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Generation of Power Quality Disturbances using MATLAB Simulink

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Abstract
Proper operation of a power system depends upon the quality of power supplied to consumers. To have preventive measures and to design power quality monitoring equipment, it is necessary to have proper information about the signals. To design relevant equipment and compensation devices, the signals are to be generated. The objective of this paper is to generate power quality disturbances in MATLAB Simulink environment. The disturbances considered for analysis are voltage sag, swell, interruption, harmonics and transient. The aim of this paper is to present different signals which can be used for signal processing and to extract more information from the signals about the disturbance. The generated disturbance signals can be used to observe the effect of preventive action by analyzing the extent of disturbance reduction. The Simulink models can be used for modeling of corrective devices.

Introduction

Electrical power is supplied must be free of any disturbances. Power quality is defined as a set of boundaries that allows electrical systems to function in their intended manner without significant loss of performance [1,5]. Power quality disturbance, also termed as power quality problem is defined as, “Any power problem manifested in voltage, current, or frequency deviations that results in failure or mis operation of customer equipment” [2,7]. Power quality disturbances are followed by faults occurring on a power system. Any deviation of voltage or current from the ideal is a power quality disturbance [3,6]. In general, poor power quality may result into increased power losses, abnormal and undesirable behaviour of equipment, and interference with nearby communication lines. [4,9]. Power quality events have become an outstanding and troublesome issue because of the increased utilization of nonlinear power electronic loads and sensitive computer controlled and microprocessor-based equipment [5,8]. By using mathematical equations for each power quality disturbance, waveforms are generated in MATLAB.

Definitions of Power Quality Disturbances

Voltage sag is a decrease in rms voltage to between 0.1 pu and 0.9 pu for durations from 0.5 cycles to 1 minute [6,10]. Voltage sag, shown in fig.1 is simulated in MATLAB and indicates a sudden decrease in voltage.

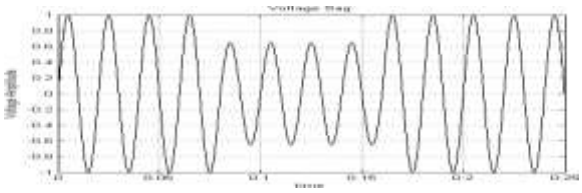


Fig.1 Voltage signal with sag disturbance

Voltage swell is an increase in rms voltage above 1.1 pu for durations from 0.5 cycle to 1 min [6,10]. Typical magnitudes are between 1.1 pu to 1.8 pu. Voltage swell, shown in fig 2, is simulated in MATLAB and indicates a sudden increase in voltage.

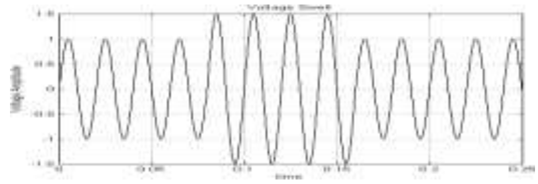


Fig. 2 Voltage signal with swell

An interruption occurs when the supply voltage or load current decreases to less than 0.1 pu for a period of time not exceeding 1 min [6]. Voltage interruption, shown in fig.3, is simulated in MATLAB and indicates a complete loss of voltage for a short duration.

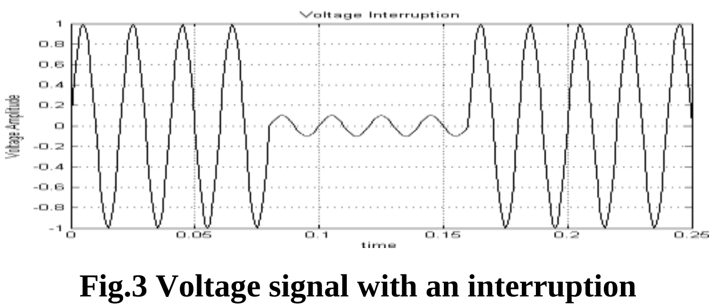


Fig.3 Voltage signal with an interruption

A transient can be a unidirectional impulse of either polarity or a damped oscillatory wave with the first peak occurring in either polarity [6,11]. Transient, shown in fig.4, is simulated in MATLAB and indicates a very short duration voltage spike in voltage waveform.

