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DESIGN AND ANALYSIS OF SERIES ACTIVE FILTERS FOR POWER QUALITY IMPROVEMENT

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Abstract: The voltage quality is one of the major concerns for industrial and distribution consumers. In this work, a series active filter for voltage compensation has been verified using vectorial power theory for a three-phase system with non-linear load. The simulation has been designed using MATLAB/Simulink. The control scheme provides better unbalance voltage compensation and voltage regulation for three phase system with non-linear loads which operates in different conditions. The design and simulation of series active filter performance results were presented in this paper to show effectiveness of controller.

Index Terms - Series Active Filter (SAF), Power Quality Improvement (PQI), Voltage unbalance, Power vectorial theory

I. INTRODUCTION

In the modern electrical distribution system, power quality is one of the major issues. The power quality can be analyzed as voltage unbalance, voltage sag and swell, partial or total loss of one or more phases. The voltage unbalance is mainly caused due to uneven distribution of single-phase loads which may continuously changes across a three-phase system.

The lack of quality power can cause loss of production, damage of equipment or appliances, increased power losses, interference of communication lines and so forth. The power system equipment and customer equipment's such as overhead and underground cables, transformers and rotating electric machines, protection systems also affected with poor quality voltage. Passive filter has been used traditionally for mitigating the distortion due to harmonic current in industrial power sector [2]. But they have many drawbacks such as resonance problem,
dependency of their performance on the system impedance, absorption of harmonic current of nonlinear load, which could lead to further harmonic propagation through the power system .

To overcome of such problems active power filters is introduced. It has no such drawbacks like passive filter. They inject harmonic voltage or current with appropriate magnitudes and phase angle into the system and cancel harmonics of nonlinear loads. But it has also some drawbacks like high initial cost and high-power losses due to which it limits their wide application, especially with high power rating system. The widespread use of power electronics-based equipment has produced a significant impact on quality of electric power supply.

The increasing severity of harmonic pollution in power networks has attracted the attention of power electronics and power system engineers to develop dynamic and adjustable solution to the power quality problems [6]. The unbalanced voltage can be compensated with use of three-phase series active filter which regulate the voltage to the desired level.

In this paper design and simulation of a three-phase series active filter for unbalance voltage compensation has been demonstrated with use of power vectorial theory.

II. BASIC COMPENSATION PRINCIPLES

Active filters are a perfect alternative to the passive filters. The active filters are used in a condition where the harmonic orders change in terms of magnitudes and the phase angles. In such conditions it is feasible to use the active elements instead of passive ones in order to provide dynamic compensation. The active filters are used in nonlinear load conditions where the harmonics are dependent on the time. Just like the passive filters, active filters can be connected in either series or parallel depending on the type of sources which create harmonics in the power system. The active filters minimize the effect of harmonic current by using the active power conditions to produce equal amplitudes of opposite phase there by cancelling the harmonics that are caused in the nonlinear components and replace the current wave from the nonlinear load

The basic compensation principle of series active power filter is shown in Fig 1. A voltage source inverter (VSI) is used as the series active power filter. This is controlled so as to draw or inject a compensating voltage $V_{s.}$ from or to the supply, such that it cancels voltage harmonics on the load side i.e. this active power filter (APF) generates the distortions opposite to the supply harmonics [8]. The compensating voltage injected by the series active power filter which contains all the harmonics, to make the load voltage purely sinusoidal. This is the basic principle of series active power filter to eliminate the supply voltage harmonics.

quality issues that are caused by the operation of the system can be traced back to its transformers, capacitors, feeders, and switching at high loads. Typically, transitory power quality concerns are caused by natural factors, such as: B. Transient phenomena of voltage drop (dip), voltage distortion, expansion, and shock and vibration. However, human causes are responsible for both temporary and permanent power quality problems. However, harmonics are one of the most significant power quality concerns. This can be caused by loads that do not operate linearly, including classic loads like transformers, electric machines, and furnaces, as well as innovative loads like rectifiers and steam lamps. Switch mode power supply (SMPS), ASD with AC-DC converter, cycloconverter, AC voltage regulator, HVDC transmission, VAR static compensator, and other similar devices. All affected utilities, customers, and manufacturers incur considerable economic losses owing to process interruptions and damaged equipment as a result of power quality concerns. The loss of production, the squandering of raw materials, the erasure of critical data, and other associated costs. Even a momentary drop or sag in voltage can cause significant problems in a number of contexts and applications, such as automated industrial processes, the production of semiconductors, the pharmaceutical industry, and banking, where it can disrupt operations for several hours and result in the waste of raw materials and other resources.

