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Simulation for the Improvement of Power Quality by Reduction of Harmonics in the Distribution System with the Placement of Unified Power Quality Conditioner (UPQC)

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Abstract: *The increased use of nonlinear loads in distribution system leads to distortion in voltage & current waveforms and injecting harmonics and thus the system inherently gets unbalanced. Harmonics generation becomes a grave concern in distribution system. Besides this, the voltage sag-swells and power factor also create the power quality problem at the utility side. Hence, reduction of these power quality issues in the system is important. There are other issues during installation of distributed generation, which must be evaluated and mitigated for the better performance of the system.*

The usage of power enhancement device such as unified power quality conditioner (UPQC) can simultaneously fulfil different objectives, such as maintaining a sinusoidal voltage at the point of Installation. The UPQC which has two filters (series and shunt active power filters) are to be placed in a distorted distribution line to provide the system sinusoidal current. This project proposes the placement of Unified Power Quality Conditioner (UPQC) for the power quality improvement and is to be tested in 33 bus radial distributed system.

Keywords: *Distributed System, Filters, Harmonics, and Power quality improvement, THD, UPQC and Voltage Harmonics.*

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I.INTRODUCTION

Due to the increased usage of power electronics devices in the power system, faults are introduced and the power quality gets highly affected. Harmonic contents of voltage and currents are injected. Besides this, the voltage sag-swells and power factor also create the power quality problem at the utility side. Hence, reduction of these power quality issues in the system is important. There are other issues during installation of distributed generation, which must be evaluated and mitigated for the better performance of the system. There are some special devices for the mitigation of power quality issues. Those include FACTS devices, filters, shunt capacitors, etc. this paper proposes the usage of power enhancement device, unified power quality conditioner (UPQC) which maintains a sinusoidal voltage at the point of installation. UPQC is a flexible device, which comprises of shunt and series Active Power Filters (APFs) sharing a common dc link. Shunt APF is used to compensate the problems caused by load current harmonics and make the source current completely sinusoidal. Series APF is used to mitigate problems related to voltage dip/rise in source voltage and make load voltage completely regulated. UPQC is used to solve all problems related to voltage and current harmonics and improve power quality. The synchronous reference frame theory for the control of filter in the device is also implemented in this paper.

II. LITERATURE REVIEW

C. Benachaiba, et al. (2010), studied the principle of the usage of power enhancement device, unified power quality conditioner (UPQC) can maintain a sinusoidal voltage at the point of installation [3]. [3]. Gowtham N, et al. (2016) defined the UPQC as a flexible device, which comprises of Shunt and Series Active Power Filters (APFs) sharing a common dc link [6]. Farid Hosein-Zdeh, et al. (2014), studied about the power quality improvement using UPQC [5]. Arya Raveendran, et al, (2014), discussed the power quality improvement with series and shunt compensation [2]. [14]. Previously, UPQCs were used for simultaneous (i) voltage sag/ swell compensation by using series inverter, (ii) load reactive power sharing by using shunt inverter of the UPQCs. This device is most preferred because it has better sag/swell compensation capability among the available power quality enhancement devices [9]-[10]. Soma Biswas, et al, (2013), have discussed the placement of shunt capacitor for the power quality M. Hosseini, et al, (2009), have used Backward/forward sweeps in load flow and convergence criterion for the model of UPQC in the 33 & 69 bus test system [8]. They have addressed not only power quality improvement, but also the minimization of the cost due to system losses, devices connected to the DG. Jayanti Sarker, et al, (2016), have proposed a Cuckoo Optimization Algorithm (COA) based Unified Power Quality Conditioner (UPQC) allocation in three phase unbalanced distribution network is proposed which is a weighted sum single objective optimization [1]. improvement [13].

