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Investigation into the Effect of Active Filter on Electric Power Quality of a Network

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Abstract –The electric power quality has always turned into a serious matter and is one the major concern and focus of interest of power system engineers. Extensive use of various devices like Power electronic, arc furnace and other non-linear devices in distribution network and power systems has contributed a lot to power quality issues. This paper investigates the effects of active shunt filter on the enhancement of power quality of 415V distribution network using MATLAB SIMULINK simulation tool. Active shunt filter reduces harmonic distortion and provides complete power quality improvement, therefore rendering distribution network trouble free and more efficient

Keywords: **Power Quality, Distribution Network, Active Power Filter, Harmonic, MATLAB/Simulink**

1.0 Introduction.

The electric power quality will always be a major concern and focus of interest of power system engineers that are involved in planning and exploitation of distribution electrical networks (Miloslava, 2011). Basic national needs of residential lighting, refrigeration, heating, transportation and air conditioning were being supplied by grid and as well as critical supply to commercial, industrial, communications and medical communities (Joseph, 2001). Ability of consumer's equipment connected to the network to perform optimally is been determined by Power quality. The power quality problems don't usually come from the utility system always. Some equipment that are sensitive and malfunction due to voltage disturbances often causes voltage disturbances for other consumers (Miloslava, 2011).

Electric motors rated in kilowatt are used in industrial applications and their speed is controlled via frequency converters. Steady increase of these electronic loads with highly non-linear current characteristics increasingly compromises the power quality of low and medium voltage distribution network (Marcus, 2021). Improvement of the power quality in the consumer network reduces electric energy consumption and save cost. Power quality involves the quality of the supply voltage that meets the required standard in term of voltage level ($\pm$ 5%) and total harmonic distortion ($\leq$3-8%) (Miloje, 2012).

Power quality is mostly affected by current flow characteristics of the consumer non-linear loads connected to the grid. Voltage changes according to current flow characteristics of load equipment at the point of load connection to the grid and this depends on the grid impedance. Voltage unbalance will cause the magnetic fields to build up by negative voltage sequence in an electrical machine. The magnetic fields act in opposite direction of the rotor rotation, therefore, lower machine torque and increase thermal losses due to induced currents in rotor and causes occurrence of pulse vibration torques. These cause additional mechanical stress and also reduce life expectancy (Marcus, 2021). This paper investigates effects of active filter on the wave shape; harmonic distortion, voltage fluctuations and frequency variations of distribution network voltage when linear and non-linear loads are been connected by simulation using Matlab Simulink model. Sensitive, intelligence and automated system calls for power that is free of disturbance or interruption

1.1 Power Quality

The power quality at the point of connection of respective load in a three phase AC network is ideal if voltages:

a have nominal value at all a times and are symmetrically constant
b frequency has constant value always
c exhibit a sinusoidal waveform always. (Marcus, 2021)

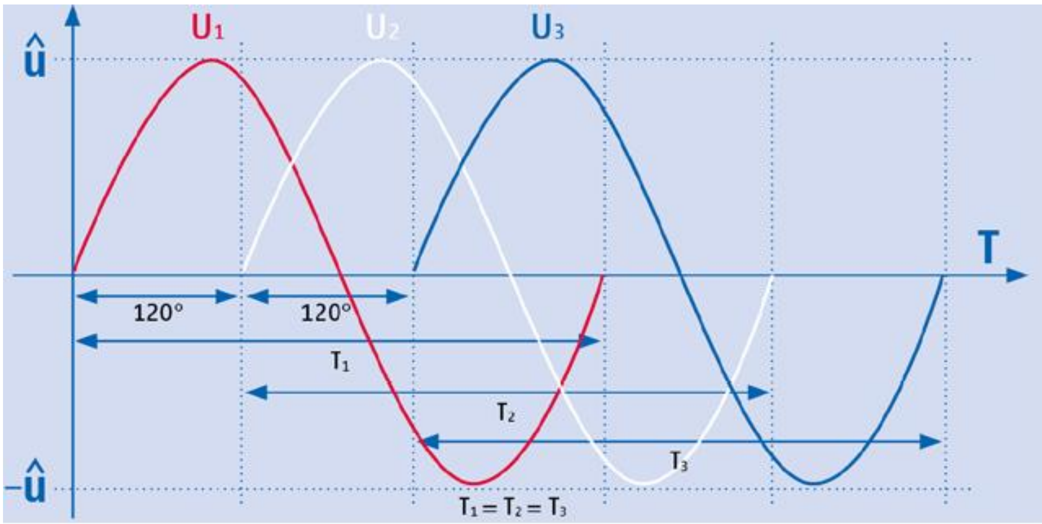

Figure 1: Smooth Sine Wave (Marcus, 2021)

