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Power Quality Issues and Its Mitigation by Unified Power Quality Conditioner

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***Abstract*—The quality of electrical power plays vital role in the utility systems and industry. The quality of the power tends to have a direct economic impact on consumers and suppliers. Nowadays, standards and regulations are imposed to maintain the power quality parameters at the Point of Common Coupling (PCC). Growing consumer demands lead to power quality issues. Many consumers may experience severe technical and economic impacts due to power quality problems such as voltage sag, swell, harmonics and voltage interruptions. Therefore, the implementations of innovative and cost-effective compensation techniques are needed.**

Compensation methodology implemented by using high speed power electronic devices is an effective solution for the power quality issues. A custom power device such as Unified Power Quality Conditioner (UPQC) is one of the most versatile active power filter device with the promising ability of improving the quality of voltage and current at the point of installation in distribution and industrial power systems.The research work is primarily concentrated on compensation of voltage sag, voltage swell, and harmonics. The proposed UPQC system improves the power quality in power distribution systems using advance control strategy. The proposed system is based on the instantaneous active power (p) and reactive power (q) control theory. The control strategy of the UPQC system used in the proposed work includes two parts, namely series control and parallel control.

***Index Terms*— Power Quality; Point of Common Coupling; Unified Power Quality Conditioner.**

I. INTRODUCTION

The fast developing countries like India heavily depends on the availability of constant, reliable and quality of electric power supply. In generally to meet the power demand crisis we have to upgrade our transmission and distribution networks, rigorous planning is done for the addition of new generation and the expansion of existing transmission and distribution networks. However, on the other side due to rapid growth in population, industrialization and the development in the IT sector the energy demand is increasing rapidly. To meet this fast growing energy demand from the conventional generation in particular thermal generation is very difficult due to the depletion of coal mines and the severe environmental pollution and in future it will be a serious issue.

On the other side Power Quality (PQ) refers to maintaining the near sinusoidal waveform of power

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distribution bus voltages and currents at rated magnitude and frequency. Thus EPQ is often used to express voltage quality, current quality, reliability of service, quality of power supply, etc. But, the developments of electronics, electrical device and appliances have become more and more sophisticated and they demand uninterrupted and conditioned power. These have pushed the present complex electricity network and market in a strong competition resulting in the concept of deregulation. The operation of these loads/equipments generates harmonics and thus, pollutes the modern distribution system. To meet the growing energy demand renewable energy sources such as solar and wind energy plays a very significant role in the future power system. The integration of these renewable energy sources into the grid involves lot of power electronics equipment during the integration which leads to power quality issues. In such conditions both electric utilities and end users of electric power are increasingly concerned about the quality of electric power.

Active power filters (APF) are placed very important role in the mitigation of various power quality issues in the distribution system. In general APF can be classified as series or shunt according to their system configuration. The series APF can be used to mitigate the voltage based power distortions, while shunt APF can be used to eliminate the current related power quality issues. The combination of both series and shunt power filter is called the unified power-quality compensator (UPQC). In general UPQC can be used to eliminate the voltage and current based distortion simultaneously as well as independently. In this paper the main focus is how UPQC can be used in PQ problems

II. Power Quality Problems And Solutions

The term power quality has become one of the most common parameter in the power industry from the past ten years. Power quality is important because electronic devices and appliances have been designed to receive power at or near these voltage and frequency parameters, and deviations may cause appliance malfunction or damage. Generally, good power quality means that the system supplies and maintains load voltage as a pure sinusoidal waveform at specified frequency and voltage to all power consumers in the power system

A power quality problem can be defined as *"Any power problem manifested in voltage/current or leading to frequency deviations that result in failure or misoperation of customer equipment"* [Dugan, 1996].

The IEEE Standard 1100 [1992], describes power quality as *"the concept of powering and grounding sensitive equipment in a matter that is suitable to the operation of that equipment".*

Power quality is influenced among other factors by utility operations, customer load types and equipment designs. Distribution utilities and their customers, along with their engineering equipment manufacturers and vendors, generate, propagate and receive power quality problems.

