Chapter 1

Introduction

1.1 Background

After invention of electricity, alternative current supply was used first for lighting and afterwards for industrial loads, as well. Earlier the factories, offices and houses were supplied by radial lines with no backups, and lengthy outages were a fact of life. With the march of time and innovation of technology, electricity became a demand for greater dependability. Accordingly, utility systems developed transmission networks with primary and secondary distribution networks. So the major concern of utilities was the improvement of reliability while using the resources more efficiently and effectively.

When utility systems grew more reliable, business grew more sophisticated. In turn reliability needs were yet emphasized. Factories and other businesses began buying backup power systems as insurance against long term outages on utility systems. Utilities also went on striving to shorten outages. Until fairly recently, power quality referred to the ability of the electric utilities to supply electric power without interruption. Today both electric utilities and end users of electric power are becoming increasingly concerned about the quality of electric power.

There are completely different definitions for power quality, depending on one's frame of reference. For example equipment manufacturer may define power quality as those characteristics of the power supply that enable the equipment to work. Power quality is ultimately a consumer-driven issue, and the end user's point of reference takes precedence. Therefore, the power quality problem can be defined as "any power problem manifested in voltage, current, or frequency deviations that result in failure or disoperation of customer equipment" [1]. Simply, the ideal power supply to a low voltage customer is 230/ 400V at 50Hz with a sinusoidal wave shape.

Today the action in power electronics is shifting expectations of power quality into an entirely different dimension. The growing number of power electronics based equipment has produced an immense impact on the quality of electric power supply. Power electronics has given us many new ways to manufacture products, provide services, and utilize energy. From a power quality impact viewpoint, applications such as follows often cause for concern.

1. Switched-mode power supplies,
2. DC arc furnaces,
3. Electronic fluorescent lamp ballasts,
4. Adjustable speed drives, and
5. Flexible ac transmission components

These converter-based systems are nonlinear. The nonlinear loads change the sinusoidal nature of the ac power current (and consequently the ac voltage drop) resulting in the flow of harmonic currents in the power system [2].

Harmonic currents result in distorted voltages and currents that can adversely impact the system performance in different ways. The harmonic voltages can lead to operational and life expectancy problems for other equipment possibly not owned or operated by the same party. Both high power industrial loads and domestic loads cause harmonics in the network voltages. At the same time, much of the equipment causing the disturbances is sensitive to the Harmonic distortions. The operations of some equipment depend on an accurate voltage wave shape and they can malfunction when harmonics are present. Harmonics such as that occur in commercial buildings due to many single phase distorting loads appeared across three phase can give neutral current exceeding the active line current.

With excessive levels of harmonics there is risk of

- Overheating the neutral conductor with loss of conductor life and possible risk of fire
- Affecting the digital equipment and local area networks (LANs) if the Earthing system is poor

- Overheating the induction motor windings causing accelerated degradation of insulation and loss of life
- Extra heating of transformers leading to a reduction in their service life
- Overheating of the dielectric of transformers with a risk of explosion
- Malfunctioning of equipment trips
- Overheating of equipment and reduction in their service life

Unlike most other types of supply problems, harmonics can go unnoticed for many years unless equipment temperature or the voltage waveform is routinely monitored.

Offices located in subject premises also reported to have several of similar experiences as above, and hence identified as a location where there is a good chance of existence of power quality problems caused by harmonics.

1.2 Motivation

Over the last 20 years utilization of power electronic devices in energy conversion has increased dramatically. Power electronics technology has played a major role in creating power quality problems. The increasing number of highly nonlinear and unbalanced distorted loads leads to operational and life expectancy problems for other equipments, as well. Therefore, following the wide use of electronic appliances, harmonics has become a serious concern for electrical engineers.

When it is looked into the utility side, since its establishment in 1969, CEB has been paying much concern on improvement of reliability of the supply. However, a lesser attention has been paid for power quality improvement. Sometimes the customers are severely affected by power quality problems that exist in the system and hence the time has come to look into the power quality issues in deep.

Power quality problem can be caused by disturbances originating in the supply system, from customer's premises and from the nearby installations [1]. Responsibility for external disturbances such as outages, sags and spikes due to switching, originated in the transmission and distribution network are acceptable by the utility. For harmonic disturbances utilities are not to be blamed, but the customers themselves are also responsible for drawing excessive non-linear currents. Due to the unavailability of proper monitoring system and regulations, and due to the lack of customer knowledge, the utility as well as the customers do not work in earnest to mitigate the voltage distortions generated by non- linear load currents.

The harmonic currents produced by non-linear loads can interact adversely with a wide range of power system equipment causing additional losses, overheating, and overloading [2]. Because of adverse effects that harmonics have on customers' equipments, it is a prime importance of customers to adapt proper customer side mitigatory measures to bring down the harmonic levels in their electrical system to a favorable limit.

On the other hand, in order to avoid deterioration of the quality of power supplied to customers, regulators are going to have to expand their thinking beyond traditional reliability indices and address the need for power quality reporting and incentives for the transmission and distribution companies. Now that we are having Public utility commission as the regulatory body, empowered under Sri Lanka Electricity Act no 20 of 2009, power quality matters will be more emphasized. As the application of semiconductor devices are further advancing, there is a need of defining a suitable framework for harmonic control to ensure steady- state harmonic limits that are acceptable by both electric utilities and customers. In that case, the customer also will have to play a role to suppress their harmonic current that injected back into the distribution system.

This phenomenon is common to Uva provincial Council building at Badulla, also. A comprehensive study on power quality problems in the selected premise will be a good contribution in order to make avenue to the area of power quality research on problems originated in customer side. Therefore, being an Electrical engineer attached to Ceylon Electricity Board, I have been greatly motivated to carry out this project.

1.3 Goals of the research

The main objectives of this research are

1. to investigate the power quality of electricity supply of Uva Provincial council building,
2. to design an active filter for filtering out the harmonics injected by load of provincial council building,
3. to develop a model for active filter and simulate it using MATLAB /Simulink environment,
4. and to make an avenue to the area of power quality research on problems originated in customer side.

1.4 Scope of Work

Based on the case study, this thesis discusses the sources and effects of harmonics in power systems and some practical solutions to the problem of harmonics in office buildings. It discusses possible harmonic mitigation techniques and compares the pros and cons of various available measures. Out of the different available techniques, the active power filter compensation with relevant control method is focused in this study.

The current (first) chapter provides an introduction to the harmonic concept and defines the thesis subject. It outlines what inspired me to do this research and its aspirations. And it gives an overview of the subject and the contents of the chapters in the thesis, as well.

The second chapter discusses the fundamentals of harmonics in power systems in details together with the causes and effects therein. This chapter presents the most commonly used theory of harmonics and available harmonics standards.

The third chapter covers the practical measurements done at Uva provincial council. It compares the collected data with harmonics standards and identifies the power quality problems in the existing system.

Harmonic mitigation techniques their pros, cons and capabilities under practical situations are discussed in the fourth chapter.

The fifth chapter describes the computer modelling and controlling of a shunt active filter and simulating it with an example load under MATLAB/Simulink environment.

The sixth and final chapter provides the concluding remarks that summarize the research results and gives future work recommendations on subjects related to the thesis.