Disturbance in the smooth sine wave of Figure 1 affects the power quality, such as change in shape, size, frequency, symmetry, and notches. 50% of Power Quality problems are related to ground bonds, grounding, and neutral to ground voltages, ground current, ground loops or any other ground associated issues (Khalid & Bharti, 2011) IEEE Standard 1159 describes power quality as concept of powering and grounding sensitive load in a manner that is suitable for operation of that equipment (IEEE 100, 2000).

Power quality has been defined as parameters of voltage that affect the customer's supersensitive equipment. The commonly used terms based on wave shape that describe or measure power quality according to IEEE are, interruptions, waveform distortion, sag / under voltage, swell / overvoltage, frequency variations, voltage fluctuations, transients and harmonics (Joseph, 2001).

2.0 Effects of Harmonic

Harmonics increase causes depreciation and losses in the transmission, distribution and power consumer's equipment (Umar and Pallavi, 2015). Continuous infliction of threat by harmonic disturbances severely affects power quality and this impacts the reliability and stability of equipment because some of them need transient-free power to perform optimally. Power quality is a measure of degree of nonlinearity presents in the sinusoidal waveforms of current and voltage. Better power quality is achieved when less nonlinearity is present in the sinusoidal waveforms (Abhishek and Sandeep, 2017).

The European Copper Institute carried out a research at 1,400 sites in 8 countries of Europe on Power quality survey in 2001. Outcome of their research shows that 20% experience harmonics damage as shown in figure 2 (Sharmistha and Sjef, 2011). Electrical equipment such as electric motors, which are industries wheels, measurement equipment, that are used for monitoring and control and relays, that guard and protect power system operations are affected by network harmonics (Hashem and Azim, 2005). Therefore a strategy to eliminate and reduce harmonics down to standard allowed are essential (Samadaei, Mina, Mohammad, Radu and Edris, 2018). .