Some power quality issues impact the protection systems and lead to malfunctioning protective equipment. These disrupt several industrial operations and procedures and other organizations. Additionally, these attributes have an impact on a diverse set of measuring equipment, in addition to the metering of quantities like voltage, current, power, and energy. In addition, the monitoring systems of a significant quantity of major, critical, emergency, vital, and expensive equipment are impacted as a direct result of these problems.

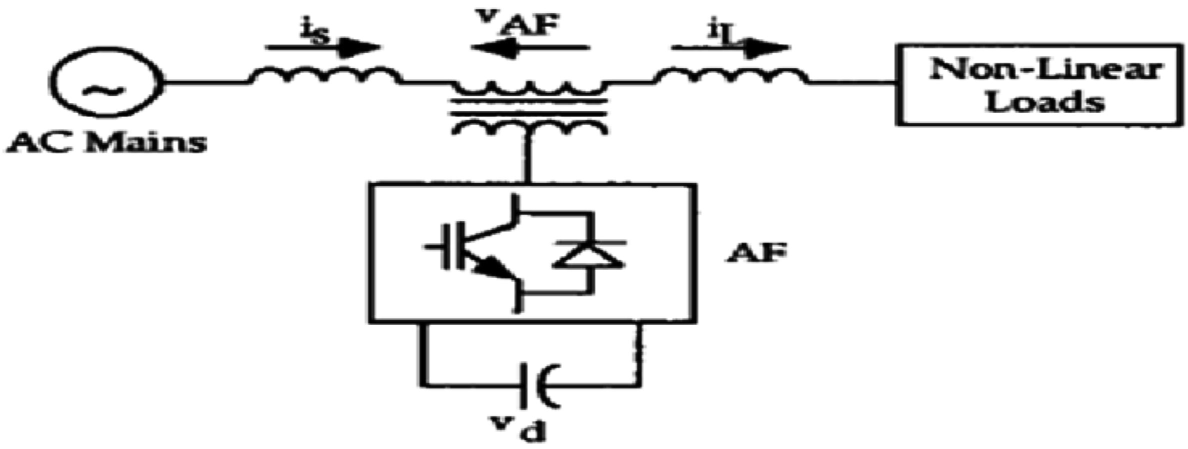


Fig.2.1 Series active filter

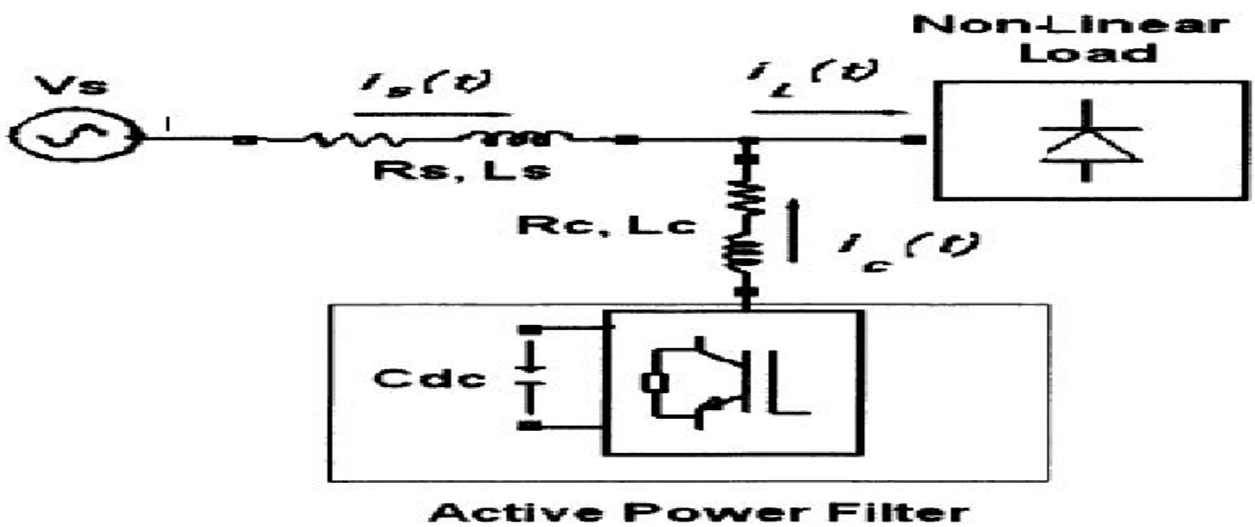


Fig.2.2 Basic compensation principle of APF

Fig.2.1 shows the basic compensation principle of the shunt active power filter. A current Controlled voltage source PWM converter with necessary passive components is used as an active power filter. It is controlled to draw/supply a compensated current from/to the utility, such that it eliminates reactive and harmonic currents of the non-linear load. Thus, the resulting total current drawn from the ac mains is sinusoidal. Ideally, the APF needs to generate just enough reactive and harmonic current to compensate the non-linear loads in the line .

The pulses for the series active filter are generated with help of power vectorial theory which corrects and regulate the unbalance voltage in three-phase system. Fig.3 shows the schematic diagram of series active filter which composed of a three-phase PWM voltage source inverter which is injecting compensation voltage through a three separate 1-Ø transformers. The output of inverter is then connected to a second order filter to eliminate the high frequency which is caused by the high switching action of Fig.3 Diagram of proposed Series active filter the inverter. The secondary winding of each transformer is connected in series with each phase of the power supply as shown in Fig.2.3