Power Quality Problems

Interruption

An interruption is nothing but failure in the continuity of supply over a period of time. Here the voltage and current signals are closed to zero. This is defined according to IEC as lower than 1% of the declared value and according to IEEE as lower than 10%. Based on the time period of the interruption interruptions are classified as short and long interruptions. If the duration for which the interruption occurs is of few milli seconds then it is called as short interruptions. If the duration for which the interruption occur is large ranging from of few milli seconds to several seconds then it is called as long interruptions

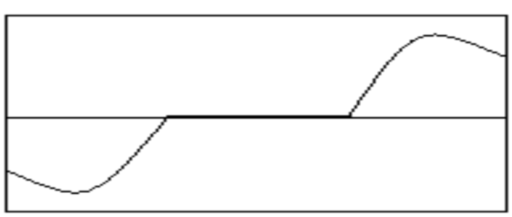

Figure. 2.1 Short Interruptions.

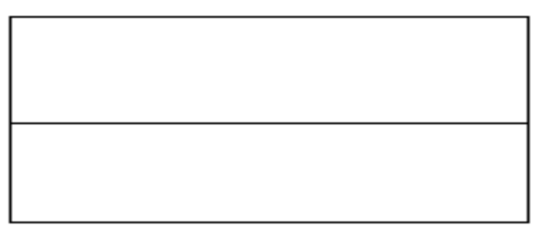

Figure. 2.2 Long Interruptions

Sags

The voltage sag or dip can be stated as decrease in nominal voltage level by 10-90% for short duration for half cycle to one minute as shown in fig.2.3. Sometime, voltage sag last for long duration such prolonged low voltage profile referred as 'under-voltage'. Voltage sag is further divided in three categories: instantaneous, momentary and temporary sags respectively. Voltage sag are mainly caused due to occurrence of faults in power system, overloading of the electrical network and starting current drawn by heavy electrical loads like motors and refrigerators. Voltage sag in power system network results in failure of relays and contactor, dim light and fluctuating power

Figure. 2.3 Voltage Sag or Dip

Swells

Voltage swell can be stated as voltage rise by 10-80% of normal value for duration of half cycle to one minute as shown. Likewise voltage sag, prolonged high voltage profile is referred as 'over-voltage'. Voltage swell is mainly caused by disconnection of large load, Single Line to Ground fault (SLG) results in voltage rise in unfaulted phases and loose connection of neutral wire. Voltage swells results in breakdown of insulation, overheating of electrical equipment and damage to electronic equipment.

Transients

The transients are nothing but momentary changes in voltage and current signals generate in the system itself or come from the other systems. Transients can be classified into two types of categories: dc transient and ac transient. AC transients are further classified into two types namely single cycle and multiple cycles

Harmonic Distortion

Any undesirable components other than the fundamental are known as harmonics. It is nothing but the alternating components having frequencies other than fundamental present in voltage and current signals. Due to the extensive use of non linear loads such as SMPS, VFD, Arc furnaces, Photo copiers, broadcasting equipments etc. are major sources of harmonics. When non-linear loads are connected to the electrical grid, the current that flows through the lines contains harmonics, and the resulting voltage drops caused by the harmonics on the lines impedances causes distortion on the feeding voltages.

III. Objective Of Work

In this paper mainly focused and build the MATLAB/SIMULINK model of unified power quality conditioner which can be used effectively to mitigate the various power quality issues in the power distribution system during the extensive use of nonlinear loads and power electronics interface in the distribution system. The main objective of this paper is to how effectively to mitigate the power quality problems by using UPQC.

IV. Enhancement Of Power Quality Using UPQC

Intrroduction

With the increased integration of renewable energy sources such as solar and wind in the electrical distribution network, power quality improvement has become more critical and to maintain the electrical parameters such as the level of voltage and current harmonics or disturbances will varying in the system. For this reason, Active power filters in that particularly Custom Power Devices (CPDs) such as the Unified Power Quality Conditioner (UPQC) can be used as the most appropriate solution for enhancing the dynamic performance of the distribution network.

Active power filters are effectively used to mitigate the power quality issues. In APF family Unified Power Quality Conditioner (UPQC) is a new member of the custom power device family. It consists of integrated shunt and series active filters. It consists of both series and shunt filter for simultaneous compensation of voltage and current distortions in a supply feeder. The main purpose of a UPQC is to compensate for supply voltage power quality issues such as voltage sags, Voltage swells, unbalance, flicker, harmonics, and for load current power quality problems, such as, harmonics, unbalance, reactive current, and neutral current. Distributed generation (mainly wind and solar generation) is one field where the UPQC can find its potential application. There has been a considerable increase in the power generation from solar PV and wind farms. The application of active filters/custom power devices in the field of wind and solar generation to provide reactive power compensation, additional fault ride through capability and to maintain Power Quality (PQ) at the point of common coupling is become more popularity.