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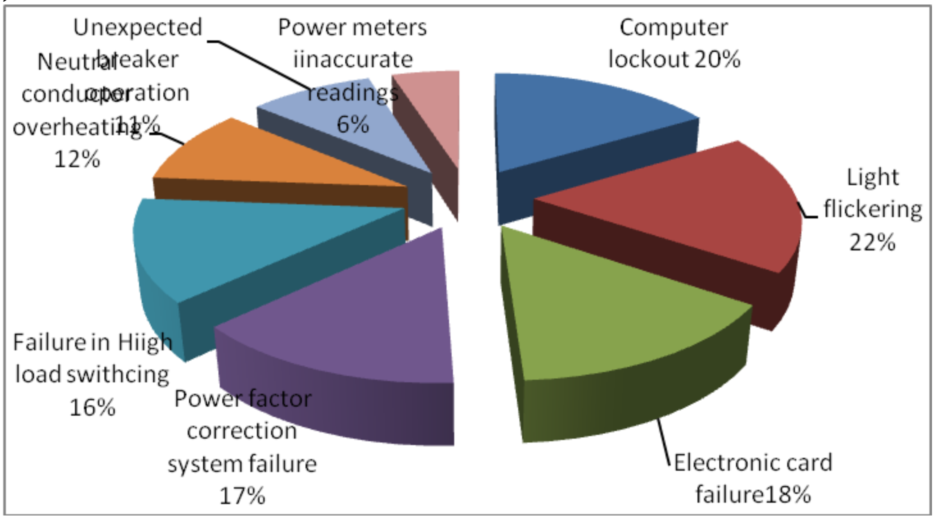
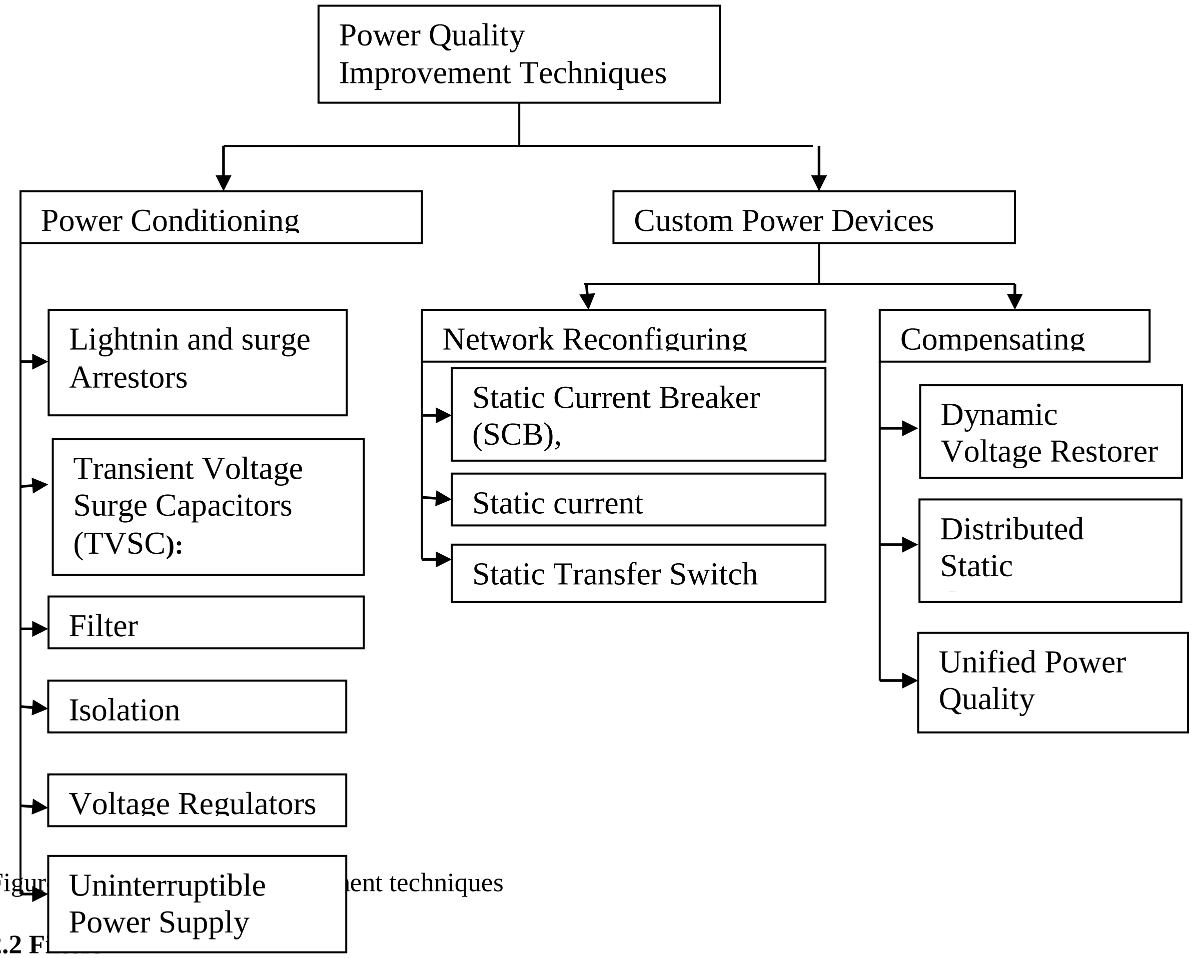


Figure 2: Harmonic interruption in 8 European countries in percent (SATEC, 2014)

2.1 Power Quality Improvement

Power quality describes the difference between quality of power from the supply authority and the quality of power needed for suitable and reliable operation of consumer's equipment (Janakrani, 2020). It is desirable that the consumers are provided with high levels of power quality in accordance with their types and demands such that they can have the flexibility to adjust their required quality level and to reduce the total running cost consequently (Bharat, 2020). In order to lower power quality problems, lightning strike and non linear loads should be prevented if possible (Adeoye, 2019). Figure 3 presents different approaches that are available to reduce and improve power quality with devices and systems (Janakrani, 2020).



Figur[illegible]ent techniques

2.2 F[illegible]

A filter provides protection against unwanted signals like high frequency low voltage noises. Filters are electronics devices classified into passive harmonic filters and active harmonic filters and designed to allow fundamental frequency to pass and reject higher frequency noise. Harmonics filters block the harmonics content of non linear loads from getting back to the power source (Janakrani, 2020).