III. POWER QUALITY ISSUES AND MITIGATION TECHNIQUES

The power system has been operating in a good condition until the power electronic devices are introduced. Once the power electronic activity increased, the quality of the power supply gets interrupted. There was more power quality issues are introduced in the system. Though the power electronic devices give a sophisticated life to all, the power quality issue leads to mal-operation of the loads / devices. In developing countries like India, voltage variations and frequency deviations are the major problems. Thus, it is necessary to mitigate these problems in order to achieve the good power quality. PQ disturbances are of broad frequency range with significantly different magnitude variations and can be non-stationary. Thus, accurate techniques are required to identify and classify these disturbances. Some solutions to mitigate the PQ problems are there with some FACTS devices in order to improve the power quality in a distribution system. By measuring the voltage and current distortions before and after placing these devices gives a detailed view of power quality issues i.e. Total Harmonic Distortions (THD), Voltage distortion index (VT), Current distortion index (CT) etc. There are two ways to mitigate the power quality problems-either from the customer side or from the utility side. The first one is called load conditioning, which is used to make sure that the equipment is less sensitive to power disturbances, allowing the operation even under significant voltage distortion. The other solution is to install line conditioning systems that suppress or counteracts the power system disturbances. Several devices including flywheels, super capacitors, other energy storage systems, constant voltage transformers, noise filters, isolation transformers, transient voltage surge suppressors are used for the mitigation of specific PQ problems. Facts devices like DSTATCOM, DVR and UPQC are capable of mitigating multiple PQ problems associated with utility distribution and the end user appliances.

IV. UNIFIED POWER QUALITY CONDITIONER

UPQC (Unified Power Quality Conditioner) is equipment used to compensate the voltage distortion and voltage unbalance in a power system. Thus, the voltage at load side is completely balanced, sinusoidal & perfectly regulated. It is also used to compensate for load current harmonics thus the current at the source side is perfectly sinusoidal and free from distortion.

UPQC is a combination of a Shunt Active power filter and Series Active power filter. The Shunt Active power filter (APF) is used to mitigate load current harmonics. The Series APF is used to mitigate for voltage distortions and unbalance which is present in supply side and make the voltage at load side perfectly balanced, regulated and sinusoidal.

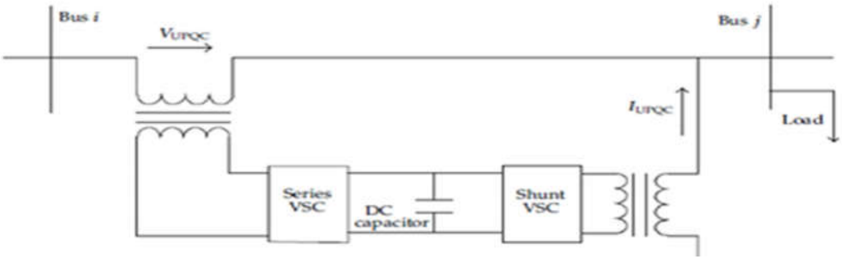


Figure. 1. Placement of UPQC in A Distribution Line

UPQC consists of two voltage source inverters connected back to back through a DC link capacitor in a single phase, three phase three wire, and three phase-four wire configurations. The inverter in shunt APF is controlled as a variable current source inverter and in series APF is controlled as a variable voltage source inverter.

Table.1. Difference between the Series and Shunt Converter of UPQC

Sl.No	Series Converter	Shunt Converter
1.	Compensation of Voltage harmonics.	Compensation of Current harmonics.
2.	Mitigation of harmonic currents.	Compensation of reactive power at load.
3.	Controlling active and reactive powers.	Regulation of load voltages.

V. CONTROL OF UPQC

A control technique must be used for the better operation of the filters in any system. The control theory used here is the synchronous reference frame (SRF) based control method to the effect of voltage sag and reduces the harmonic present in the system. SRF method can be used for the mitigation of power quality problems from the supply voltage and current. In the case of UPQC the voltage and current signals are transformed from a-b-c quantities to d-q frame. In the case of SRF theory d-q coordinates rotates with supply voltage. The figure 2 shows the control block of series active filter. The voltage at the point of common coupling is converted in to the rotating frame by using abc-dqo conversion. With the help of low pass filter (LPF) the harmonics and oscillatory components of voltage are eliminated.