Basic Configuration Of Upqc

Fig. 4.1 shows system configuration of a three-phase UPQC. The key components of UPQC are as follows:

1. Two inverters one connected across the load which acts as a shunt APF and other connected in series with the line acts as voltage source inverter or series APF.
2. Shunt coupling inductor LSh is used to Interface the shunt inverter to the network. It also helps in smoothing the current wave shape. Sometimes an isolation transformer is utilized to electrically isolate the inverter from the network.
3. A common dc link that can be formed by using a Capacitor or an inductor. In Fig.4.1, the dc link is realized using a capacitor which interconnects the two inverters and also maintains a constant self-supporting dc bus voltage across it.
4. An LC filter that serves as a passive low-pass filter (LPF) and helps to eliminate high-frequency switching ripples on generated inverter output voltage.
5. Series injection transformer that is used to connect the series inverter in the network. A suitable turn ratio is often considered to reduce the current or and voltage rating of the series inverter.

The integrated controller of the series and shunt APF of the UPQC to provide the compensating voltage reference V_C^* and compensating current reference I_C^* to be synthesized by PWM converters

The shunt active power filter of the UPQC can compensate all undesirable current components, including harmonics, imbalances due to negative and zero sequence components at the fundamental frequency.

The series active power filter of the UPQC can compensate the supply voltage related problems by injecting voltage in series with line to achieve distortion free voltage at the load terminal.

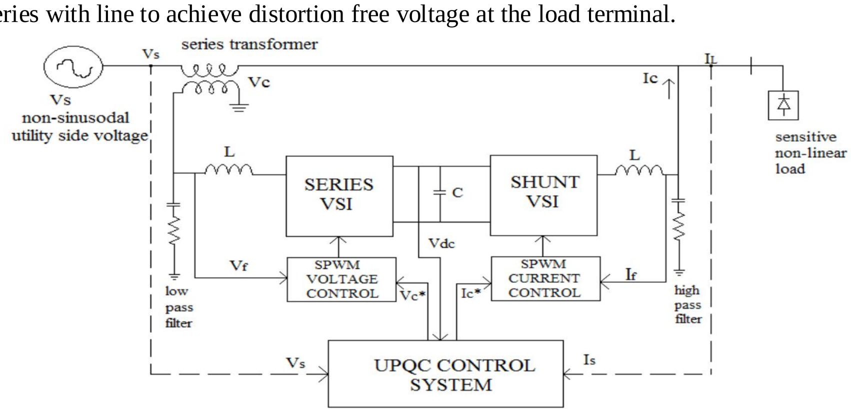

Figure.4.1: Schematic Diagram of UPQC

V. Results And Discussion

In this section, simulation results of Unified Power Quality Conditioner are evaluated by using MATLAB/SIMULINK environment, simulation models have 0been developed. The model is been simulated for non-linear loads to have the distortions in the line. A 3φ diode bridge with RL load on dc side is been used as non-linear load. There are 3 different conditions have been executed with UPQC viz voltage swell, voltage sag & under current distortions. The developed model of UPQC in MATLAB/SIMULINK0environment is shown in Fig.5.1below. Here in this model two filters are used i.e. Series Active Power Filter & Shunt Active Power Filter. Compensation of voltage related problems for maintaining required sinusoidal load voltage is been done by series active power filter. While the shunt filter mainly compensates for current distortions & also maintains the dc link voltage to reference value.