The inadequate performance of the normal passive filter techniques to improve power quality problems has led to introduction of advanced power electronic based topologies in the improvement of power quality. Active Power Filter is the best among various power quality improvement techniques using Flexible AC Transmission System (FACTS) devices. Shunt Active Power Filter is an advanced power electronics system that mitigates power quality problems like current harmonics, poor power factor and reactive power demand in the distributed electrical power system (Bharat, 2020).

2.3 Proposed System Configuration and Simulation

A distribution network of Orita Alajue in Ede, Osun State is configured and active power quality filter is then connected to radial distribution system at point of common coupling as shown in figure 4.

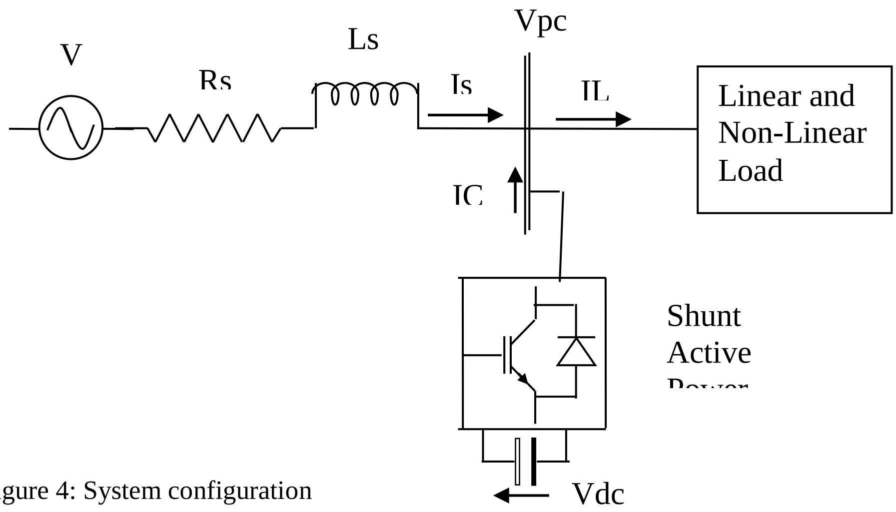


Figure 4: System configuration

The Vs, Ls and Rs represent source voltage, source inductance and resistance respectively. The non-linear load is realized by simulating the induction furnace and resistive load is used to realize linear load. The main function of Shunt Active Power Filter is to supply reactive power as required by the load. Therefore, correct the power factor of the source current and improve the waveform.

The basic Shunt Active Power Filter configuration in figure 4 is modelled in MATLAB SIMULINK and is as shown in figures 5-7. Three phase source having line to line voltage of 415 V is modelled and connected to the linear and non- linear loads and the filter is connected at the point of common coupling (pcc). Simulated model is used to study the waveform and various power quality parameters.

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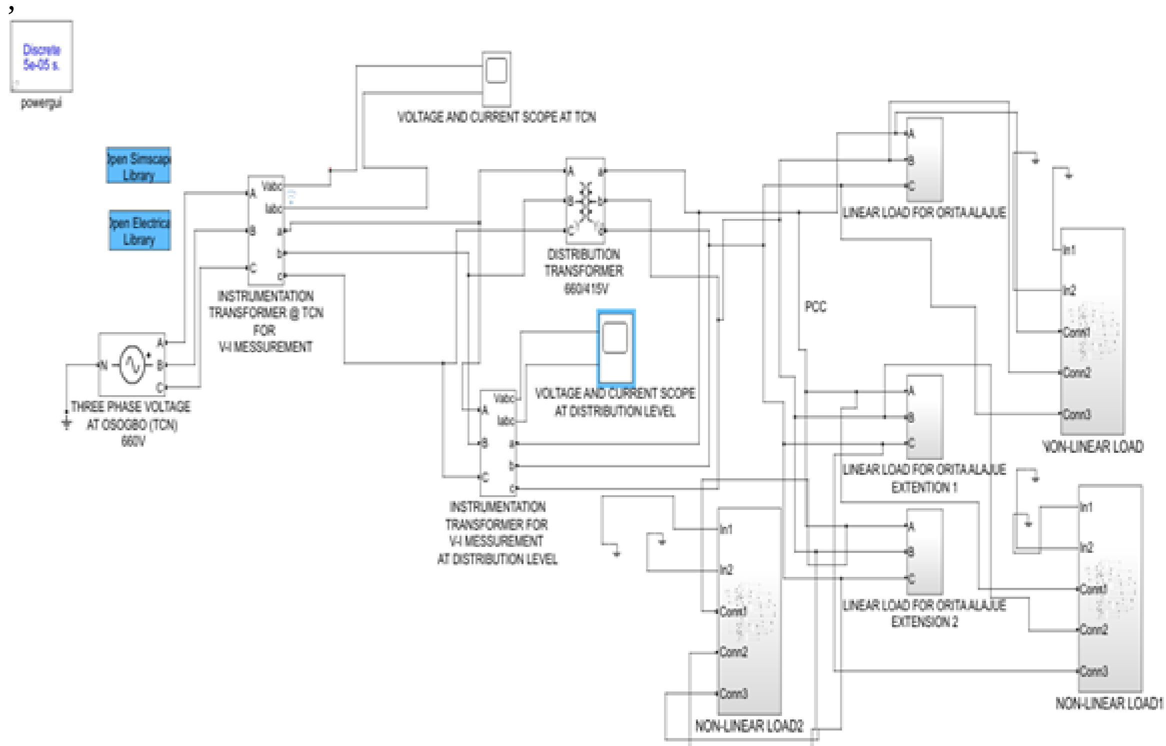