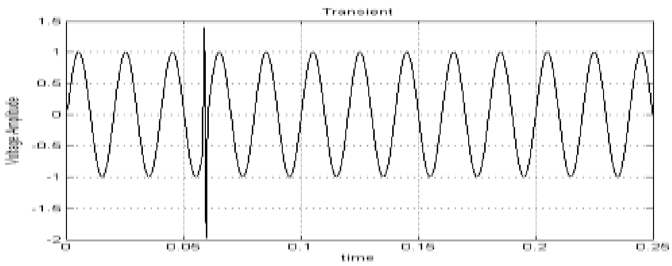


Fig.4: Voltage signal with a transient

Harmonics are sinusoidal voltages or currents having frequencies that are integer multiples of the fundamental frequency [6,12]. Voltage signal with harmonics, shown in figure 5, is simulated in MATLAB.

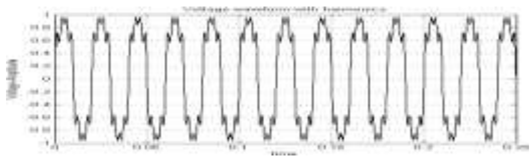


Fig.5 Voltage waveform with harmonics

Power Quality Disturbance Signal Generation using MATLAB Simulink Environment

All the short-duration voltage variation signals represent a disturbance or variations on comparison with a pure sine signal. System specifications for the Simulink models are given in table 1 From the models, disturbance signals of sag, swell, interruption harmonics and transient are generated.

Table 1 System specifications

Type	Rating
Synchronous generator of nominal power	4200MVA
Line to line voltage	13.8kV
number of pole pairs	2

Series RLC load with an active power	200MW
Length of distributed line	100 Km
Fault resistance	0.0005Ω
Ground resistance	0.001Ω
Load resistance	3Ω
Load inductance	50mH

Signal generation can also be carried out in Simulink environment of MATLAB. Few different models are developed based upon initialization of the conditions of the occurrence of disturbances. In all the models a synchronous generator of 35 MVA, 13.8 KV connected to a load drawing an active power of 200MW feeding a 100 km distributed line is considered for generation of signals.