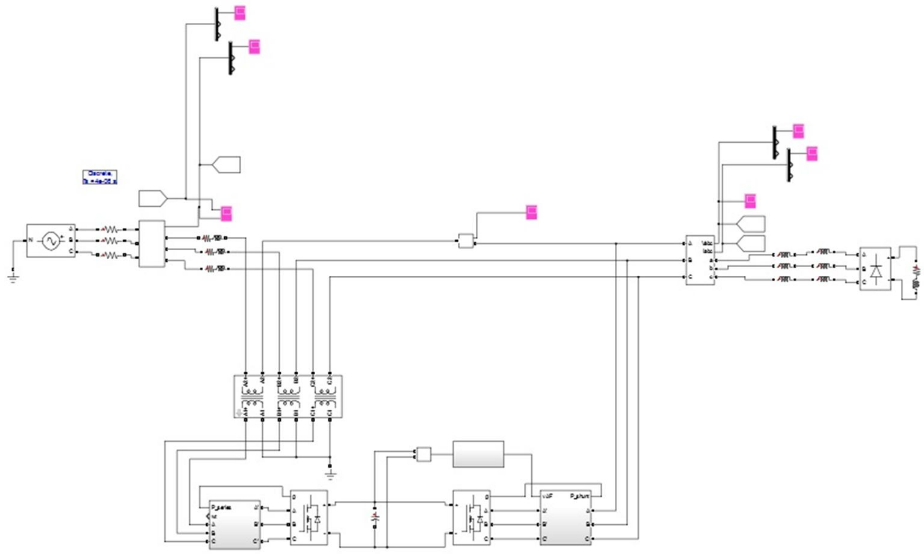

Figure. 5.1: Matlab Simulink Model of UPQC

Voltage Swell and Current Harmonic Compensation

Using simulation model, 20% of swell is introduced in to the supply voltage at 0.1s which lasts till the instant 0.2s as shown in the Fig 5.2. When swell occurs on source side voltage, APF which is connected in series comes into picture. This APF injects out-of phase voltage which equals difference between the actual load voltage & the desired load voltage. Injected voltage is shown in the Fig 5.2(a) By injecting out-of phase voltage by series APF, UPQC cancels the increased source voltage which may appear on the load side & load voltage profile is maintained at desired level Fig Swell in the source voltage means there is some extra power is supplied to the load which may damage the equipments & even the load because of the increase in current drawn. Voltage swell also leads to the increase of DC link voltage. Under such situations, fundamental out-of phase current component is injected by the shunt APF at the instant of swell time. This maintains the DC link voltage at desired magnitude. Thus the source current magnitude decreases. Shunt APF filters the load distortions from entering into the source side thus protecting the system. It is done by injecting required compensating current on the load side & thus making it free from distortions

Voltage Sag and Current Harmonic Compensation

Using simulation model, 20% of sag is introduced in to the supply voltage at 0.1s which lasts till the instant 0.2s as shown in the Fig 5.3. When sag occurs on source side voltage, APF which is connected in series comes into picture. This APF injects in-phase voltage which equals difference between the actual load voltage & the desired load voltage. By injecting in-phase voltage by series APF, UPQC adds up to the decreased source voltage which may appear on the load side & load voltage profile is maintained at desired level. To inject in-phase voltage, some amount of active power will be required by the UPQC. The overall results of the series compensation along with current distortion filtering is shown in the Fig 5.3. Shunt APF filters the load distortions from entering into the source side, thus protecting the system. It is done by injecting required compensating current on the load side & thus making it from free from distortions. Below figure shows the required results.

Current Harmonic Compensation

Simulation results of UPQC which is working as current harmonic compensator is shown in Fig 5.4 All the terminal voltages are assumed sinusoidal for this case, & UPQC is kept into action at 0.1s Current harmonics which are generated by the non-linear load are compensated by shunt APF by injecting current in such a way that the source current becomes sinusoidal. At the same time, power factor is improved by the shunt APF by compensating reactive current of the load.