Figure 5: Simulink model of the network with linear and non-linear loads

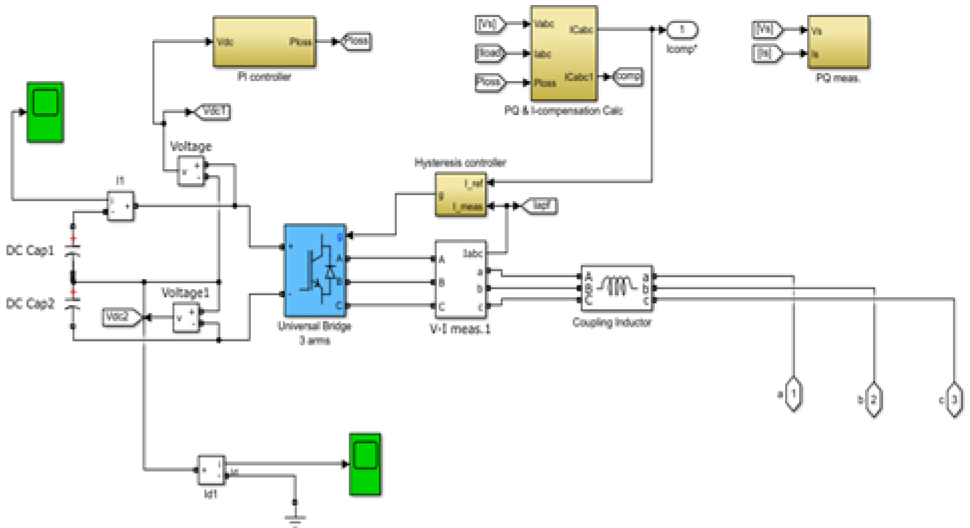

Figure 6: The Active filter in Simulink subsystem

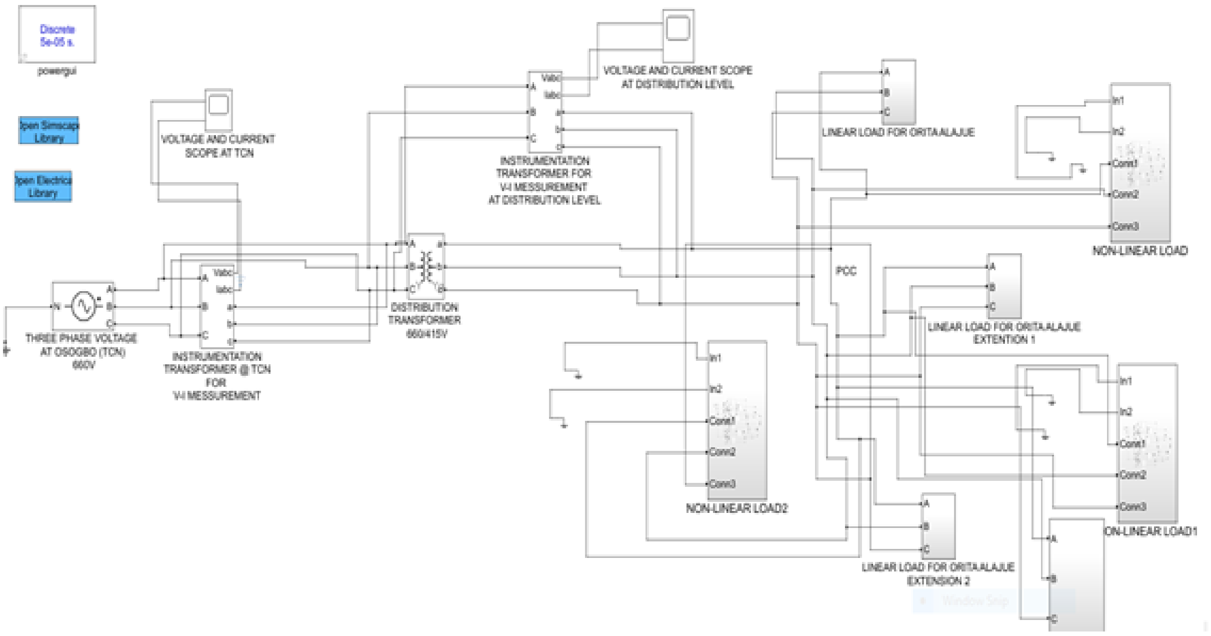

Figure7: Simulink model of the Network with linear and Non-Linear Loads incorporated with Active Power Filter

3.0 Results and Discussions

The improvement in the power quality of 415V distribution Network is studied by observing the voltage and current waveforms without filter and with filter connected. The results of three phase load current and its FFT analysis are as shown in figures 8-11. From Figure 8 it is observed that the voltage and current waveforms are not sinusoidal in nature, some distortion present in it due to combination of linear and non- linear load connected. The total harmonic distortion (THD) is at 213.55%, this is more than the expected harmonics level expected on a distribution network.

There is a noticeable improvement in the waveforms and THD of the distribution network with the filter connected. There is reduction in the distortion and THD is measured to be 53.43% and the percentage reduction is in THD achieved 74.98%. This implies that, with the incorporation of Active Power Filter on a Distribution network containing linear and Non-Linear loads, the level of reduction of THD achieved is 74.98%. Table 1.0 summarizes performance of the active filter connected network.

