IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
PP 39-49

IEEE 14 Bus System Power Quality Disturbance Analysis

Ms. Sneha K.Wadibhasme, Prof. Pritee R. Rane
Electrical Engineering Department P. R. Pote (Patil) Educational & Welfare Trust's College of Engineering & Management Amravati, Maharashtra, India
Electrical Engineering Department P. R. Pote (Patil) Educational & Welfare Trust's College of Engineering & Management Amravati, Maharashtra, India

Abstract: *In very little over 10 years, electricity power quality has fully grown from obscurity to a serious issue. Power quality is among the most things that's stressed and is taken into thought by power system utilities so as to satisfy the strain of power distributor and customers. At every passing day this issue has changing into a lot of serious and at identical time the user's demand on power quality additionally gets a lot of important. Therefore it's essential to determine an influence quality analysis system to observe power quality disturbance. Many analysis studies concerning the facility quality are done before and their aims of times targeting the gathering of information for an additional analysis, therefore the impacts of varied disturbances may be investigated. This paper deals with the implementation of IEEE fourteen BUS system with completely different power quality disturbance conditions like voltage sag, voltage swell, momentary interruption and harmonics conditions.. Additionally a technique is shown for determinative the foremost sensitive bus and also the most sensitive load. Result analysis is completed at the sensitive bus and also the load.*
Keywords: *IEEE 14 Bus, Power quality (PQ)*

I. Introduction

Good power quality refers to disturbance-free electricity offer. With the event of technology, additional and additional electronic devices are being connected to the grid, inflicting potential disturbance and deviation from the provided voltage curving wave form, which can lead to instrumentality being disturbed or broken. Having in mind that power quality (PQ) disturbances are sources of voltage disturbances, that degrade and would possibly injury trendy devices [1], power electronic devices are latterly developed considering PQ problems [2]. Moreover, power quality is a crucial side to think about for renewable energy integration. For instance, current harmonics made by power converters are restricted to ensure power quality in renewable energy systems.

PQ disturbances like swell, sag, interruption, periodical transients, flicker and harmonic distortion have become difficult problems for power systems analyses. The modulated power sinusoids also detected once there are changes in masses and ranging energy sources [3]. Of these problems could impose penalties to the customers by adding reactive power, re-dispatch price and cargo curtailment price.

To understand PQ disturbances, the time-frequency options of those signals ought to be detected and analyzed [4,5]. Fourier remodel (FT) is one in every of the foremost used technique within the frequency domain, alongside Short Time Fourier remodel (STFT) [6] that enable to perform windowing techniques. Foot calculations square measure wide enforced with broad pertinence, however some disadvantage square measure gift attributable to it's troublesome to balance the frequency resolution exploitation STFT. The signals should be stationary in each amplitude and frequency. Otherwise, the analysis results are going to be not acceptable.

PQ watching will typically be a posh task involving hardware instrumentation and software system packages. The instrumentation entails communication software system to accomplish the expected practicality. Varied kinds of intelligent electronic devices may be used for collection the specified PQ information. Examples embrace dedicated digital fault recorders and protecting relays.

After PQ information of interest square measure obtained, a comprehensive PQ assessment may be administrated counting on the aim of the study. This might embrace power grid and instrumentation modeling verification, PQ downside mitigation and optimization, and information analysis. In most cases, machine-controlled PQ assessment is fascinating as a result of manual analysis is also troublesome to hold out thanks to lack of your time and special experience. Specialized software system tools will create use of intelligent techniques to automatism the PQ assessment for improved accuracy and potency.

This paper is focus on power quality disturbance generation in IEEE 14 bus system. Then next in future we will propose one of technique using Neural Network for classification of power quality disturbances in IEEE 14 bus system.

II. Proposed Approch

Figure 1 shows the block diagram of proposed approach for generation of different types of power quality disturbances and analysis of system. In this approach, the different unbalance loading condition was generated using breaker timing and 3 phases inductive or capacitive loading parameter adjustment in matlab simulink.

Also momentary interruption was done by using breaker switch timing adjustment. Also harmonics was generated using three phase source. In this approach IEEE 14 bus system was developed in MATLAB simulink 2015 software.