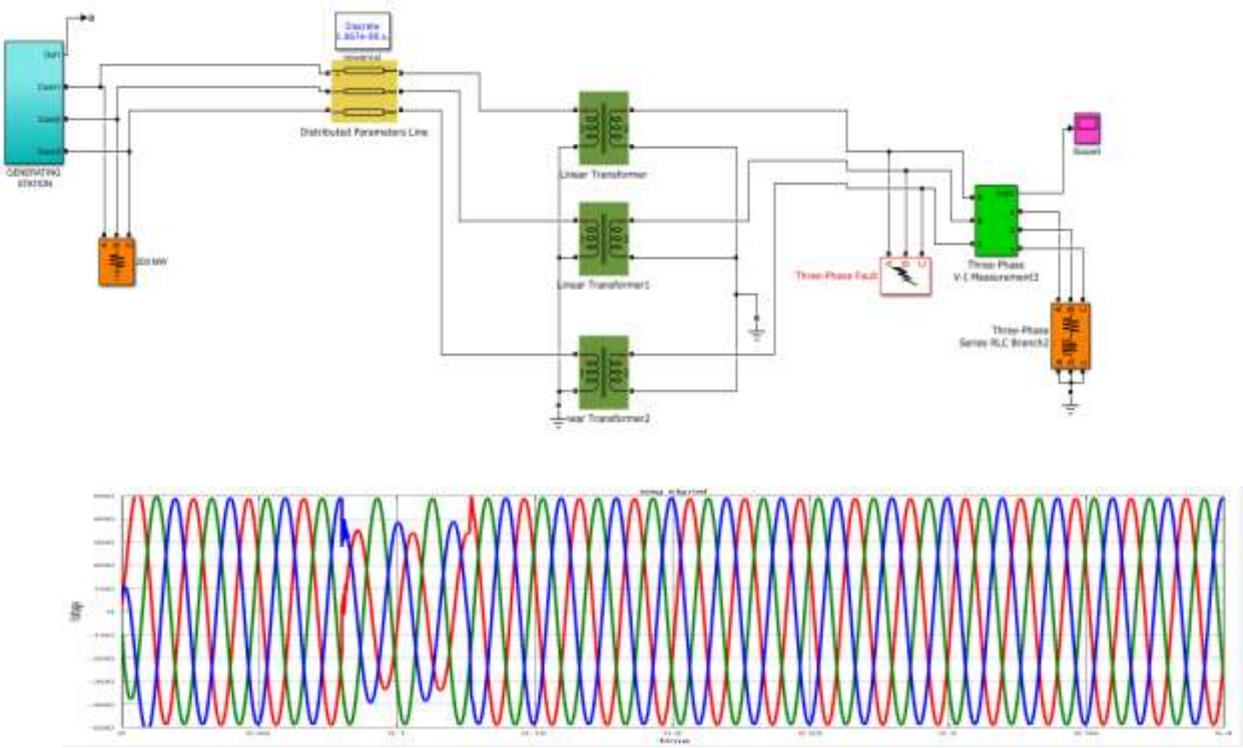


Fig.6 (a) Simulink model for generation of voltage sag (b) Waveform of sag

For sag generation, RL load and linear transformer are connected and line to ground fault is initiated to observe decrease in voltage for a short duration. Due to fault, a decrease in voltage of 0.6765 and 0.7728 times of peak voltage is observed in R and B phases for duration of 0.04 seconds as depicted in fig.6.

For swell generation, a three-phase source and parallel RLC branch are connected. Due to load changes and additional sources connected to the system, an increase in voltage is observed in all the three phases for duration of 0.064 seconds as shown in fig.7. In phases R, Y and B voltage increases from 1.35 to 1.428, 1.439 and 1.116 to 1.446 times of peak voltage respectively.