Table 1: Summary of Results.

S/N	Parameters	Distribution Network with Linear Loads	Distribution Network with linear and non-Linear Loads	Distribution Network with Filter
1	Voltage waveform characteristics	The waveform is sinusoidal and periodic. Contain no observable distortion Harmonic Signal, Phase In-Balance	The waveform is characterized with some level of distortions. It has some level transient instability and Phase in-balance	Waveform is characterized with high magnitude , Balance phase, Harmonics level and other power quality are improved
2	Current waveform Characteristics	The waveform is sinusoidal and periodic. Contain no observable distortion Harmonic Signal, Phase In-Balance	The waveform is characterized with some level of distortions . It has some level transient instability and Phase in-balance	The Waveform is characterized with reduced level in magnitude of the distortion Considerable balanced Phase is achieved. Harmonics mitigate
3	THD (%)	0.00%	213.55%	53.43%

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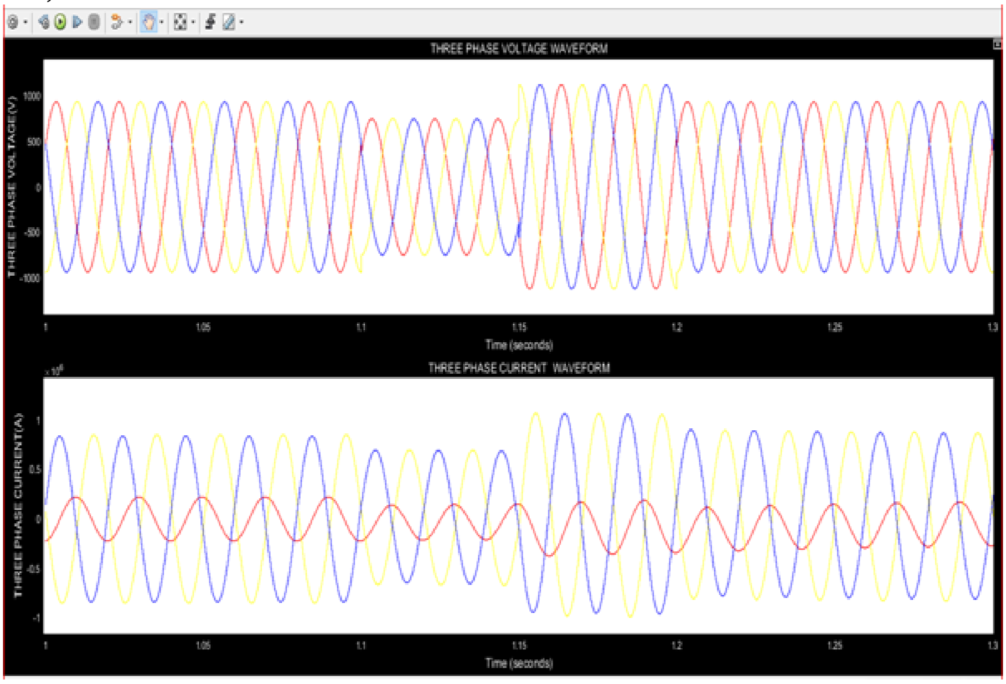