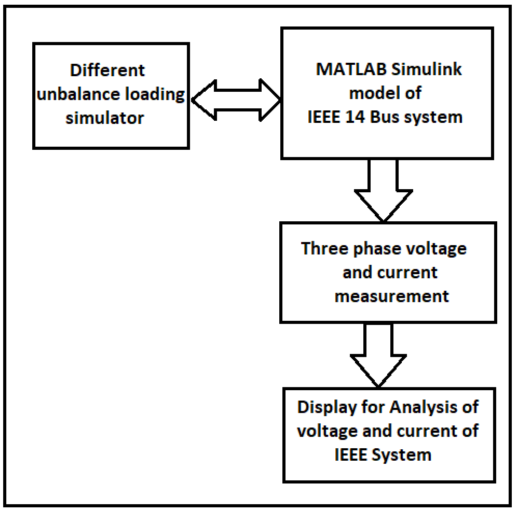

Fig.1. Block diagram of proposed approach

In this approach, IEEE 14 bus system was run at different power quality disturbance conditions and then three phase voltage and current waveform was analyzed.

III. Matlab Simulation Model

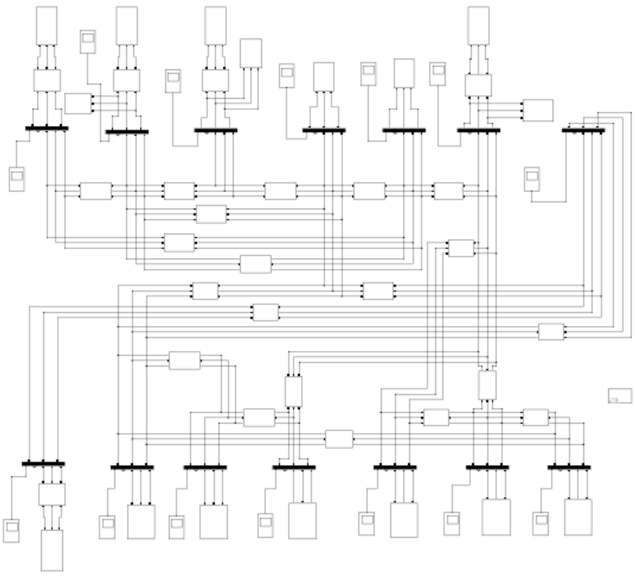

Fig.2. MATLAB simulink model of IEEE 14 bus system

Figure 2 shows the complete IEEE 14 bus system and their corresponding transmission line parameters are shown in table 1. That transmission line was utilized for interconnection of all 14 buses of power system.

Table 2 shows the different generator and synchronous compensator parameters which are connected at different bus bars. That data set was referred from IEEE standard data set and then implement in matlab simulink blocks.

Table 1: IEEE 14 Bus system MATALB Simulation transmission line data

Line Number	**From Bus**	**To Bus**	**Line impedance (pu)**		**MVA Rating**
			Resistance (pu)	**Inductance (pu)**	
1	1	2	0.01938	0.05917	120
2	1	5	0.05403	0.22304	65
3	2	3	0.04699	0.19797	36
4	2	4	0.05811	0.17632	65
5	2	5	0.05695	0.17388	50
6	3	4	0.06701	0.17103	65
7	4	5	0.01335	0.04211	45
8	4	7	0	0.20912	55
9	4	9	0	0.55618	32
10	5	6	0	0.25202	45
11	6	11	0.09498	0.1989	18
12	6	12	0.12291	0.25581	32
13	6	13	0.06615	0.13027	32
14	7	8	0	0.17615	32
15	7	9	0	0.11001	32
16	9	10	0.03181	0.0845	32
17	9	14	0.12711	0.27038	32
18	10	11	0.08205	0.19207	12
19	12	13	0.22092	0.19988	12
20	13	14	0.17093	0.34802	12

Table 2. IEEE 14 Bus system bus bar and generator data for MATLAB simulink model

Bus bar No	**Bus voltage (pu)**		**Generation (pu)**		**Load**	
	Magnitude (pu)	**Phase difference (pu)**	**Real power (MW)**	**Reactive Power (MVAR)**	**Real power (MW)**	**Reactive power (MVAR)**
1	1.060	0	114.17	-16.9	0	0
2	1.045	0	40	0	21.7	12.7
3	1.010	0	0	0	94.2	19.1
4	1	0	0	0	47.8	-3.9
5	1	0	0	0	7.6	1.6
6	1	0	0	0	11.2	7.5
7	1	0	0	0	0	0
8	1	0	0	0	0	0
9	1	0	0	0	29.5	16.6
10	1	0	0	0	9	5.8
11	1	0	0	0	3.5	1.8
12	1	0	0	0	6.1	1.6
13	1	0	0	0	13.8	5.8
14	1	0	0	0	14.9	5
1	1.060	0	114.17	-16.9	0	0
2	1.045	0	40	0	21.7	12.7
3	1.010	0	0	0	94.2	19.1
4	1	0	0	0	47.8	-3.9
5	1	0	0	0	7.6	1.6

After designing of IEEE 14 bus system, different conditions of power quality disturbances were simulated in matlab simulink model by utilizing the three phase load parameter adjustment. Also some time breaker was utilized for connect and disconnect the load and generator of IEEE 14 bus system by adjustment of simulation ON and OFF time of breaker. The different power quality disturbances and their analysis models were discussed in next section of paper.