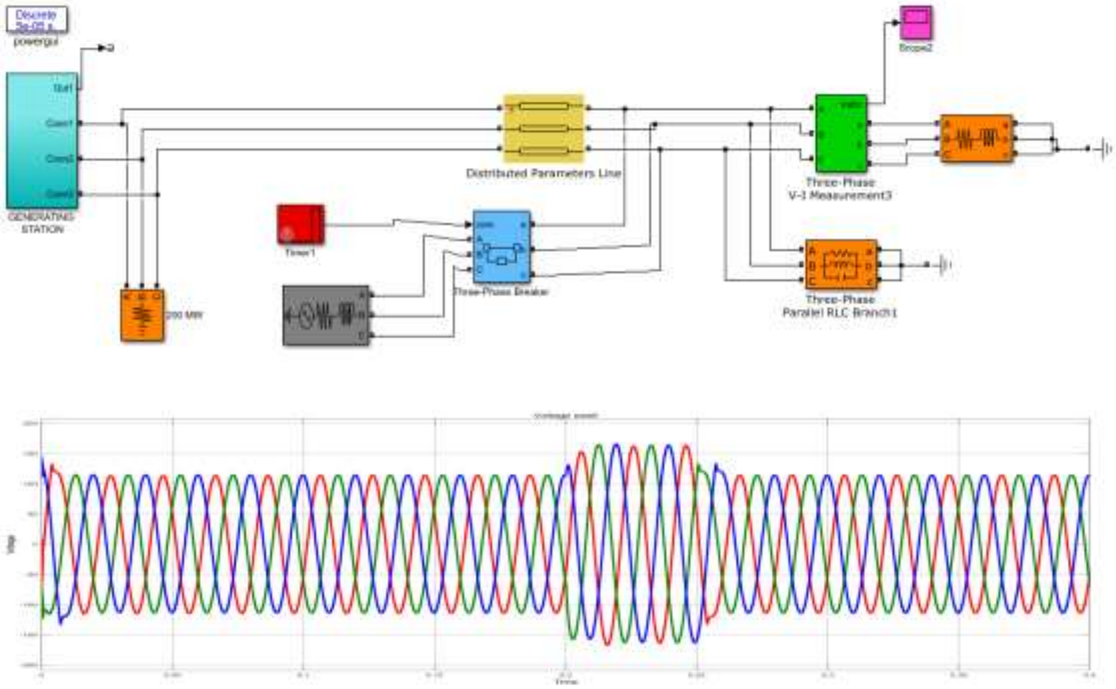
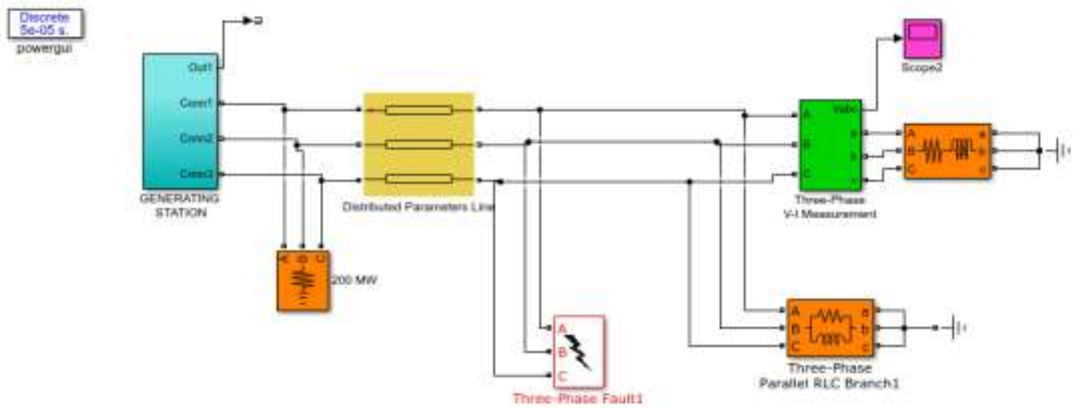


Fig.7 a) Simulink model for generation of voltage swell b) Waveform of swell

For an interruption generation, fault involving three phases without ground is initiated to observe complete loss of voltage for 0.066 seconds. Voltage in all the three phases has reduced to zero for certain duration as shown in fig.8.



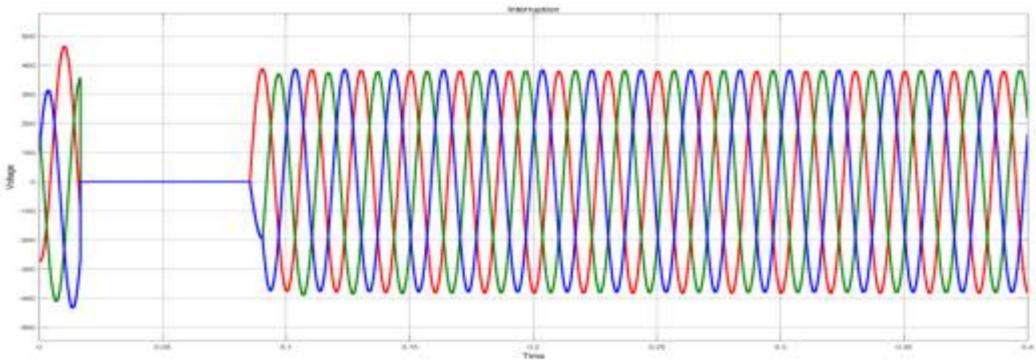


Fig.8(a) Simulink model for generation of voltage interruption (b) Waveform of interruption

For harmonics generation, different power electronic device based bridges, which exhibits nonlinear characteristics, are connected in the system as load. The voltage waveform will be distorted due to addition of frequency components resulting in an overshoot of 120.74%, 2.739% and 30.717% in R, Y and B phases respectively as shown in fig.9.