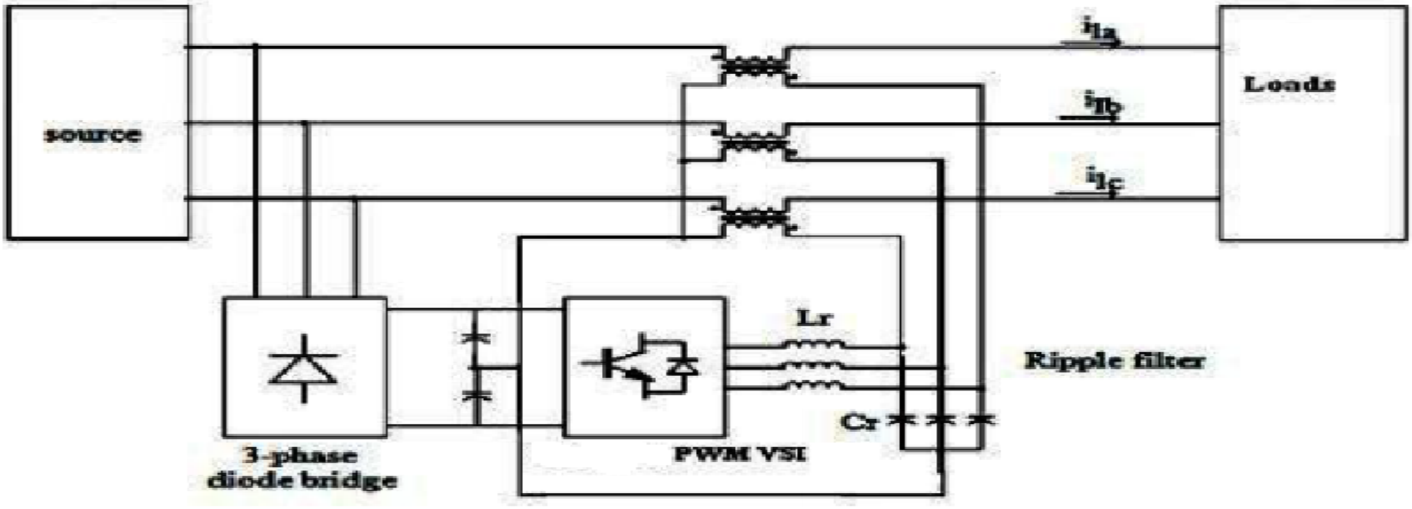


Fig.2.3 Diagram of proposed Series active filter

III. PROPOSED METHOD

From the review of some papers on power quality improvement, using passive filter, active filter etc., so many methods will be introduced but when we use passive filter it suffers from resonance and additional fault will be needed like active filter suffer from mitigate problems and standard hybrid power filter is unable to compensate the reactive power because of the behaviour of the passive filter. Due to this problem we unable to reach IEEE THD standards. In this proposed work, it is a new combination of a passive filter and shunt active filter is proposed to suppress current harmonics and compensate the reactive power generated from the load. The hybrid filter consists of a series connection of a small-rated active filter and a fifth-tuned *LC* passive filter. In the proposed topology, the major part of the compensation is supported by the passive filter and the TCR while the APF is meant to improve the filtering characteristics and damps the resonance, which can occur between the passive filter, the TCR, and the source impedance. The shunt APF when used alone suffers from the high kilo volt ampere rating of the inverter, which requires a lot of energy stored at high dc-link voltage. Hence, the proposed combination of SHPF and TCR reduces significantly the volt ampere rating of the APF part. The control method of the combined compensator is presented. A control technique is proposed to improve the dynamic response and decrease the steady-state error of the TCR.

IV. SIMULATION & RESULTS

The below figure 4.1 is the schematic diagram of the modelled diagram of distribution system which has uncontrolled rectifier feeding an Resistive-Inductive load. PCC is the point on the transmission line at which the active filter can be connected. The non-linear load connected at the load side can either be single phase or three phase supply based on the industrial requirement. The MATLAB Simulink model of three phase uncontrolled rectifier feeding an Resistive-Inductive load is depicted here which has the voltage source and impedance connected to the single-phase electric arc furnace. The measurement devices are connected to the load block which kept inside the subsystem connected at the end.