A. Normal loading condition

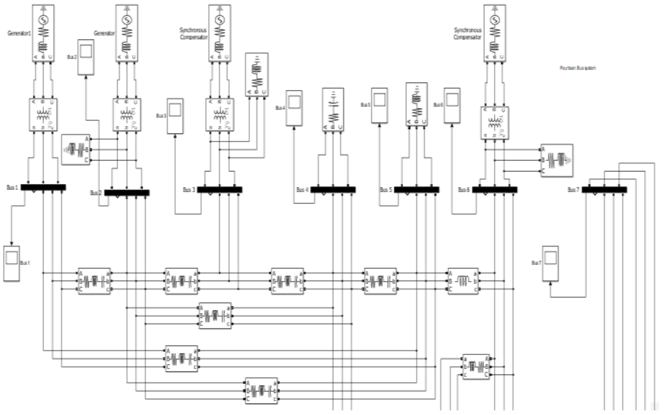

Fig.3. Zone 1 upper portion of IEEE 14 bus power system

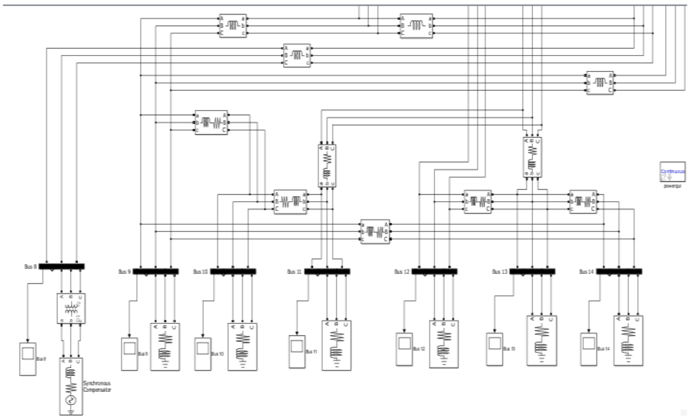

Fig.4. Zone 2 lower portion of IEEE 14 bus power system

Figure 3 and 4 shows the upper and lower portion of IEEE 14 bus system model for normal loading condition without any power quality disturbance conditions. In this model, parameters in table 1 and 2 was set and power system voltage profile was analyzed.

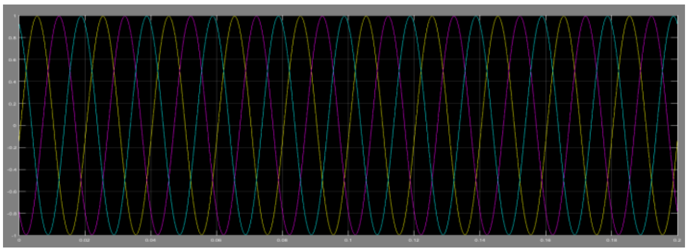

Fig.5. Normal voltage of IEEE 14 bus system at bus bar 4

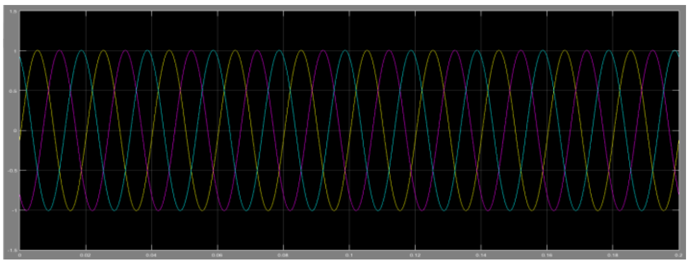

Fig.6. Normal voltage of IEEE 14 bus system at bus bar 6

Figure 5 shows the three phase voltage of IEEE 14 bus which measured at bus bar 4. Similarly figure 6 and 7 shows the three phase voltage of IEEE 14 bus which measured at bus bar 6 and 7 respectively. In this waveform, it is cleared that voltage generated in IEEE 14 bus system is normal supply voltage and without any fluctuation as well as harmonics contents not present.