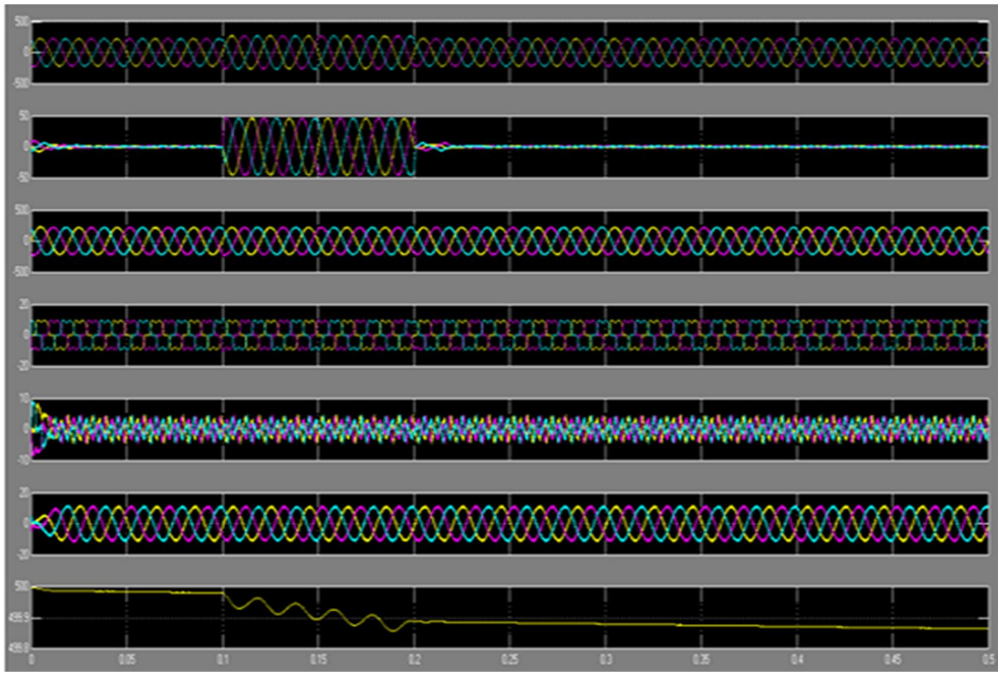

Fig 5.2: Simulation Results of UPQC for voltage swell condition a) Source voltage b) Series injected voltage c) Load voltage d) Load current e) Injected current f) Source current g) DC Capacitor voltage

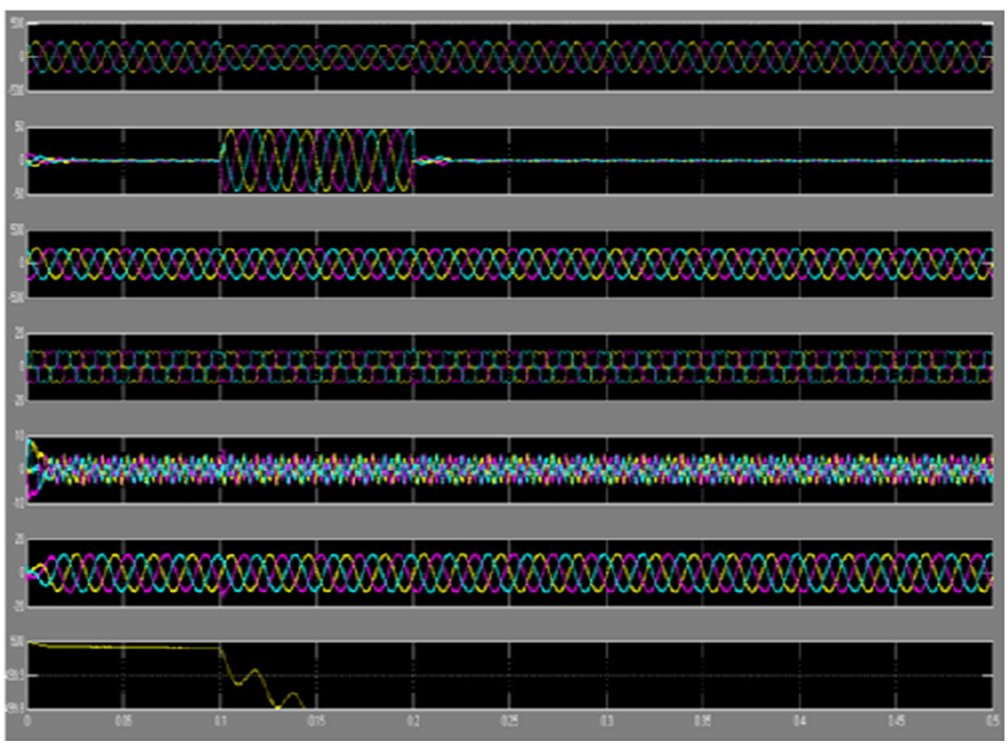

Fig 5.3: Simulation Results of UPQC for voltage sag condition a) Source voltage b) Series injected voltage c) Load voltage d) Load current e) Injected current f) Source current g) DC Capacitor voltage