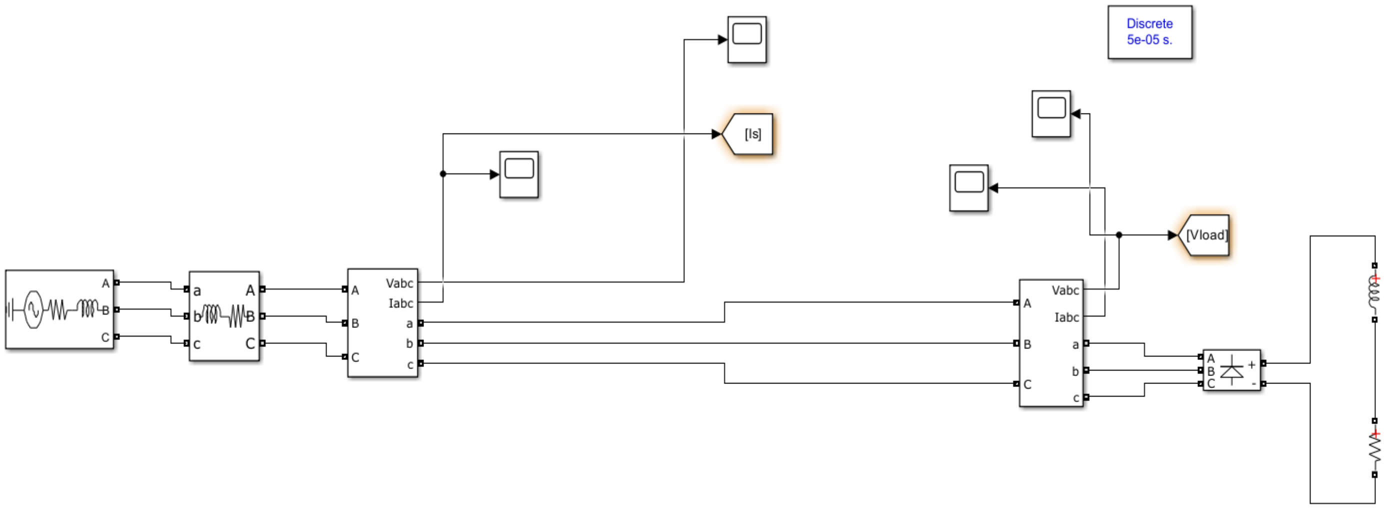
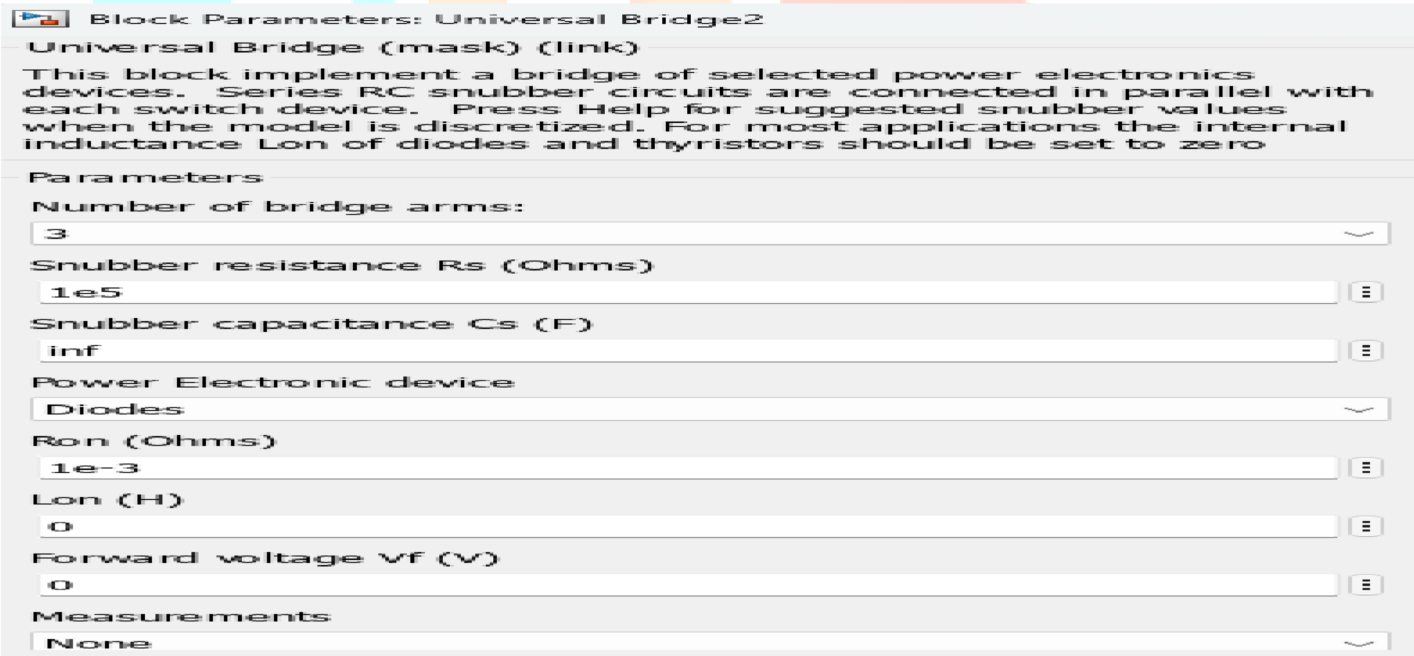


Fig: 4.1 single line diagram of system

In order to create a harmonic injecting load for the harmonic analysis and its impact on the supply, an uncontrolled rectifier feeding a Resistive-Inductive load is taken into the consideration and the specification of the realized rectifier is as depicted in the figure 4.2



Block Parameters: Universal Bridge2

Universal Bridge (mask) (link)

This block implement a bridge of selected power electronics devices. Series RC snubber circuits are connected in parallel with each switch device. Press Help for suggested snubber values when the model is discretized. For most applications the internal inductance Lon of diodes and thyristors should be set to zero

Parameters

Number of bridge arms:
3

Snubber resistance Rs (Ohms)
1e5

Snubber capacitance Cs (F)
inf

Power Electronic device
Diodes

Ron (Ohms)
1e-3

Lon (H)
0

Forward voltage Vf (V)
0

Measurements
None

Fig 4.2 load description of an uncontrolled rectifier

The circuit is simulated to assess the performance of the system for evaluating the harmonics of the system parameters

