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An Improved Power Quality Solution for Power System using Custom Power Devices

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Abstract*: This paper handles the virtual implementation of the Unified Power Quality Controller (UPQC) in distribution network to improve the excellence of power in an electrical distribution network. The UPQC mainly consists of a series and a shunt active filter. The harmonics compensation is achieved series filter by providing a sinusoidal network current. Whereas, the distortion in the network such as sag, swell and flicker are balanced by the shunt active filter by providing the voltage. The Proposed system uses phase lock loop (PLL) control algorithm for series filter and hysteresis current controller (HCC) for shunt filter. The results of the proposed system are appraised by comparing with Dynamic Voltage Restorer (DVR) scheme of control. The proposed control scheme of UPQC proved that quality of power can be significantly better than DVR Scheme of control.

Index Terms*: Power Quality, Dynamic voltage restorer (DVR), Power conditioning Devices, Total harmonic distortion (THD), Sag, Swell.

I. INTRODUCTION

At present, in today's life, electrical energy has become very important . Most of the industrial and commercial loads need high quality constant power. The maintenance of the qualitative power is of top most important. Power electronics devices cause harmful effects on quality and continuousness of electric supply such as UPS (Uninterrupted Power Supply), flicker, harmonics, and voltage fluctuations etc. Apart from this, there also exist the problems associated with power quality (PQ) such as voltage rise or dip due to network faults, lightning, switching of capacitor banks etc. There exist a reactive power disturbances and harmonics in PDS (Power Distribution System) due to redundant use of loads such as computer, lasers, printers, rectifiers which are non-linear Therefore, it is necessary to overcome this type of problems as its effects may increase in future and cause unfavorable effects. The FACTS and custom power devices are being used for improving power quality in electrical system.

Swapnil Y et.al [1] proposed UPQC with d-q-0, and P-Q theory which reduces the complexity of the control. It reduced voltage distortion and current harmonic. The authors in paper [2] proposed the FACTS device DSTATCOM to compensate the issues in quality of power in the electrical system. It generates the reference load voltage for DSTATCOM with voltage control mode. And also it satisfies several advantages compared to traditional voltage controller DSTATCOM.

Marcos balduino et.al [3] proposed a technique to balance individual DC voltage to minimize number of switching losses by eliminating the excessive unwanted commutations by using modulation approach for symmetrical cascaded MLI. In [4] discussed the main advantage of control scheme in relation to other scheme.

Manoj kumar et.al. [5] Proposed a three leg DSTATCOM to alleviate the power quality problems due to the loads that are unbalanced and non-linear. In this discussion the proposed control algorithm meaning fully compensate problems related to power quality due to the unbalanced nonlinear loads in turn maintain the source current in sinusoidal balanced state at preferred power factor. In paper [6], author proposed the theory for elimination of harmonic content and also estimated the theories for three phase system power quality improvement. In this work, series active power filter has been designed and implemented to eliminate the harmonics and also discussed the algorithm used for estimation of the harmonics.

In [7] Dual voltage source inverter is recommended for the improvement of Power quality in micro-grid system. Here reference currents are produced by a algorithm called instantaneous symmetrical component theory. This system has a capability of compensating local unbalanced, nonlinear loads and also the exchange of power from distribution generators. In [8], the DSTATCOM is proposed for compensating the reactive power, balancing the load as well as the harmonic compensation., moreover the inner current control of DSTATCOM is achieved by multiband hysteresis current control. is used for inner current control of DSTATCOM. This system possesses many advantages such as economical, compact size and superior attenuation capability.

In this work [9] Modular Multilevel Converter fed by current source along with the static compensator (STATCOM) is suggested for High Voltage DC transmission and Flexible AC Transmission System applications. Here the STATCOM topology is based on voltage source inverter (VSI).