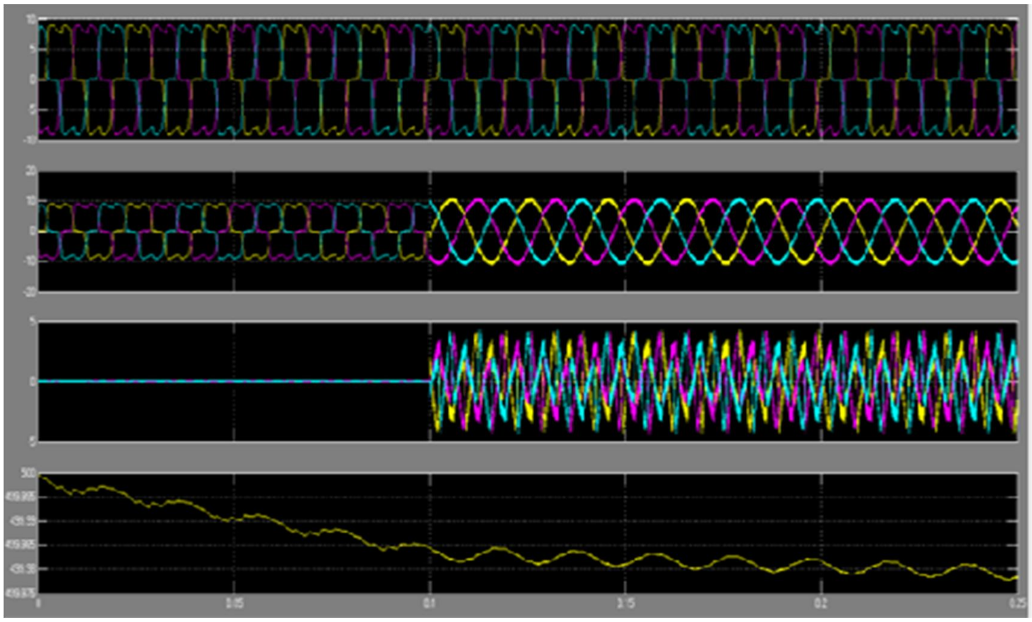

Figure 5.4: Simulation Results Current Harmonic Compensation of UPQC for a) Load current b) Source current c) Shunt APF current d) Capacitor voltage

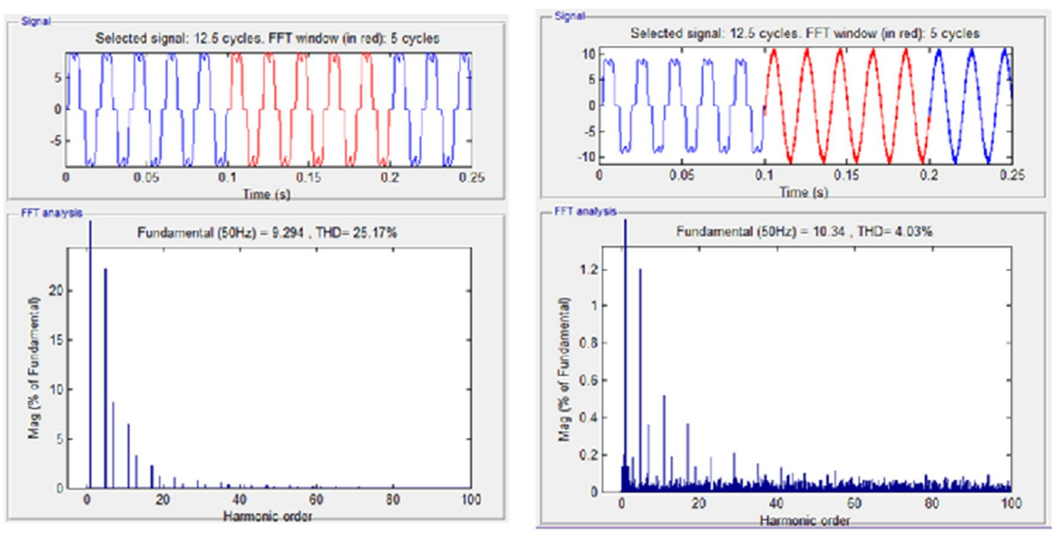

Fig.5.5: THD before and after compensation (a) distorted source current (b) compensated source current

CONCLUSION

In this thesis, a Unified Power Quality Conditioner (UPQC) has been investigated for power quality enhancement. UPQC is an advanced hybrid filter that consists of a series active filter (APF) for compensating voltage disturbances and shunt active power filter (APF) for eliminating current distortions. The modelling of series APF, shunt APF and the UPQC has been carried out. A simple control technique, extraction of unit vector template has been used to model the control scheme for series APF. This scheme utilizes phase locked loop (PLL) and a hysteresis band controller to generate the reference signals for series APF. The instantaneous reactive power theory has been used to model the control scheme for shunt APF. The series and shunt APF models are combined to configure the UPQC model.

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