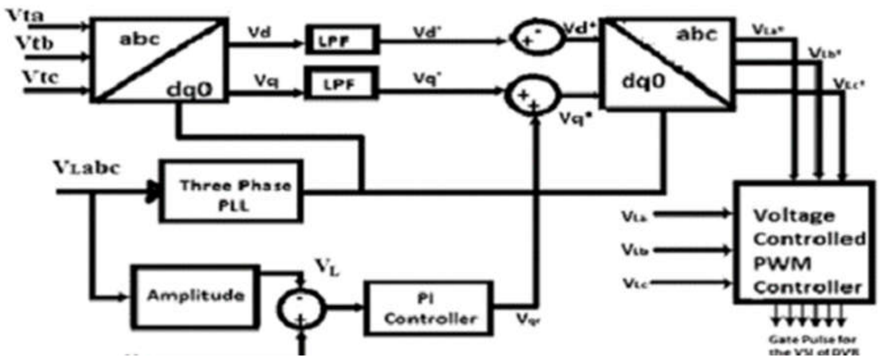


Figure.2. Control Block of Series Active Filter

The figure 3 shows the control block of shunt active filter. In this control method the inputs are given to the controller. A PLL is used to generate unit voltage templates. Current signals are transformed into d-q frame and again back to a-b-c frame. In order to maintain constant DC bus voltage, the error between the reference dc capacitor voltage and the sensed dc bus voltage is given to the PI controller. The output signals are fed to the hysteresis controller for generating pulses for the inverter.

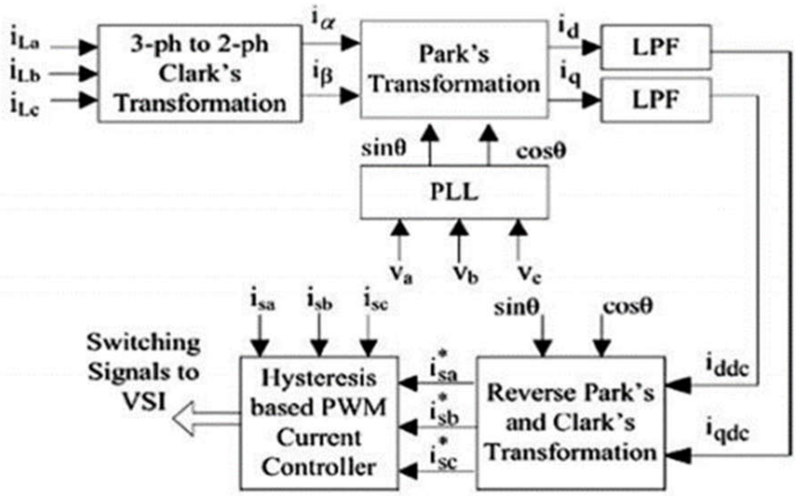
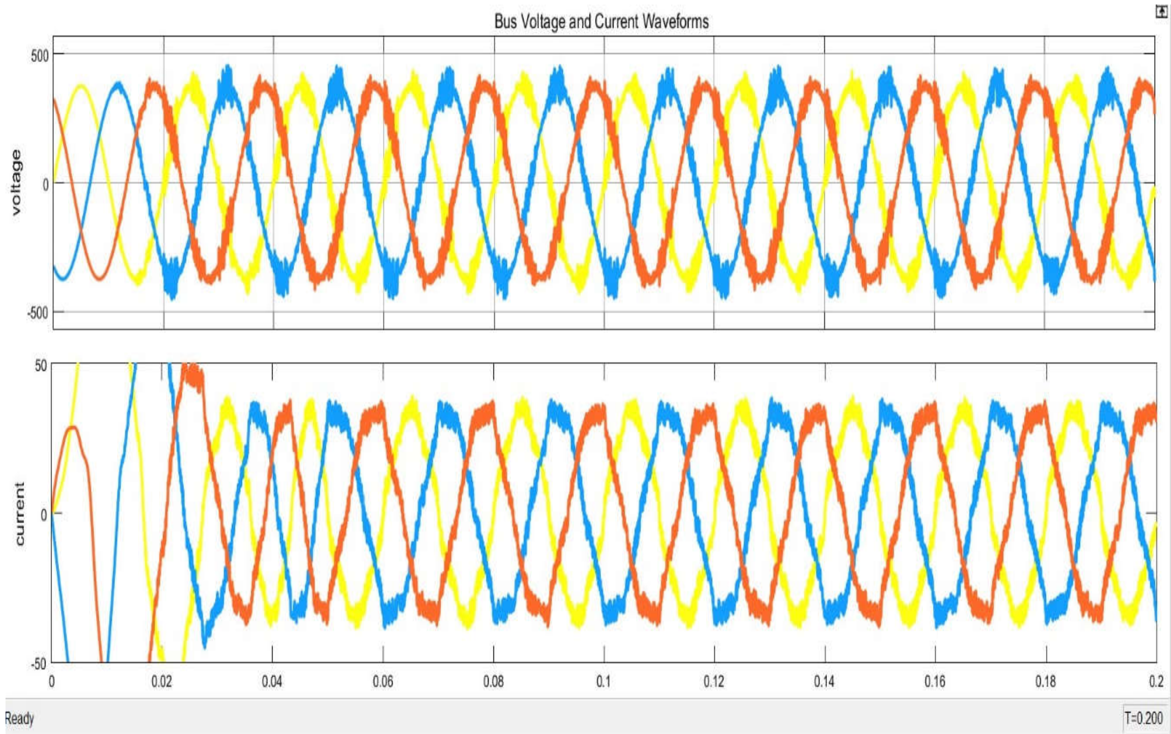