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Due to this topology high b performance characteristics is achieved better when comparing with other compensation technique like thyristor switched capacitor and thyristor-controlled reactor. In [10] the STATCOM is used to supply and consume the reactive power. Chandan kumar et.al [11] addressed power quality issue like reduction of current and voltage by using unified power quality conditioner. This arrangement utilizes an inductor capacitor inductor (LCL) with VSI, here the LCL arrangement is connected with the Shunt VSI at the starting end. This system possesses compensation of current and voltage in better way. More over it has the better ripple attenuation due to the presence passive components.

M.K. Elango et.al [12] proposed a methodology for the improvement of PQ by using UPQC with distributed generator. The proposed system compensates quality issues in the current and voltage with respect to sensitive loads. These works also addresses the compensation of voltage sag / swell, suppression of harmonics in load current, the problem of harmonics in phase and neutral current due to distorted supply conditions. In [13], Hybrid Series Active Power Filter has been used to minimize the harmonics in voltage and current, this work considers transient as well as the steady state for the performance study of power system. The author [14], proposed a solution for the generation of clean energy with enhancement in power quality. This work also proposed a personalized p-q theory for PV integrated UPQC for enhancing the performance of the system.

Priyanka kumari et.al [15] recommended an efficient model of DVR which is used in Electrical Power Distribution Network (EPDN) to minimize the voltage dip. This also has advantages of fast dynamic response to the disturbance, less cost and compactness. This method is most suited only for custom power devices at low voltage applications. In [16]. Compensating electrical network disturbances in the form of sensitive load protection and compensation of voltage sag / swell and oscillatory response was examined and also analyzed with the dynamic behavior of DVR. This paper [17] mainly deals with the power quality problems due to voltage dip, swell & harmonic in the distribution system.

In [18]**,** the role of DVR is discussed to compensate the parameters which lead to poor power quality like sudden fall in voltage and rise in voltage. Tuo dong et.al [19] considers the per quality issues in microgrid. This work enhances the micro grid's power quality by incorporating an integrated Active Power Filters (APF) along with Static Var Compensator (SVC). This arrangement provides reactive power; minimize power losses and voltage variation on the transmission line. Here Active power filter (APF) reduces the harmonics. In [20] the role of DSTATCOM, DVR in the improvement of power quality of wind power distribution system was studied. In existing methodology two different devices, DVR for voltage related Power quality problems and STATCOM for current related power quality issues are used. The most of the existing methodology consider, any one of the power quality issues like sag & swell (or) harmonics. Very few literatures find the solution for sag, swell & harmonics by a single device. The proposed work handles the power quality issues with the design and the simulation of the UPQC system for improving and mitigating the sag, swell and also harmonics. In this work PLL controller is adopted for series Active Power Filter (APF) and Hysteresis Current Controller (HCC) for Shunt Active Power Filter. The advantages of HCC are fast dynamic performance and controllability of the peak-to-peak current ripple within hysteresis band, the implementation of this control is simple.

II. UPQC FOR POWER QUALITY ISSUES

Generally, UPQC (Unified Power Quality conditioner) is apparatus mainly used for compensating voltage distortion and current unbalance in Electrical power distribution system (EPDS).

UPQC consists of two back to back connected inverter. A common DC link capacitor is used for the back to back connection. One of the inverter in the circuit model is controlled by a variable voltage source of the Series Active Filter (SAF) which is connection with the supply through series transformers. At the same time the variable current source of PAF which is connected in parallel with supply main through parallel inverter controls the other inverter. The UPQC basic schematic diagram with proposed control strategy is as shown in figure 1.

