CHAPTER 1

INTRODUCTION

1.1 GENERAL

Power quality is of ever growing concern to utilities and consumers. In the optimal operation of power systems, it is desirable to have the wave shapes of voltage and current as close to sinusoids as possible. Sixty percent of electric power flows through electronic devices which contain non linear loads and contribute to power quality disturbance according to a study by Electric Power Research Institute (EPRI). The variations in voltage, current and frequency in the power system constitute “Power quality disturbance”. Generation of harmonics can be considered as one such form of disturbance.

Harmonics can be generally defined as sinusoidal components of periodic waveforms with frequencies that are integral multiples of the fundamental frequency of the waveform. When a sinusoidal voltage is applied to linear load, a sinusoidal current waveform results and hence no harmonic is said to exist. However a problem arises, if the loads of the power systems are nonlinear and draw current not proportional to the voltage applied. Back to back DC stations and SVC installations belong to the category of harmonic sources. Similarly industrial applications and consumer load connections pump harmonics into AC supply systems. Variable Frequency Drive, Electric arc furnaces, Power supply units involving dc application, Electric Traction systems are all examples of harmonic generators from the load end. Low power
factor, harmonic distortion, voltage sags and voltage flicker are the major problems faced by industrial customers of any electric power utility. Power factor compensation and harmonic suppression in plants supplying non linear and distorting loads require the design of a system which will provide reactive power compensation as well as suppress harmonic currents injected by the loads into ac network. Harmonic pollution in power systems is an issue of concern and methods for control and regulation are called for on all fronts. The causes of harmonic generation can be traced to the interplay of dc with ac at interfacial nodes.

Harmonics in power systems can be the source of a variety of ill effects. Harmonics can not only cause signal interference on both telephone and data transmission lines, but also cause over voltage, data loss and circuit breaker failures as well as malfunction of relays and meters, equipment heating and damage etc. Power systems have natural frequencies which are often in the range of harmonics caused by non-linear devices. Matching of these frequencies lead to resonance which cause the over voltage.

When loads that injects large harmonics are added to an industrial power system, it is good engineering practice to analyze the impact on the system by performing harmonic analysis on the system. Such a study can identify any potentially harmful source of harmonics and harmonic levels that are in excess of the standard limit specified for the industrial power consumer. This is also the first step to identify and understand the power quality problems that arise at the customers premises.

Harmonic field measurements were conducted at various locations in four industries manufacturing steel, brake assemblies for four wheeler, tools
and small motors. The data gathered from these measurements were used to
develop models for the steady state harmonic analysis of the entire plant. Study
also covered interaction of harmonic currents with power factor correction
capacitor banks leading to equipment damage. This discussion helps us to
analyze the problems caused by harmonics in these industries, which had
frequent capacitor failures, motor failures, and other damaging events in spite
of all precautionary measures.

Harmonic analysis of any industrial power system centers on
(1) modeling of various components in the system,
(2) characterizing harmonic producing loads as current sources for
each characteristic frequency and
(3) performing impedance analysis for each bus of the system in a
way that the self impedance plot gives a visual indication of the
natural frequency at a specific bus.

Passive filters can not only prevent harmonics from entering a supply
system but are also useful in improving the power factor. But in general, these
filters are designed to filter specific harmonic component. Single tuned filters
are designed for improving the power factor and the computation of voltage and
current harmonics is done in accordance with IEEE Standard 519-1992 limit.

Use of active filters to eliminate harmonics seems to be costly and
impractical but due to technology development in the field of solid state
devices, there is ample scope for their continued use.
1.2 REVIEW OF LITERATURE

Many interesting state-of-the-art reports and papers discussing the importance of harmonics problem and methods of analysis are available. A brief review of the existing methods to control harmonics is presented here.

Michel (1993) developed an empirical approach to be used for tuned filters on linear loads, providing harmonic removal as well as power factor correction. Traps used are single-tuned LC shunt filters. The trap is sized between 0.4 and 0.6 times the full load KVA rating for rectifiers, UPS, battery chargers etc. When fifth harmonic current is high, the higher values are used. For adjustable motor drives, the trap should be between 0.3 and 0.45 times the horse power rating.

Robert (1996) presents results of harmonics analysis in a paper mill where large harmonic producing loads are added to the power system, and describes the data required to conduct a harmonic study and the type of analysis that can be performed. He further explains some of the mitigating measures that can be taken to deal with the potential harmonic problems and concludes that it is not feasible to single out one strategy as being superior in all cases.