Figure.3. Control Block of Shunt Active Filter

VI. SIMULATION RESULTS

The UPQC is placed in the 14th bus if the test system (IEEE 33bus system). The overall system is simulated in MATLAB/SIMULINK. The 33 bus voltages can be measured individually and three phase faults can be added to the bus. Here 14th bus is assumed to be the bus with the power quality issue.



The bus voltage in the test system can be determined by the load flow. Its waveform can be found in simulation as shown in above figure 4. This waveform has more distortions in it. Thus, it implies any bus in the distribution system having three phase RLC load have injected harmonics in it.

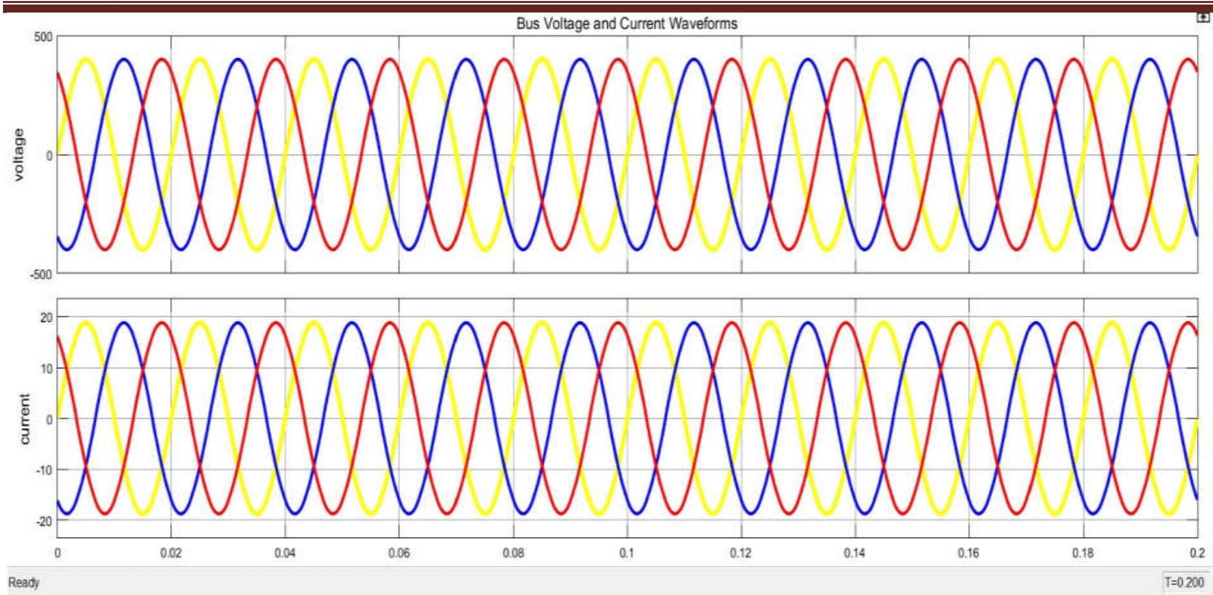


Figure.5. Bus Voltage and Current Waveforms at 14th bus by using UPQC

The bus voltage is thus given as input to the UPQC installed at the bus. Here, the bus taken into consideration is 14th bus. The figure 5 shows the input voltage current of UPQC. There is an enormous amount of injected harmonics in the line. Thus large current flows in the line.