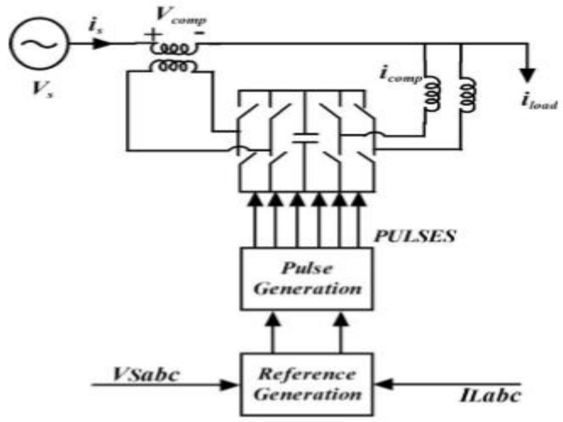

Figure 1.General Block diagrame of UPQC

A. Control scheme of shunt APF

The devices which produce the same amount of harmonics which are produced by the load but at 180˚ phase shifted are known as active power devices. At the point of common coupling (PCC), the Shunt Active Power Filter (APF) introduces the compensating current to make the voltage free from distortions and sinusoidal.

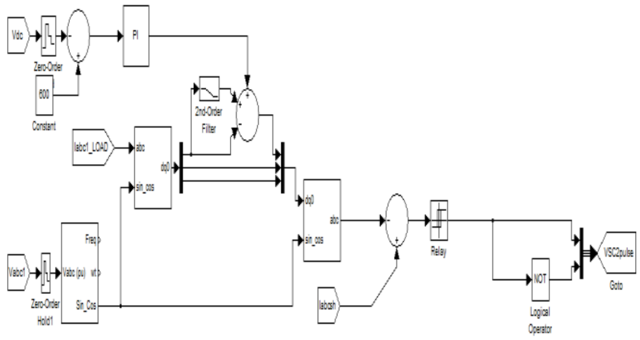

Figure 2 Control strategy for shunt APF

In this type of control strategy, the source voltage and load currents are initially transformed from *a-b-c* phases to d-q-0 coordinates using Parke's transformation. A PI controller with proper gain is used to calculate the power loss across the DC capacitor. The harmonic component of power which is to be compensated is nothing but the imaginary component f real power. The compensating current is determined by d-q-0 coordinates and is converted again into *a-b-c* coordinates by using inverse Parke's transformation method. The transformed current also known as the reference compensating current. This reference compensating current is given to the HCC along with actual out put current of APF.

B .Series APF Control Scheme

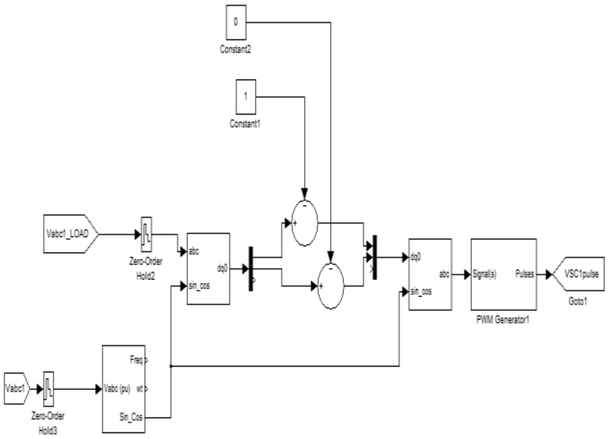

Figure 3 Control strategy for series APF

The series APF control is based on $dq0$ transformation or Park's transformation. In this type, the reference voltage and the actual output voltage of series APF are compared to obtain the control signal . The supply voltage is transformed from abc phases into $dq0$ coordinates. Now, the output voltage is compared with reference input voltage to give an error voltage which is transformed into dqo coordinates. Then, the input and output voltages are again converted to a-b-c phases from *d-q-o* coordinates. Now, Phase lock loop (PLL) is fed by the input voltage and transform *d-q-o* to *a-b-c* coordinates or vice versa.

C. Voltage Balancing of Capacitor

The UPQC system's performance will be able to enhance by maintaining the DC link capacitor voltage at arbitrary reference value of DC voltage. To fix that DC link capacitor voltage the PI controller is being used to analyze it with DC voltage reference. The PI controller presets a DC current as reference so that the voltage across capacitor is maintained as shown in figure 4.

