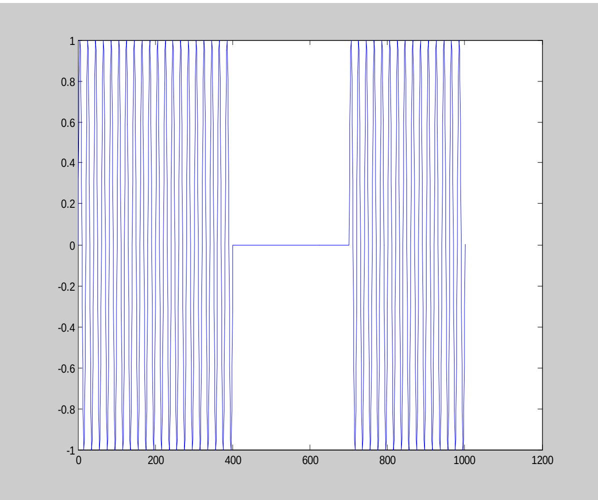

Fig. 4(d) interruption

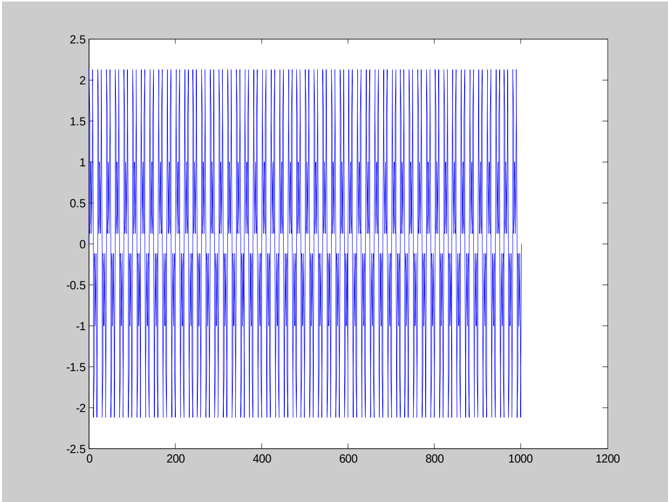

Fig. 4(e) harmonics

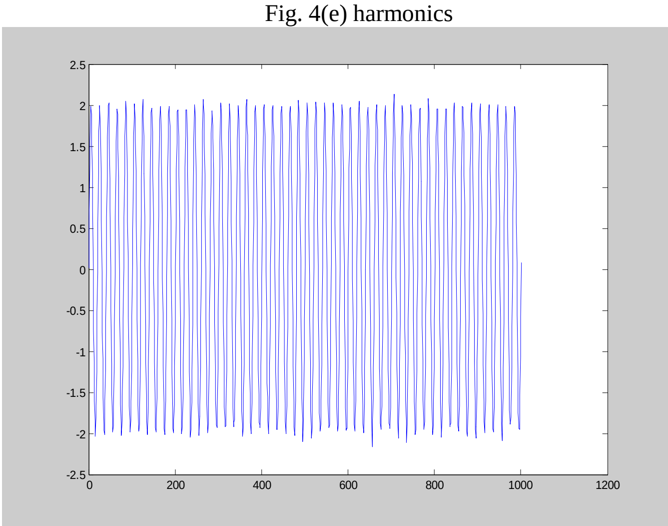

Fig. 4(f) noise

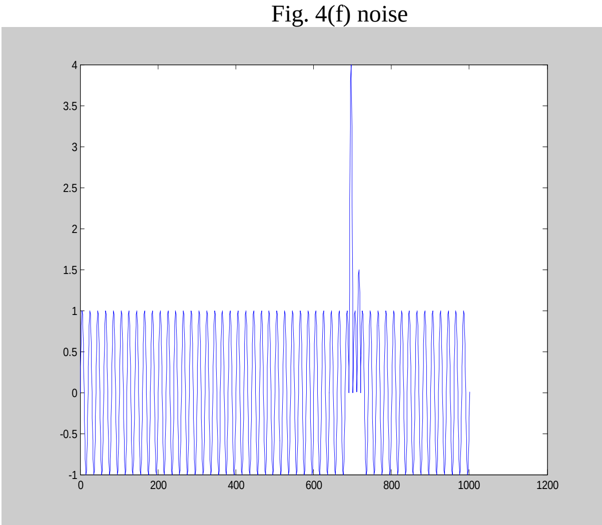

Fig. 4(g) transients

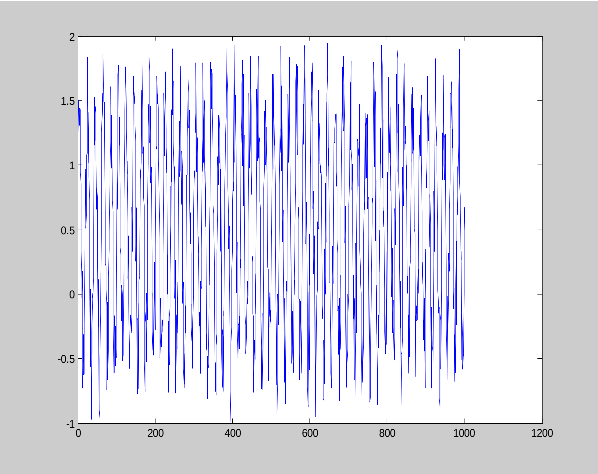

Fig. 4(h) flicker

PQ disturbances are generated as shown in Figure 4(a-h). The properties of these signals are given in table 2.as shown below.

TABLE
estimated parameters of PQ signals

PQ disturbances	**Duration(sec) & Amplitude(p.u.)**
Normal	t=1000 amp=1 simulation for 10 cycles
Sag	t=200 amp=0.5 for 2 cycles
Swell	t=300 amp=1.5 for 4 cycles
Interruption	t=300 amp=0
Harmonics	
Notch	
Transients	t=20 max. amp=3.99
Flicker	

V. CONCLUSION

In this paper, mathematical models of power quality signal is generated and simulated in software called MATLAB. The mathematical models for power quality disturbances like sag, swell, interruption, harmonics, transients, noise and flicker are being developed using software. The parameters in terms of duration of occurrence and amplitude (p.u.) of the PQ disturbances are being studied in the form of tables.

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