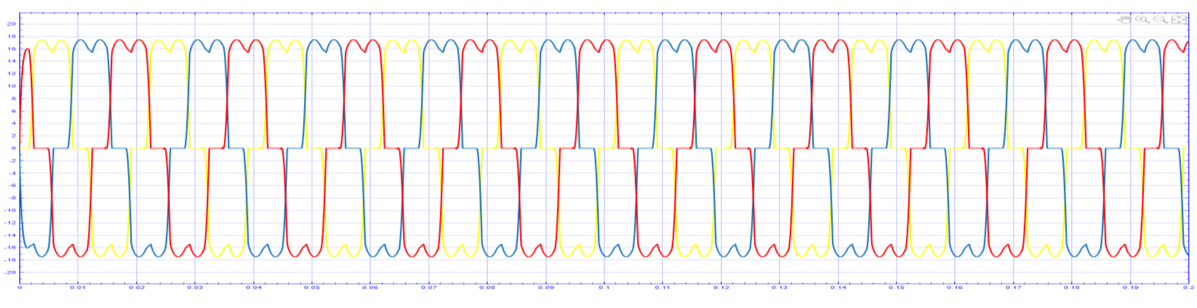


Fig 4. 3-phase load current of an uncontrolled rectifier

The fig4.3 depicts the three-phase load current of an uncontrolled rectifier and it is observed from the figure that the current drawn by the load is non-linear in nature and signifying the presence of harmonics leading to the distortion of the waveform.

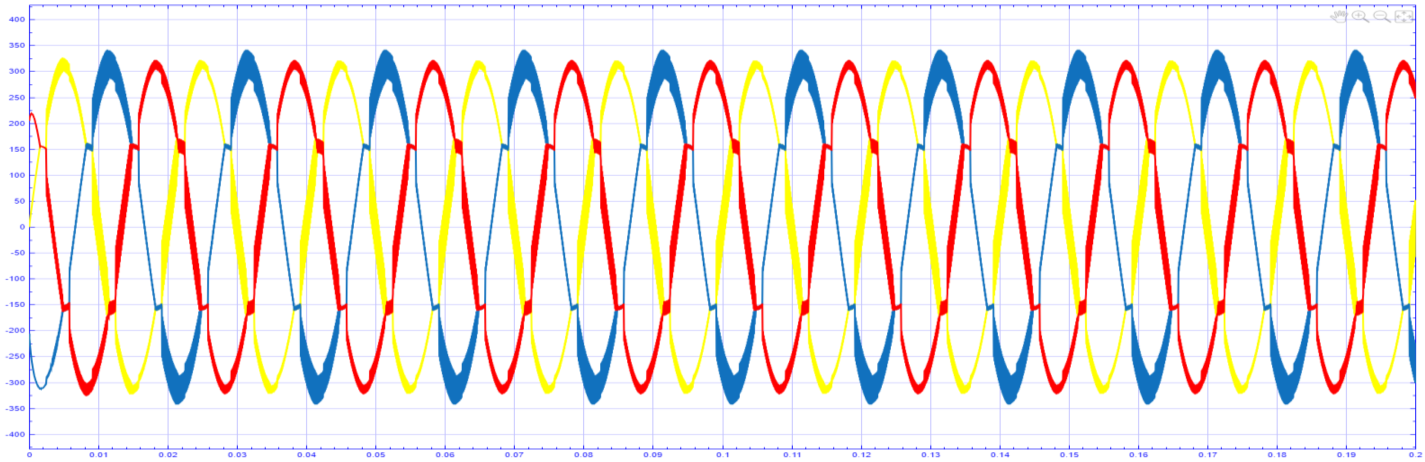
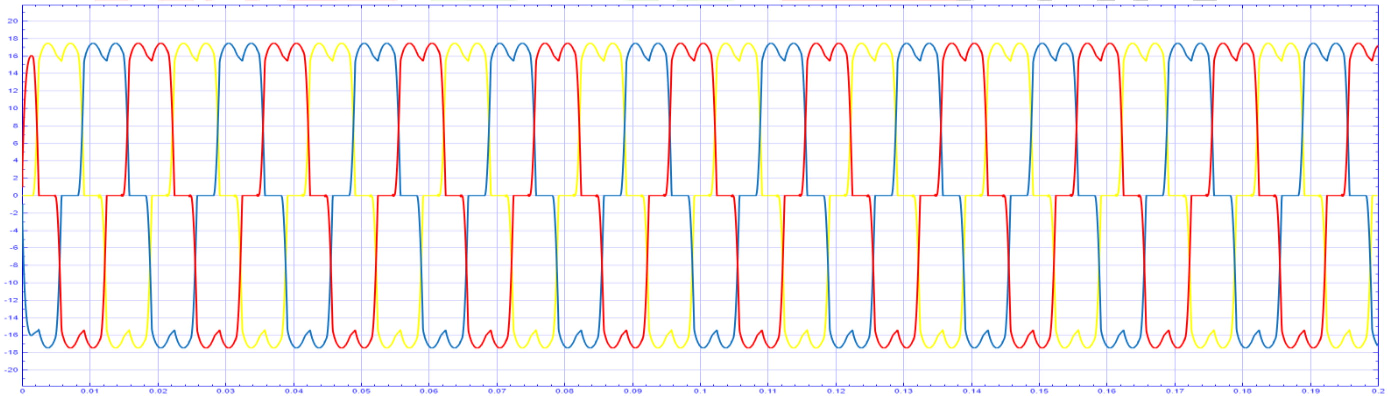