Figure 8: Waveform of The Network with Linear And Non-Linear Loads Connected

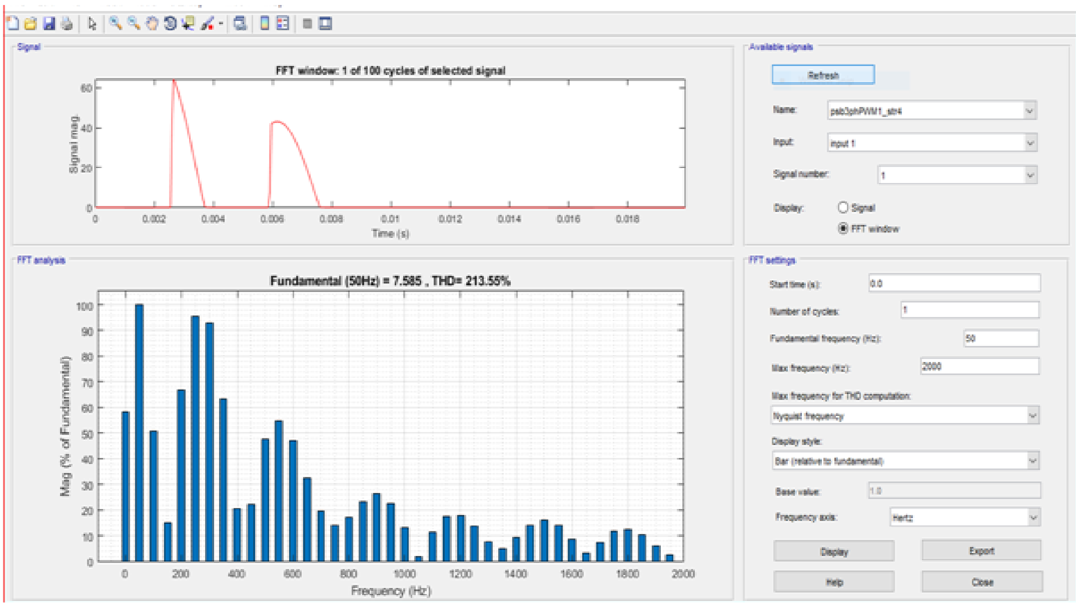

Figure 9: FFT analysis of the distribution network with linear and non-linear loads