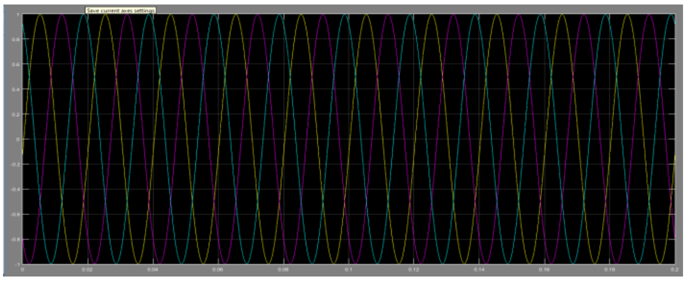

Fig.7. Normal voltage of IEEE 14 bus system at bus bar 7

B. Voltage sag model

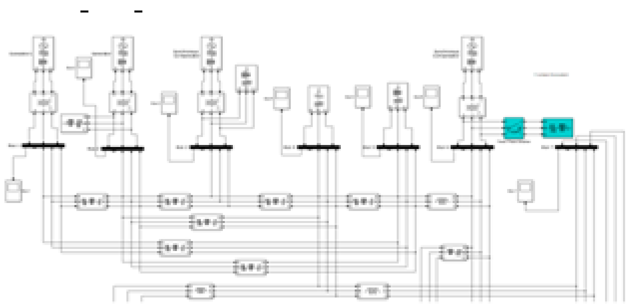

Fig.8. IEEE 14 Bus system for voltage sag power quality disturbance

Figure 8 shows the IEEE 14 bus system for voltage sag power quality disturbances. For generation of voltage sag, the highly inductive load was connected at bus bar 6 through breaker. Breaker time was simulated in such way that breaker on at 0.15 sec and OFF at 3 sec i.e. highly inductive load was connected with IEEE 14 bus system from 0.15 sec to 0.3 second duration and complete operation time of IEEE 14 bus system was 0.5 seconds. Load and breaker parameters are shown in table 3.

Table.3. Simulation blocks parameter for voltage sag generation at bus bar 6

Sr No	Simulation block	Specifications
1	Three phase breaker (Light blue color)	Initial status = open; Switching time: start time = 0.15 sec and end time = 0.3 sec; Breaker resistance (Ron) = 0.01Ω; Snubber resistance (Rs) = 1 M Ω
2	Three phase RLC Load (Light blue color)	Nominal phase to phase voltage = 1 pu; Nominal frequency = Hz; Active power P =0.5 pu; Inductive reactive power = 7 pu

Figure 9 shows the three phase voltage measured at bus bar 2 during voltage sag conditions takes place at bus bar 6 of IEEE 14 bus system in MATLAB simulink model. In this waveform, it is cleared that voltage of power system decrease at 0.15 sec and again maintain normal at 0.3 second when highly inductive load connect with IEEE 14 power system model. Similar behavior of voltage sag waveform shown in figure 10 and 11 for bus bar 4 and 14 of IEEE system model.