Fig :4.4 Three phase load voltage of an uncontrolled rectifier

The figure 4.4 depicts the three phase load voltage of an uncontrolled rectifier and it is observed from the figure that, since current drawn by the load is non linear in nature results in the distortion of the voltage at the point of common coupling, and the voltage waveform is deviated from its pure sinusoidal form.



The fig.4.5 depicts the three phase Source current of the system, since the load is an uncontrolled rectifier and it is observed from the figure that the current drawn by the load from the source is also non-linear in nature and signifying the presence of harmonics leading to the distortion of the waveform.

The fig.4.5 depicts the three-phase source voltage of the system comprising of an uncontrolled rectifier and it is observed from the figure that, since current drawn by the source is non-linear in nature results in the distortion of the voltage at the source, and the voltage waveform is deviated from its pure sinusoidal form. the harmonic analysis is carried out for the source voltage and the harmonic spectrum of the source voltage is depicted in figure 4.5 and signify the necessity of a suitable compensator to mitigate the effect of harmonics.

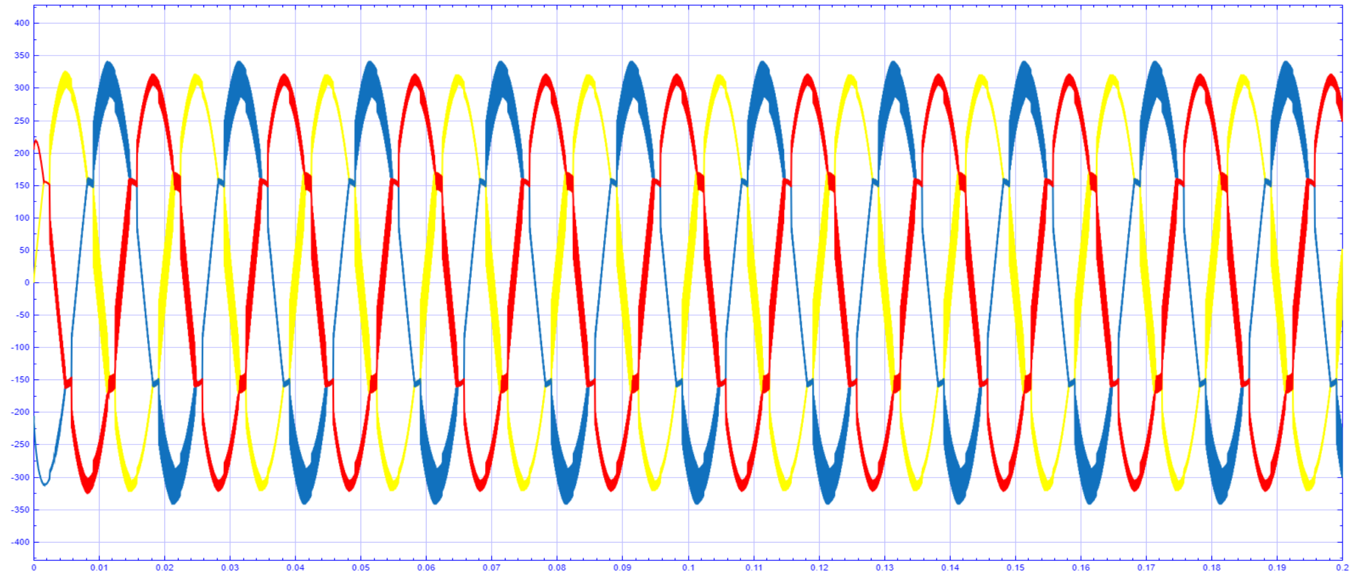


Fig.4.5Three phase Source voltage at source.

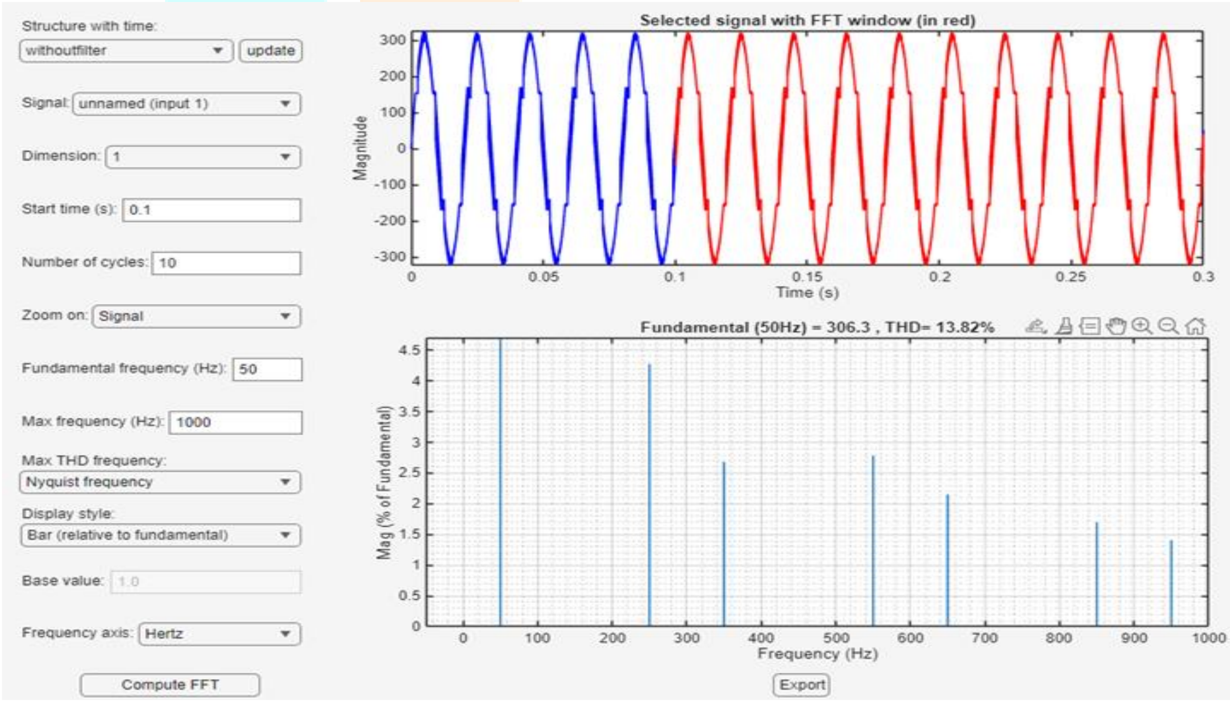


Fig.4.6Harmonic spectrum of the source voltage

IV. CONCLUSION

The proposed idea is to design, develop of series active filter with proper control scheme. The controller has ability to generate the faster reference compensation voltage signal which has been presented and analyzed by computational load and symmetrical components decomposition. The series active filter can perform better in reduction of voltage THD. The simulation results show a very good performance of the proposed algorithm and it was tested under balanced source supplying to non-linear load and also unbalanced source supplying non-linear load. Both cases the controller was able to compensate voltage unbalances at the load terminals.

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