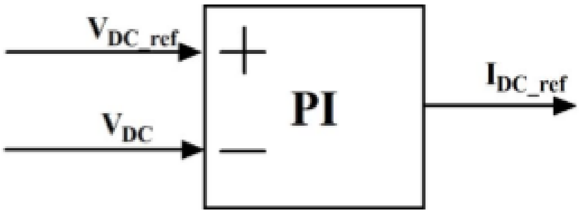

Figure 4 Voltage Balancing of Capacitor by PI Controller

III. Results and Discussions

A. With UPQC

This paper evaluates an UPQC system with a controlled algorithm under input voltage and current distortion at load side by using simulation results. The simulation block diagram of suggested system is shown in figure5. The UPQC system's parameters are shown in Table.1. The results are observed before and after the presence of UPQC.

Table 1. Parameters of UPQC System

S. No	Parameters	Rating
1	Source voltage	400Vrms, 50 Hz
2	PAF side coupled inductor	$50e^{-3}$
3	SAF side couples inductor	$50e^{-3}$
4	DC link capacitor	2000 mF
5	PI gain	Kp-1 Ki-2
6	Linear Transformer	1:1

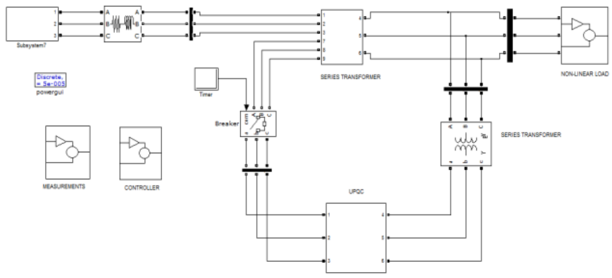

Figure 5 Simulation diagram of UPQC

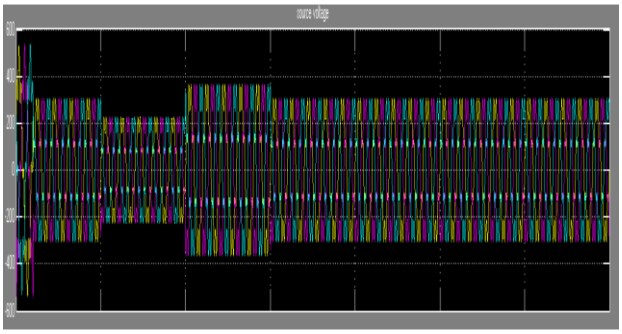

Figure 6(a): voltage at Source

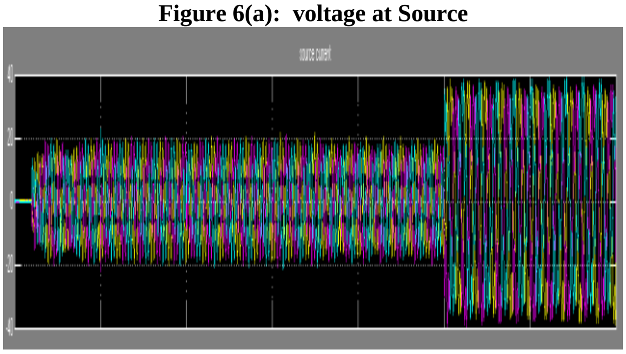

Figure 6(b): Current at source sideside

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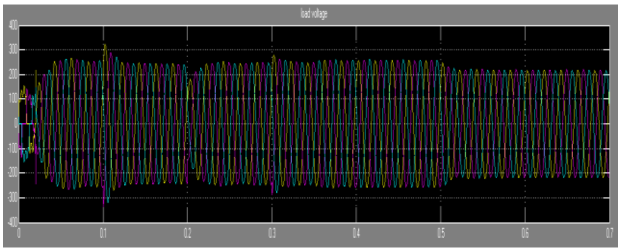