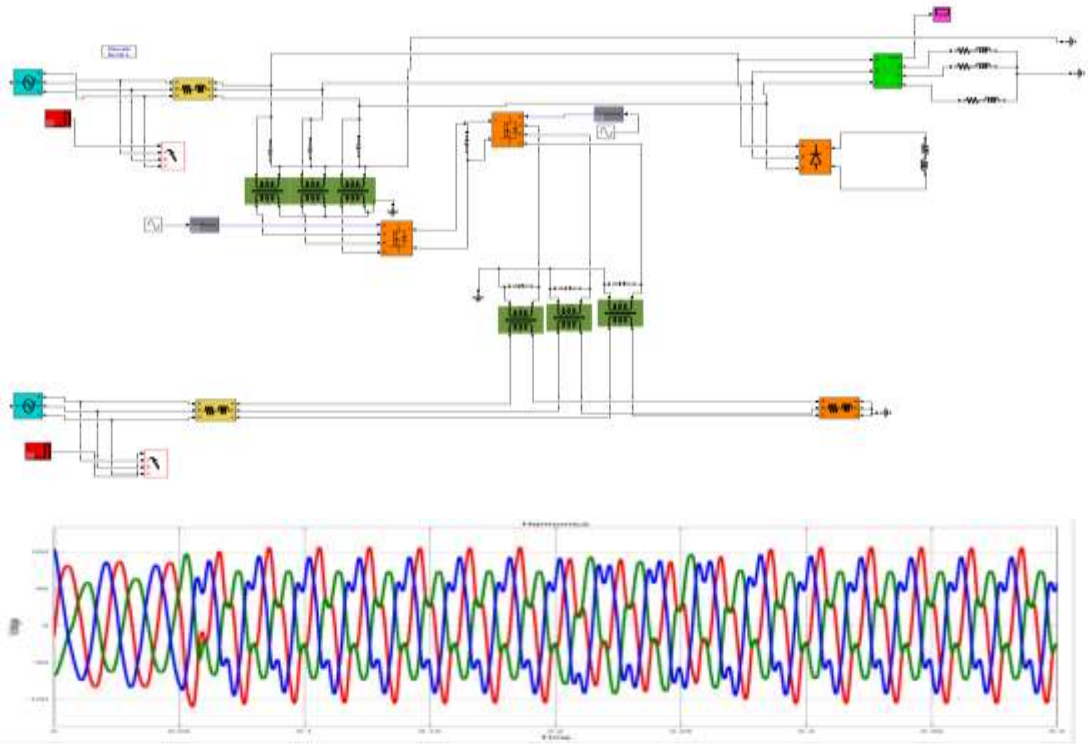


Figure 9 (a) Simulink model for generation of harmonics (b) Waveform of harmonics

For transient signal generation, by changing the capacitance of the capacitive load, severity of oscillatory transient can be changed. It can be observed from that predominant oscillations are observed in R phase out of prevailing undesirable transients in all the three phases which cannot be neglected. The magnitude of voltage in R phase oscillates from 1.93.% at 0.004 seconds, 1.84% at 0.006 seconds and 1.59% at 0.025 seconds and reaches the steady state of sine wave after all the oscillations get decayed. If the transient is in the form of an impulse will be momentary in nature.