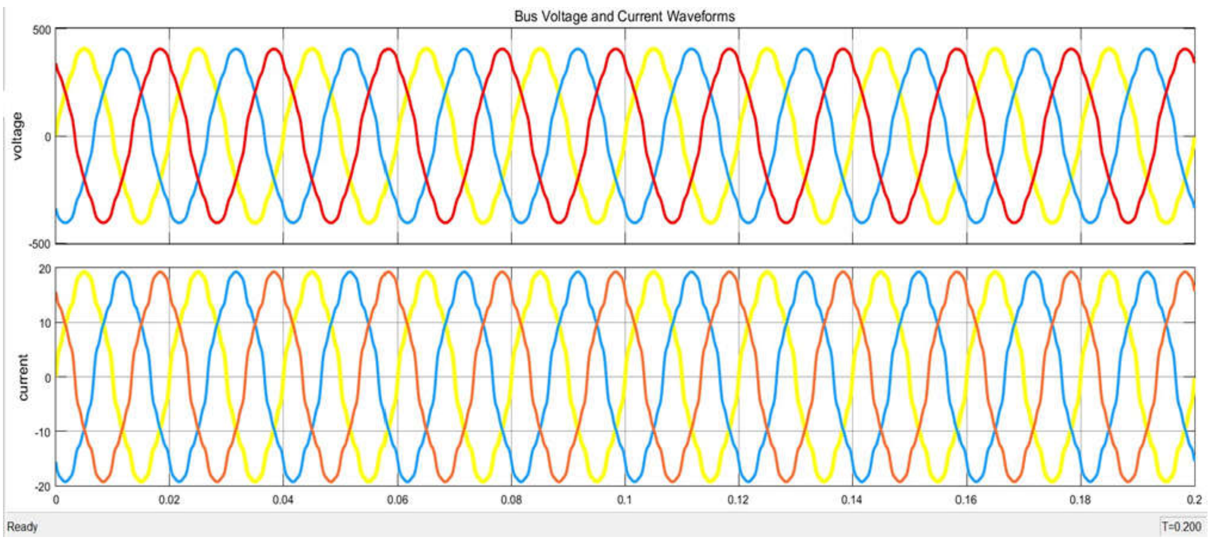


Figure.6. Voltage and Current Waveforms at the source end

After the installation of the UPQC, the line distortions are much reduced because of the capability of the device to improve the power quality at the point of installation. The figure 6 shows that the line current has much lesser injecting harmonics in it. And there is an approximately pure sine wave for each phase. But the process takes some time to give the output. Similarly, for the voltage waveform, the UPQC is connected to the line which is distorted and is simulated. The figure 7 shows the output voltage with lesser injecting harmonics in it.