Figure 6 (c): Compensated Load voltage

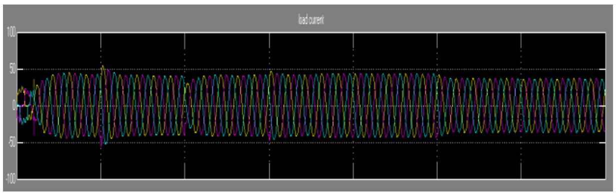

Figure 6(d): load side Current after compensation

From the proposed system, the obtained simulation results are as shown in fig 6. Fig, 6(c) & (d) shows the waveform of the voltage and current at load after mitigating the UPQC with the system. The SAF part of UPQC mitigates the voltage related power quality issues and the PAF of UPQC mitigates the power quality issues related to current.

B. Harmonic analysis with UPQC

FFT analysis is performed adequately for determining the frequency components in the distorted signal. The FFT analysis for the source voltage is shown in figure 7. From the figure, it reveals that the THD percentage in source voltage is about 21.97%. This total harmonic distortion can be further minimized with the help of UPQC. The FFT analysis is again performed after placing UPQC and the result obtained is as shown in figure 8. From figure 8, it is observed that, the percentage of THD has been minimized to 1.79%.

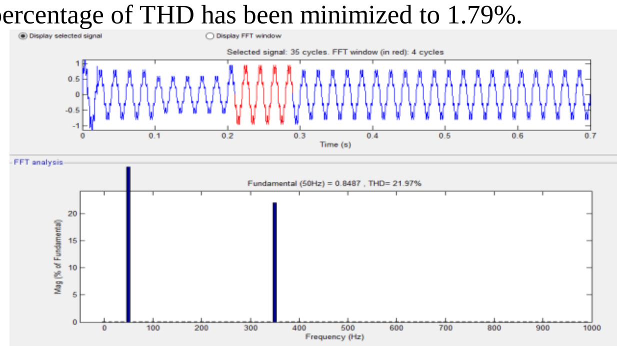

Figure 7. FFT Analysis of source voltage

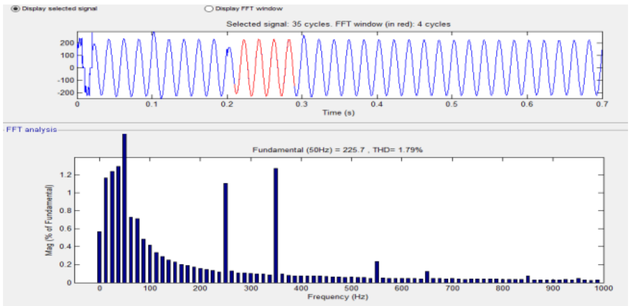

Figure 8 FFT .Analysis of load voltage

Similarly the analysis for source current and load current for FFT are considered and are shown in figure 9 and 10 respectively.