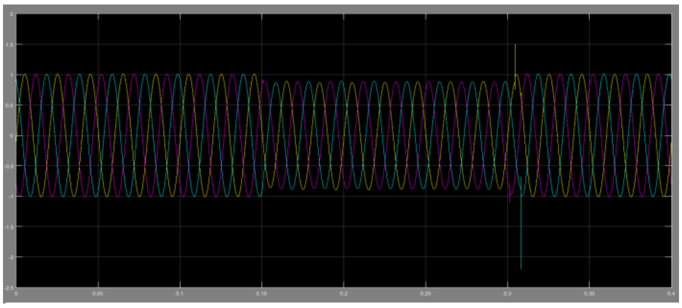

Fig.9. Voltage sag generation at bus bar 2

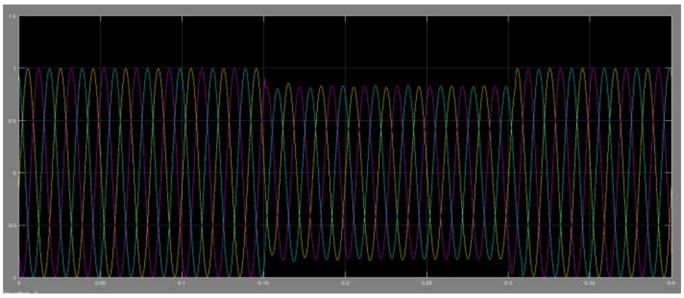

Fig.10. Voltage sag generation at bus bar 4

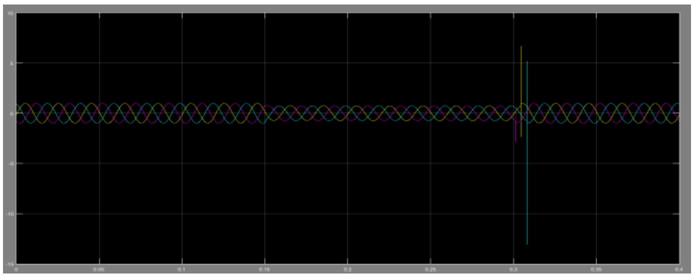

Fig.11. Voltage sag generation at bus bar 14

C. Voltage swell model

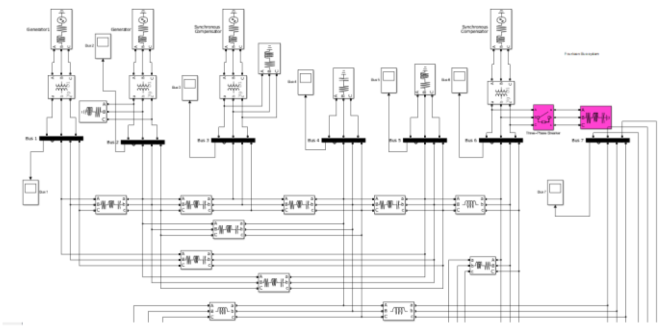

Fig.12. IEEE 14 Bus system for voltage swell power quality disturbance

Figure 12 shows the IEEE 14 bus system for voltage swell power quality disturbances. For generation of voltage swell, the highly capacitive load was connected at bus bar 6 through breaker. Breaker time was simulated in such way that breaker on at 0.15 sec and OFF at 3 sec i.e. highly capacitive load was connected with IEEE 14 bus system from 0.15 sec to 0.3 second duration and complete operation time of IEEE 14 bus system was 0.5 seconds. Load and breaker parameters are shown in table 3.

Table.4. Simulation blocks parameter for voltage swell generation at bus bar 6

Sr No	Simulation block	Specifications
1	Three phase breaker (Pink color)	Initial status = open; Switching time: start time = 0.1 sec and end time = 0.15 sec;

		Breaker resistance (Ron) = 0.01 Ω; Snubber resistance (Rs) = 1 MΩ
2	Three phase RLC Load (Pink color)	Nominal phase to phase voltage = 1 pu; Nominal frequency = Hz; Active power P = 0.5 pu; Inductive capacitive power = 11 pu

Figure 13 shows the three phase voltage measured at bus bar 2 during voltage swell conditions takes place at bus bar 6 of IEEE 14 bus system in MATLAB simulink model. In this waveform, it is cleared that voltage of power system rises at 0.15 sec and again maintain normal at 0.3 second when highly capacitive load connect with IEEE 14 power system model. Similar behavior of voltage sag waveform showed in figure 14 and 15 for bus bar 4 and 14 of IEEE system model.