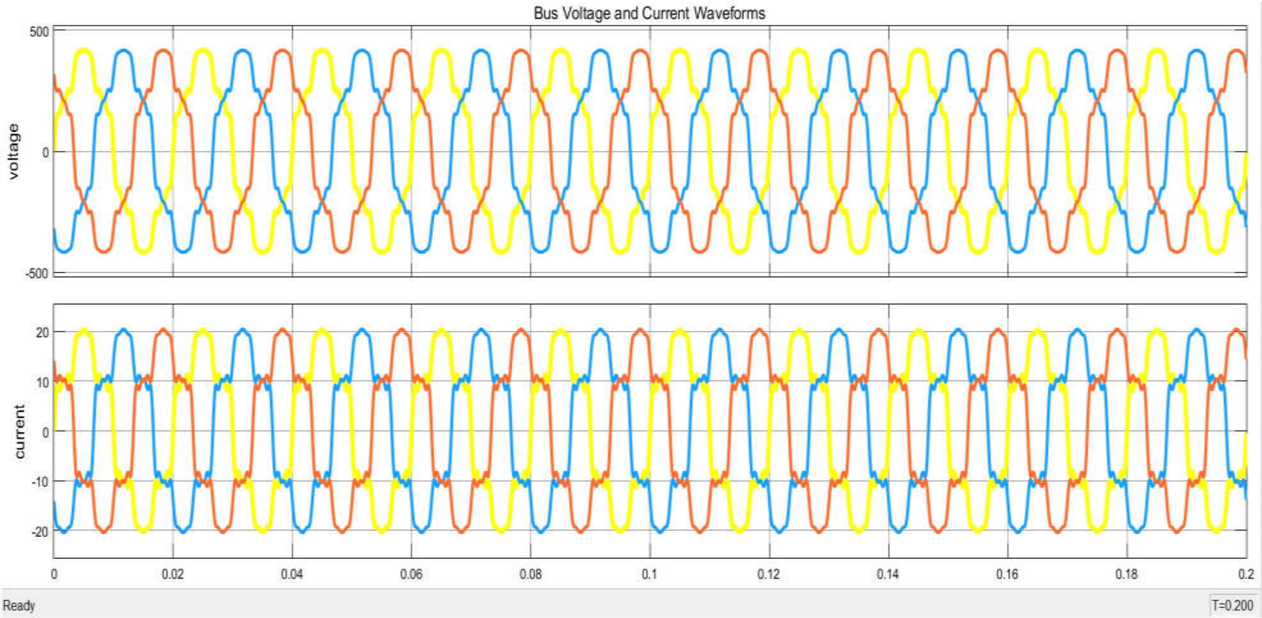


Figure.7. Voltage and Current Waveforms at the load end

VII. FFT ANALYSIS

The FFT analysis is done in order to find the frequency components in the noisy distorted signal. By doing FFT analysis with the frequency of 50Hertz the THD obtained at output voltage is 0.42% and THD for output current is 0.63%.