Douglas Andrews et al. (1996) present the analytical technique used to correct power factor in a modern steel manufacturing facility. The study included field measurements, harmonic analysis and filter design to reduce the amount of harmonic distortion in the plant. It is stressed that the elimination of the utility penalties can sometimes pay for the studies and that the harmonic filter is a real pay off, which yields the improvement in plant productivity.
Atkinson Hope (1994) compares the international and local power system harmonic standards for a manufacturing plant and traction substation. The plant was simulated using two harmonic software packages and their results were compared with the field measurements. It is concluded that all the voltage standards are adequate and yield similar results.

Daniel Satin et al. (1999) present the statistics relevant to harmonic distortion using sampling technique. Many utilities are implementing extensive monitoring systems to assess service quality data due to the increased sensitivity of end use equipment. Hence indices are developed to assess power quality levels and benchmark values and confirm incidence of small increase in levels of harmonic distortion levels.

Bind et al. (1969) proposed an idea of shaping the current waveform by injecting a third harmonic current, (displaced in phase) by a current generator into converter itself. This results in partial neutralization of the harmonics. The major drawback was that it was impossible to fully eliminate more than one harmonic.

Ametani (1972) proposed a technique to eliminate multiple harmonics. According to this technique, an active control circuit could be used to precisely shape the injected current which contain harmonic components of opposing phase and this could be adapted to a broader range of converters. Separate current sources are connected in parallel in the each phase, but a control circuit proposed by Ametani was not successful in producing a precise current control.
Sasaki and Machinda (1971) discussed elimination of harmonics by using the principle of magnetic flux compensation. In this method, use of a current to produce a flux to counteract the flux produced by the harmonics is adopted. The control circuit was designed to inject the required current capable of producing the flux, into the compensating winding. The practical control circuit was not realized since the circuit was not capable of differentiating between the fundamental and other harmonics.

Epstein et.al (1979) developed a switching system to produce two level current waveform. The switching system consisted of a simple bridge circuit to produce waveforms and the timing of the switching system was determined by the control circuit which monitored the instantaneous load voltage and current.

Vanwyk et.al. (1984) describe the use of active components in control circuitry to compute and generate the current required to improve the supply current waveform using fixed PWM techniques. The thyristor pairs were switched based on the difference between the calculated current and measured current.

Akagi et.al. (1984) proposed multiple voltage source inverters and a time delay PWM switching strategy for an active filtering system. A compensator is developed which could eliminate harmonic current based on reactive power compensation. The innovative concept of new instantaneous reactive power compensator comprising switching devices is proposed and it requires no energy storage components. Further, utilizing the concepts of instantaneous reactive power, the active filter control circuit was constructed using four series connected PWM converters. The instantaneous real and
imaginary load powers were calculated, using phase voltage and load current measurements. The drawback in this is due to complex circuit which involves high cost that might prohibit its general use.

Janko Naotram et al (1994) developed a series active filter for non linear loads with the power part being carried out in bridge connection. The use of the series active filter resulted in the elimination of low frequency harmonic components with low switching frequency.

1.3 OBJECTIVES AND SCOPE OF THE WORK.

In the previous section detailed review of literature about passive and active filters have been presented.

The literature reviewed points out that there exists a need for designing passive filters as per IEEE Standard 519-1992 in order to meet stringent limits on individual and total current harmonic distortion and designing active filters which are effective for multiple non linear loads for harmonic suppression.

The primary objective of this thesis are as follows:

i. To identify the industrial loads that generate harmonics

ii. Design a process chart for passive filter based on power factor improvement or power system characteristics as per International IEEE Standard 519-1992.

iii. Comparison of Power factor improvement method with that of power system characteristics method.
iv. Designing a prototype active filtering system based on a novel current compensation method to reduce the harmonic distortion for a multiple non linear loads.

v. Comparison of novel current compensation method with that of sliding mode control method

1.4 OUTLINE OF THE THESIS

The thesis is organized into five chapters with summaries. Chapter wise summaries stating the development and results obtained from investigations are presented in the sections that follow.

The second Chapter describes the observations on harmonics field measurements conducted at four different types of industrial loads and observations.

In Chapter three, the methodology for computation of harmonic distortion to meet IEEE Standard 519-1992 is dealt with and procedure for design of passive filters to suppress harmonics as per the above standard is suggested for each of the four cases chosen for study.

In the fourth Chapter, a novel current compensation technique for an active filtering system is presented. A prototype model is designed and tested for multiple non linear loads. Finally the novel current compensation method is compared with the sliding mode control method for its effectiveness in reducing the harmonic content or the non-linear load current. The current compensation method performs better if rapid load changes are taking place, since the inverter output current tracks the current compensating signal very closely.