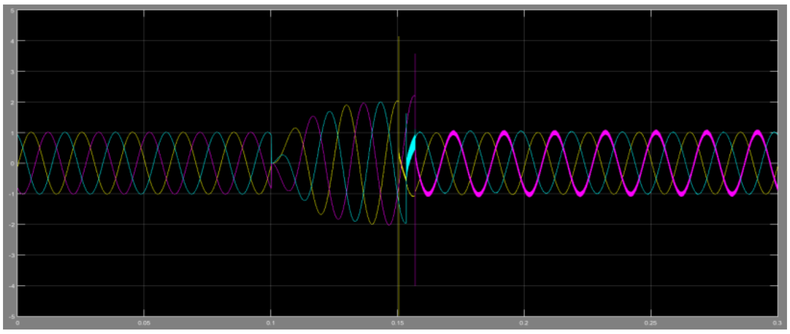

Fig.13. Voltage swell generation at bus bar 6

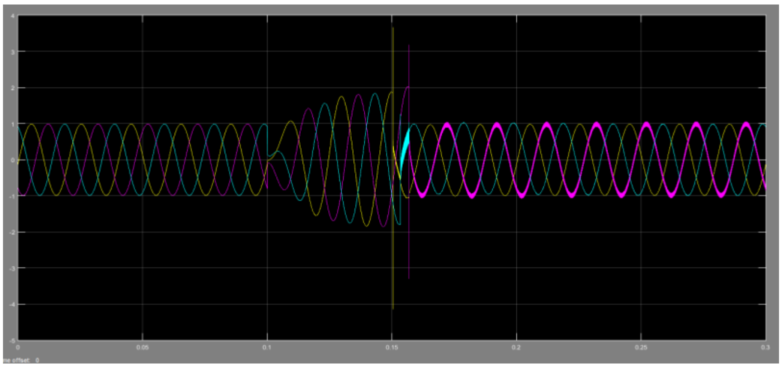

Fig.14. Voltage swell generation at bus bar 7

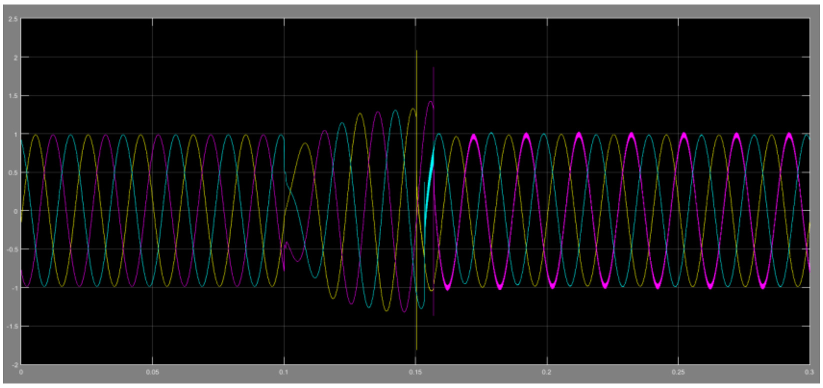

Fig.15. Voltage swell generation at bus bar

D. Momentory Intrruption

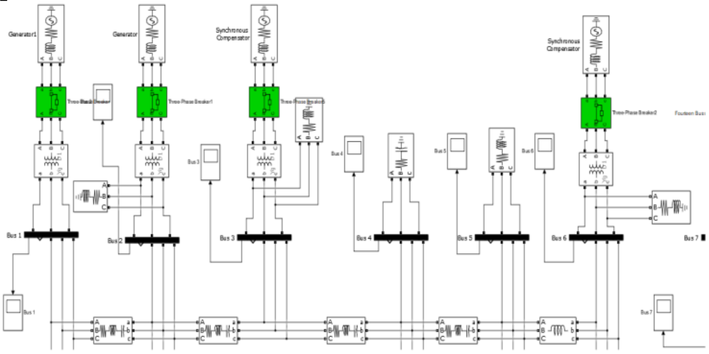

Fig.16. IEEE 14 Bus system for momentary interruption power quality disturbance (Upper zone)

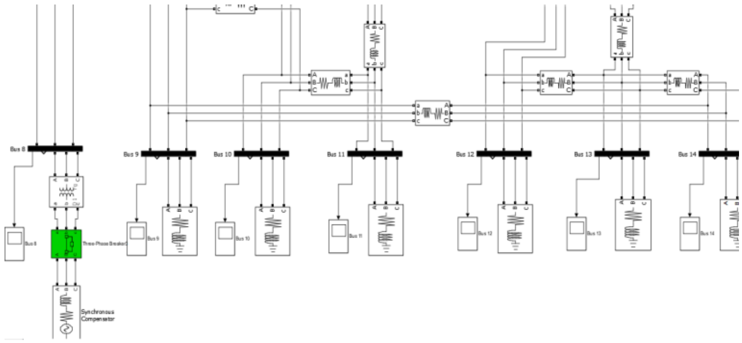

Fig.17. IEEE 14 Bus system for momentary interruption power quality disturbance (Lower zone)

Figure 16 and 17 shows the IEEE 14 bus system upper zone and lower zone in which momentary interruption of power quality disturbance was generated using breaker. Breaker was installed at before each power generator bus bar for ON and OFF of complete power system supply so that interruption was occurred. In this model, momentary interruption was generated in between 0.2 sec to 0.25 second time duration while complete power system model was run for 0.5 second simulation time. Breakers are shown in figure by green color and parameters of breaker are shown in table 5.