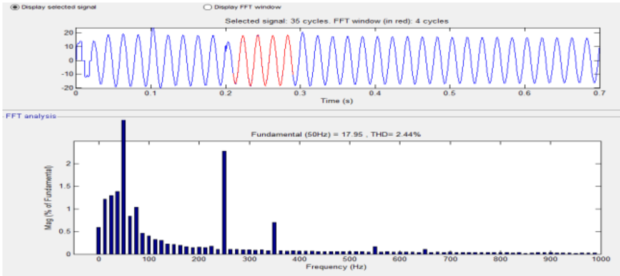

Figure 9. Analysis of Source current for FFT

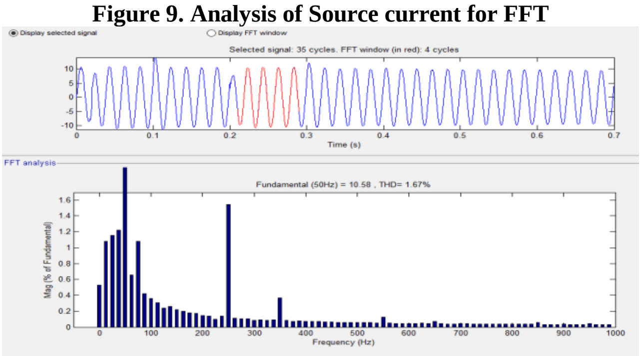

Figure 10. Analysis of load current for FFT

IV. POWER QUALITY ANALYSIS WITH DVR

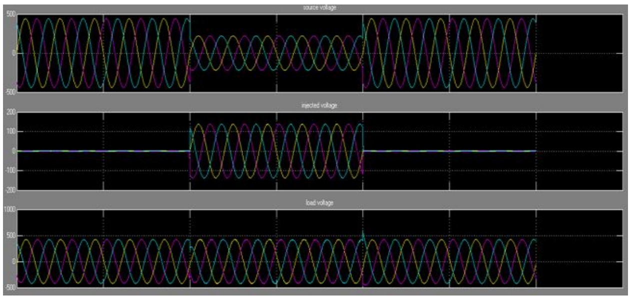

Figure 11 Performance of DVR in sag condition

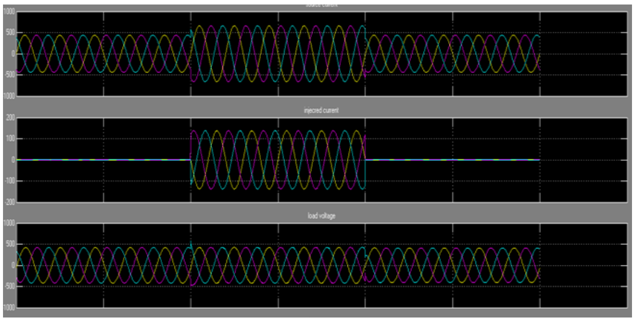

Figure 12 Performance of DVR in swell condition

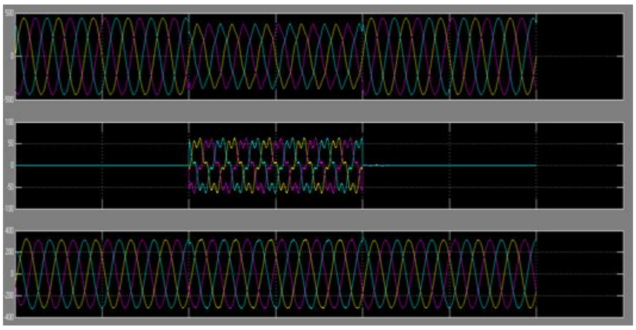

Figure 13 Performance of DVR in harmonic mitigation

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A. Harmonic Analysis with DVR

FFT analysis is performed before and after placing of DVR and results is presented below:

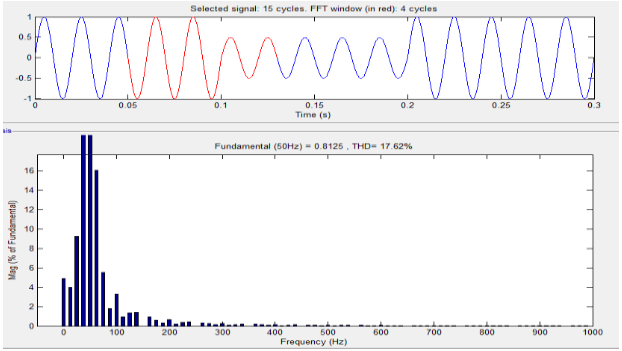

Figure.11 Source voltage FFT Analysis with DVR

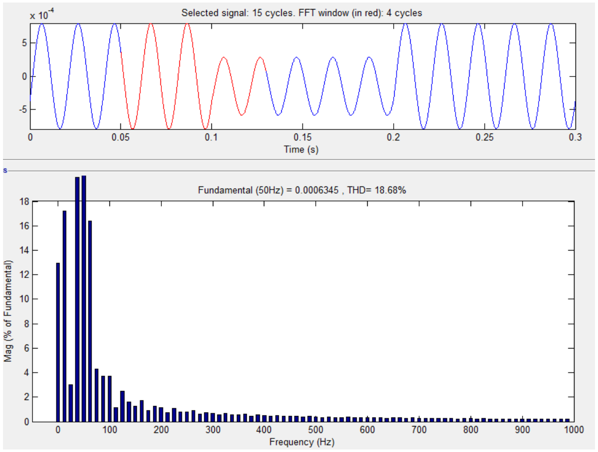

Figure 12 Source current FFT analysis with DVR

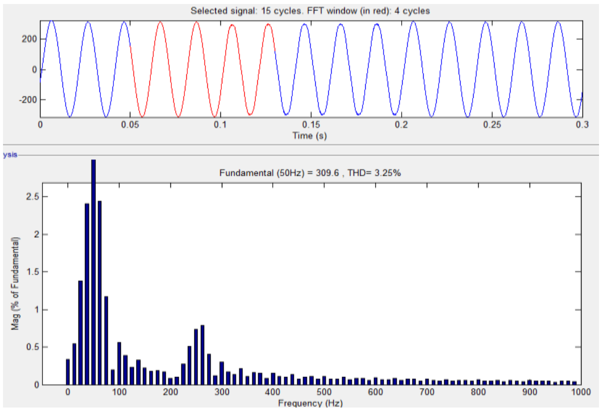

Figure 13. FFT analysis of load voltage with DVR

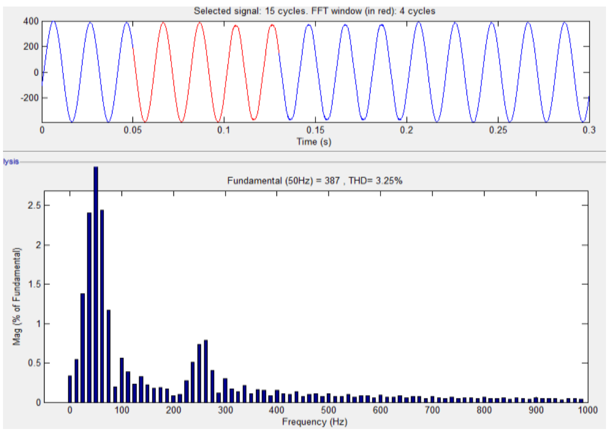

Figure 14. FFT analysis of load current with DVR

B. Comparative Analysis of DVR with UPQC

Table.2 Percentage of THD

S.N O	PARAMETERS	DVR THD (%)	UPQC THD (%)
1	Source voltage	17.62%	21.97%
2	Source current	18.68%	2.44%
3	Load voltage	3.25%	1.79%
4	Load current	3.25%	1.67%

From the FFT analysis, the THD for DVR is 3.25 whereas for UPQC is 1.79. It is proven that the THD can be better with the UPQC control scheme when compared to DVR.

Each and every custom power devices has its own merits and limitations. When compared with all the custom power devices, due to its advantages and special features like flexibility UPQC is considered as most efficient device and is widely used to solve the problems associated with large capacity loads having disturbances in load current and supply voltage . UPQC consists of combined features of DVR and D-STATCOM. Hence, UPQC replaces the use of two devices (DVR & D-STATCOM).

V. Conclusion

This paper recommends a solution for getting quality power through electrical distribution system. The major power quality problems considered in this paper are voltage dip, voltage swell and variations in harmonics. The performance of UPQC in power quality issue is compared with DVR scheme of control. The proposed UPQC control scheme proved that the power quality issues can be considerably mitigated better than the DVR Scheme of control. This work utilizes the UPQC with an improved control scheme to mitigate the problems related to power quality like swell, sag and harmonics. The phase locked loop control algorithm is used for the control of series filter, whereas hysteresis current controller adopted for shunt filter.

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