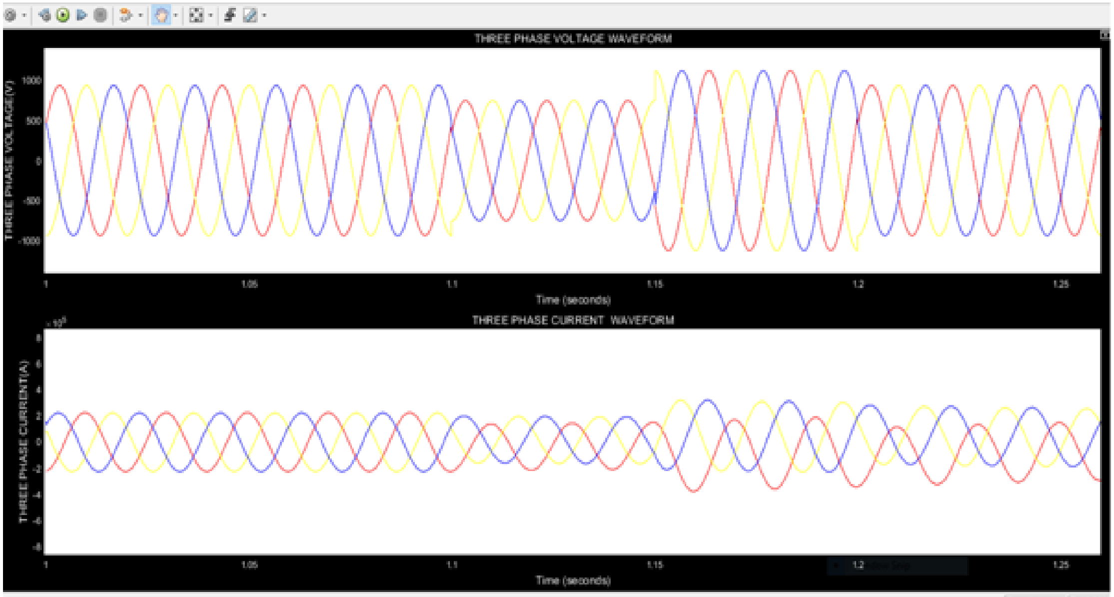

Figure 10: Three phase current and voltage Waveforms with Active Power Filter

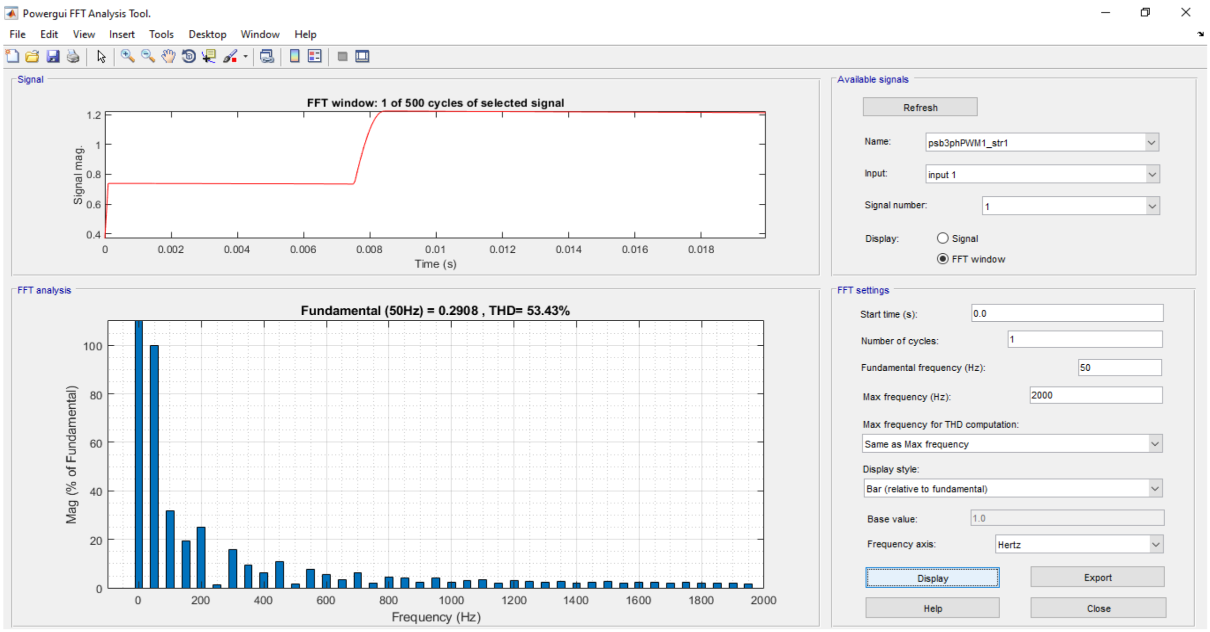

Figure 11: The FFT analysis of the distribution network with linear and non-linear load connected with active power filter

4.0 Conclusion

In this research investigation of **e**ffect of shunt active filter on electric power quality of 415V distribution network built in MATLAB /Simulink environment has been studied and analyzed. Results were generated, discussed and analyzed for various scenario of loading without filter and with filter connected. Shunt active power filter offers an excellent solution for tackling several power quality issues. THD of the network is improved and reduced by 74.98%. The proposed filter maintains the significant features, improved waveforms and therefore improved other power quality like voltage sag/swell and so on. Shunt active power filter can effectively be used for harmonic mitigation and power quality improvement.

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