Table.5. Simulation blocks parameter for momentary interruption generation

Sr No	Simulation block	Specifications
1	Three phase breaker (Green color)	Initial status = closed; Switching time: start time = 0.2 sec and end time = 0.25 sec; Breaker resistance (Ron) = 0.01 Ω; Snubber resistance (Rs) = 1 MΩ

Figure 18 shows the three phase voltage waveform at bus bar 3 in which voltage becomes completely zero or interrupt at 0.15 seconds up to 0.3 seconds time slot. That done by simulation time adjustment of three phase breaker which were connected after each power generator sources so that voltage supply was interrupted. Similar behavior was analyzed in figure 19 and 20 for voltage measured at bus bar 6 and 10 respectively.

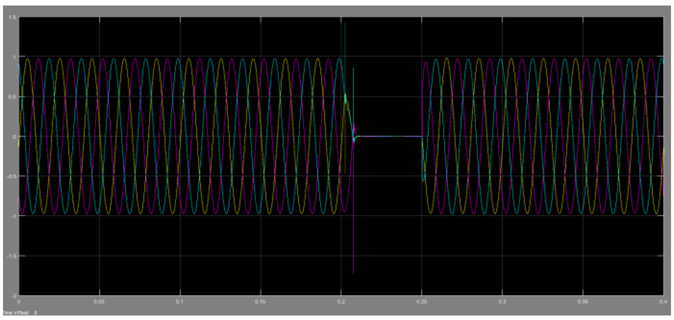

Fig.18. Momentary interruption voltage waveform measured at bus 3

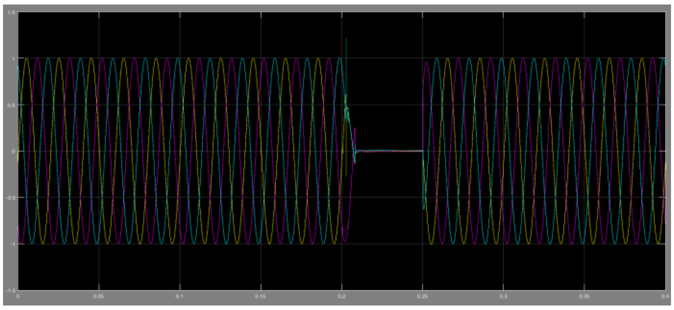

Fig.19. Momentary interruption voltage waveform measured at bus 6

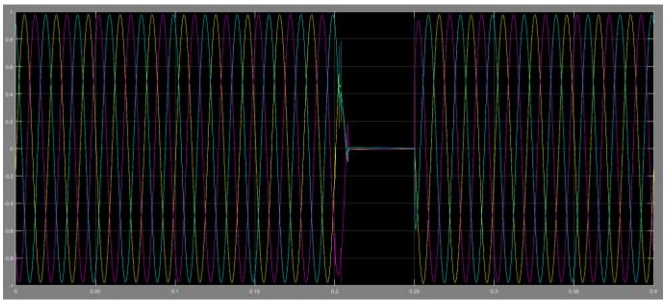

Fig.20. Momentary interruption voltage waveform measured at bus 10

E. Voltage harmonics model

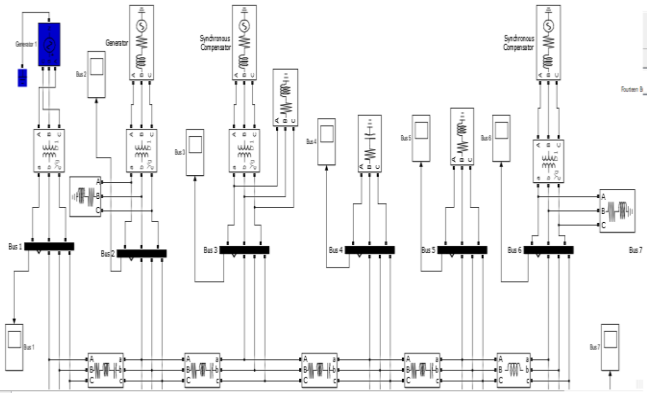

Fig.21. MATLAB Simulation model for momentary interruption voltage generation

Figure 21 shows the IEEE 14 bus system for generation of harmonics as power quality disturbance in power system. For harmonics generation, programmable voltage source was connected at bus bar 1 which simulated for generation of 5^{th} harmonics and 7^{th} harmonics from simulation time of 0.1 sec to 0.15 sec time slot while complete simulation time is sec. The complete parameters of programmable voltage source is shown in table 6.