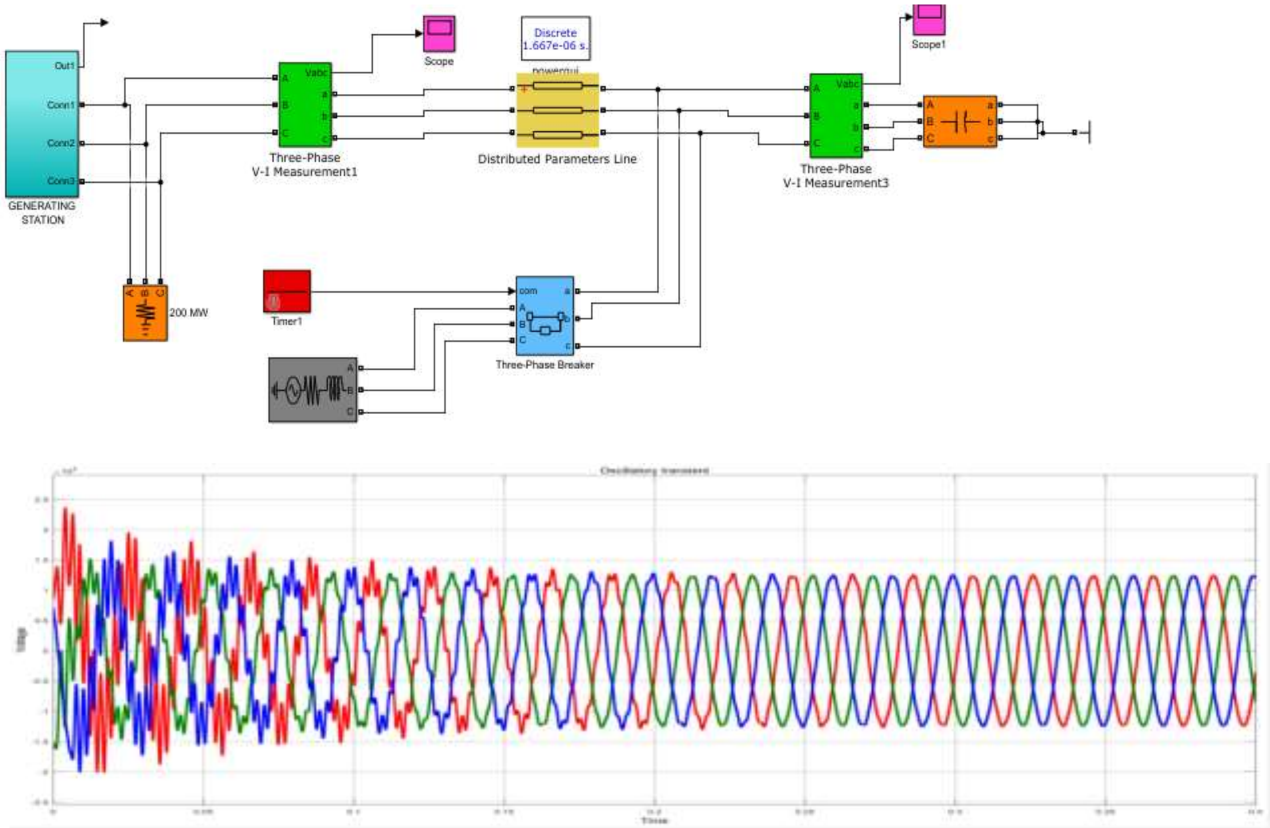


Figure 10 a) Simulink model for generation of oscillatory transient b) Waveform of transient

Conclusion

In order to implement mathematical transforms or to connect different preventive devices for correction, the signals generated using Simulink environment which are to be analysed are to be loaded in MATLAB either in workspace or in the form of ".mat" files. The equations generated depict the variations present causing a deviation from pure sinusoidal signal. It is observed from the simulations by considering the various conditions responsible for deviation in the waveform of signals. Different power quality disturbances are generated by MATLAB/ Simulink environment.

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