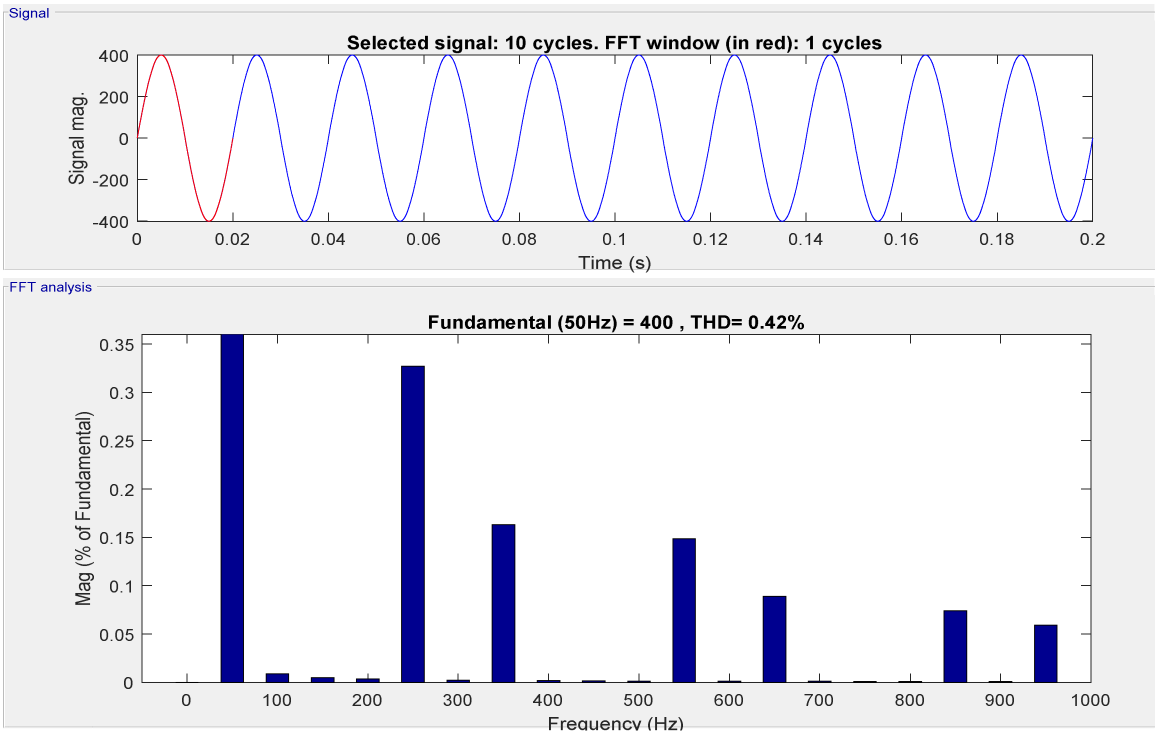


Figure.8.FFT Analysis of Output Voltage

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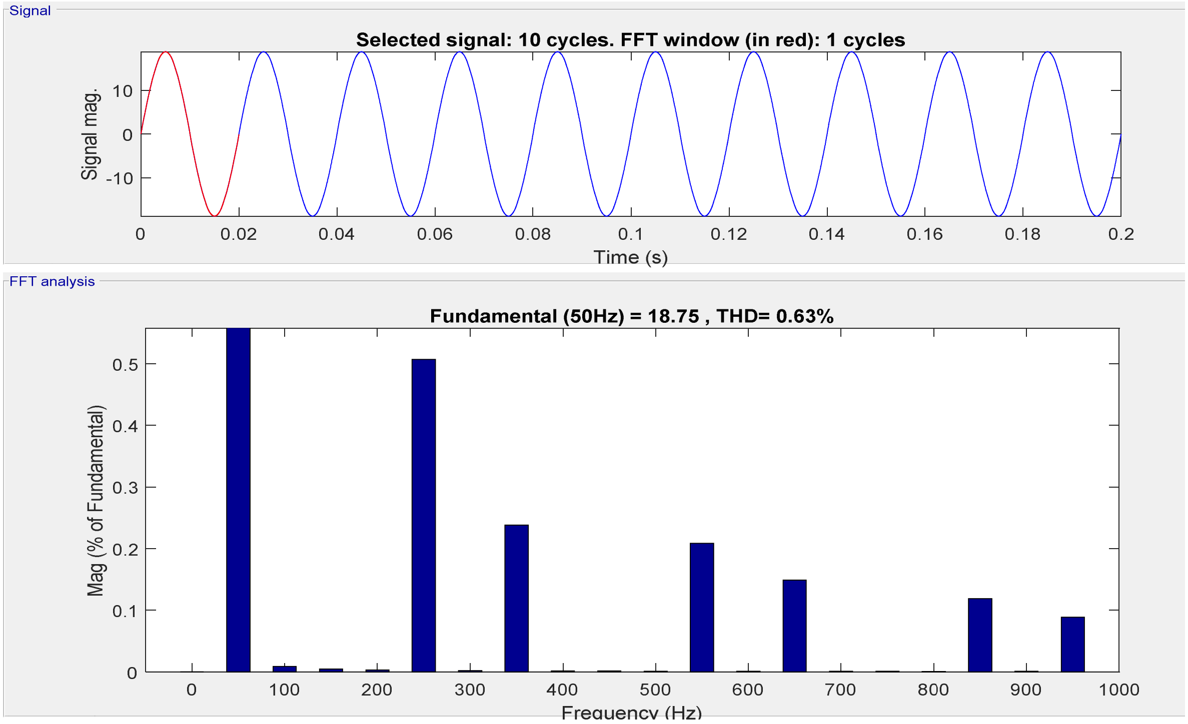

Figure.9.FFT Analysis of Output Current

VIII.CONCLUSION

A noticeable trend in the distribution systems is the emergence of distributed harmonic producing loads. These loads typically have comparable sizes and are distributed all over an electric network. There is a need to develop new techniques to assess harmonic distortions for systems with distributed harmonic sources. The objective of the project is to minimize the power quality problems with the implementation of power quality enhancement device UPQC. This device has the capacity to improve the power quality at the point of installation. Here, UPQC has been placed in the IEEE 33 bus radial distribution systems. Thus, the improved voltage and current waveforms are obtained i.e., with lesser injecting harmonics. The system is simulated in MATLAB/ SIMULINK.

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