Table.6. Simulation blocks parameter for harmonics waveform generation at bus bar 1 For IEEE 14 bus system

Sr No	Simulation block	Specifications
1	Three phase programmable voltage source (Blue color)	Amplitude of ph to ph voltage = 1 PU; Phase angle = -30 Degree; Frequency = 50Hz; 5^{th} order harmonics data: Amplitude of harmonics = 0.4 pu; Phase difference = -45 Degree; 7^{th} Order harmonics data: Amplitude of harmonics = 0.2 pu; Phase difference = -36.7 Degree Time for entering the harmonics into system: Start time: 0.1 Sec; End time: 0.15 Sec;

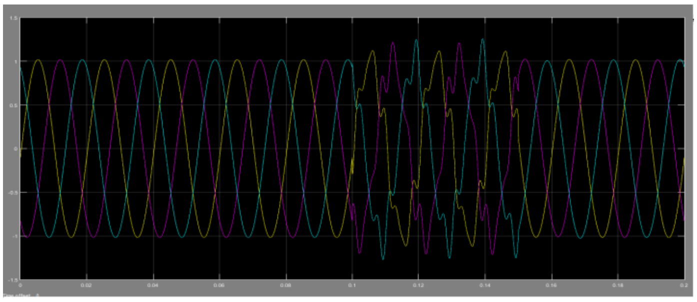

Fig.22. Harmonics voltage measured at bus bar 1

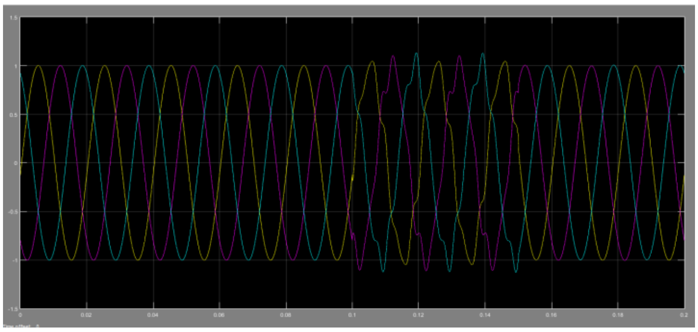

Fig.23. Harmonics voltage measured at bus bar 5

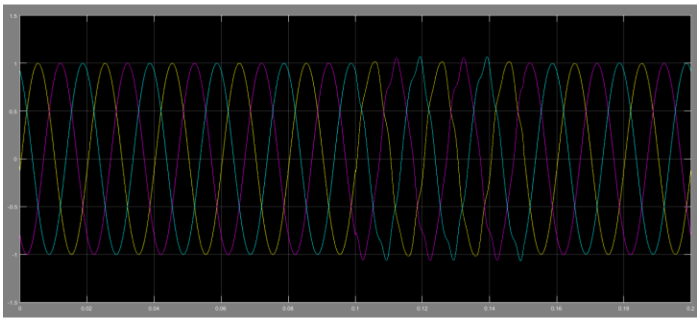

Fig.24. Harmonics voltage measured at bus bar 7

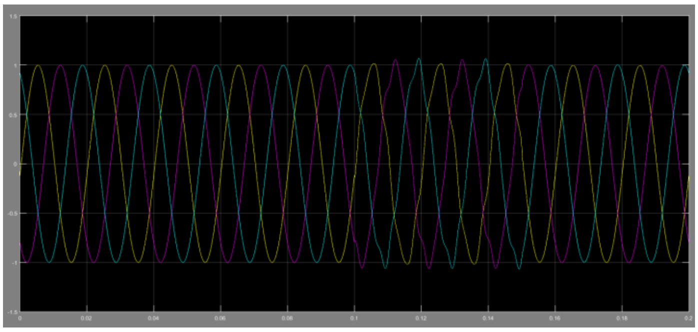

Fig.25. Harmonics voltage measured at bus bar

Figure 22 shows the three phase voltage measured at bus bar 1 in which it is observed that harmonics was generated from 0.1 to 0.15 sec simulation time slot. While the effect of harmonics was decreases when transmission impedance included due to transmission interconnection between different bus bar. Figure 23 to 25, it is observed that harmonics decreases with increasing with transmission lone impedance.

IV. Conclusion

This paper deals with the implementation of IEEE fourteen BUS system with completely different power quality disturbance conditions like voltage sag, voltage swell, momentary interruption and harmonics conditions.. Additionally a technique is shown for determinative the foremost sensitive bus and also the most sensitive load.

This paper is very much useful for generation of different power quality disturbances and analysis of voltage-current profile of IEEE 14 bus system using MATLAB simulink model. This paper will be extending in future for classification different power quality disturbances using neural network approach and fuzzy logic controller approach. Also this paper will be extending for implementation of controller which takes the action of power quality improvement based on improving the power system voltage and current.

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