CHAPTER 1

INTRODUCTION

1.1 GENERAL

Electrical transmission and distribution play a vital role as they become the basic need of human society which is evolving astronomically. The demand for energy has grown at an average rate of 3.6% per annum over the past 30 years. In December 2012, the installed power generation capacity of India stood at 210.951 GW. The demand is depicted by 17.4 GW in the current year. The additional need of India is expected to be another 600 to 1200 GW by 2050. As the population increases, it is very difficult to meet the power requirement. To overcome this problem it is not possible to install new lines as they are very complex and do not seem to be feasible. As the loads are also becoming very much nonlinear, the level of harmonics is also increasing. Since the distribution system is radial, the power quality problems are major and serious in nature. Considering all the above facts it is highly necessary to concentrate on power quality issues.

The presence of harmonics in the power lines result in greater power losses in distribution, interference problems in communication systems and sometimes in operation failures of electronic equipments, which are more sensitive since they include microelectronic control systems, which work with very low energy levels. Because of these problems, the issue of the power
quality delivered to the end consumers is, more than ever, an object of great concern. Hence this thesis focuses on enhancement of power quality and harmonic suppression methods.

1.2 POWER QUALITY ISSUES

According to IEEE Standard, “Power quality is the concept of powering and grounding sensitive equipment in a matter that is suitable to the operation of that equipment”.

The power is required for all the electrical equipments to operate. For proper working of the electrical equipments, the power quality must be maintained. If the power quality is poor, the equipment may get damaged or it will malfunction even in normal conditions. Basically power quality focuses on system reliability, dielectric selection on equipments and conductors, long-term outages, voltage imbalance in three-phase systems, power electronics and their interface with the electric power supply, and also many other areas. From the waveform distortion one can measure the power quality problem. The response involves the change in waveform shapes (current and voltage in an ac system), the presence of harmonic signals in bus voltages and load currents, the presence of spikes and momentary low voltages, and other issues of distortion. The other problems due to the above are blinking of incandescent lights, power factor correction capacitor failure, circuit breakers tripping for no visible reason, computer malfunctioning, communication failure, conductor failure due to heating, electronic equipment shutting down, flickering of fluorescent lights, fuses blowing without reason, motor malfunctioning and overheating, neutral conductor and terminal failures,
overheating of metal enclosures, power interference on voice communication and transformer failures on overheating.

The major power quality problems are voltage sags, harmonic distortion and low power factor. Voltage sag appears in the line when the lines are overloaded. Harmonic distortion is due to the interference of noise and non-linearity of power electronic devices. Low power factor is the result of inductive loads. In olden days electrical equipments were designed to meet only problems such as over loads, short circuits and lightning. In the development phase, power electronic devices were introduced. Hence the electrical equipments cannot be designed with the same features. The major problem with power systems is non-linearity caused by equipments such as inductors and transformers. The power electronic devices are highly nonlinear and they produce switching losses also. The introduction of power electronic devices to power transmission lines increases the complexity in maintaining power quality. Increase in such a non-linearity causes different undesirable features like low system efficiency and poor power factor. It also causes disturbance to other consumers and interference in nearby communication networks. The effect of such non-linearity may become sizeable over the next few years. Hence it is very important to overcome these undesirable features.

There are many kinds of power quality problems which affect the performance of the distribution line which are explained as follows.
1.2.1 Interruption

Figure 1.1 shows the waveform representation of a line interruption. When the voltage drops below 10% of its nominal value, it is called an interruption or a blackout. There are three types of interruption such as momentary (which lasts for 30 cycles to 3 seconds), temporary (which lasts for 3 sec to 1 min) and sustained (which lasts more than 1 min). Though interruptions are more severe form of power problems, they do not occur often. Sometimes voltage sags are mistaken as interruptions because the equipment shuts down or lighting goes off since the voltage drops below the level that these devices can operate. Thus the voltage sags and the under voltage typically represent more than 92% of power quality problems whereas the interruptions represent less than 4% of such problems.
1.2.2 Brown Out

Figure 1.2 shows the waveform representation of under-voltage of a line. Under-voltage is a decrease in voltage below 90% of its nominal value for more than one minute. It is also called “brown out”. The term “brown out” is not officially defined but it is often used when the utility intentionally reduces the system voltage in order to accommodate high demand or other problems.

![Waveform representation of under voltage of a line](image)

Figure 1.2 Waveform representation of under voltage of a line

The symptoms of under-voltage are equipment malfunction and premature equipment failure. Under-voltage may go unnoticed until the new equipment is installed or the electrical system is changed. The new combined load depresses the voltage to a point where the symptoms are made visible. When the under-voltage lasts for a long time, it can cause excess wear on certain devices and it is a chronic problem which gets worsened by a number of factors beyond the end-user’s control. Electric utilities try to maintain the voltage level delivered to the customers at ±5% of tolerance limit. However, factors like weather, high demand and others can cause the utility voltage to fall within a ±10% range of tolerance limit. Even under ideal conditions, the
customers will see a drop in utility voltage level because the demand increases around 8 AM as well as around 3 or 4 PM during peak hours.

The characteristics of distribution system can also contribute to the low voltage situation. For example, the customers at the end of a long line may suffer from permanent voltage drop due to line losses on top of the utility voltage variations. Frequent or high levels of noise can cause equipment malfunction, overheating and premature heating.

1.2.3 Harmonics

Figure 1.3 shows the waveform representation of harmonics.

![Figure 1.3 Waveform representation of Harmonics](image)

Harmonics are a recurring distortion of the waveform that can be caused by various devices including variable frequency drives, non-linear power supplies and electronic ballasts. Harmonic distortion is significantly added to the waveform by certain types of power conditioners like Ferro-resonant or Constant Voltage Transformers (CVT). Waveform distortion also occurs in Uninterruptible Power Supplies (UPS) and other inverter-based power conditioners. The UPS does not actually add distortion since the UPS digitally synthesizes the waveform, and as a result the wave is in the form of square or jagged rather than smooth sine wave. Symptoms of harmonic distortion are overheating and equipment operational problems.
1.2.4 Short Circuit

A short circuit is a dangerous operational malfunction or fault which is not considered to be a serious power quality problem. It refers to a condition where two hot lines are connected directly (or through small impedance) or one hot line is connected directly to the ground. A short circuit causes very high fault current to flow through the wiring, and when all the devices between the point of short and the incoming power line are left unchecked, the short circuit can very quickly lead to catastrophic melting, overheating and burning of wiring and devices.

The damage that occurs due to short circuit is protected by opening of the breaker or by the operation of protective fuses. In order to avoid the dangers of short circuit, the breaker and protective fuses should be of proper rating.

1.2.5 Notching

![Figure 1.4 Waveform representation of Notching](image)

Figure 1.4 shows the waveform representation of notching of a line. Notching is a disturbance of opposite polarity to the normal voltage waveform (which is subtracted from the normal waveform) lasting for less than one-half cycle. It occurs frequently due to the malfunctioning of electronic switches or
power conditioners. Though it is not a major problem, it causes the electronic devices to operate improperly.

1.2.6 Swell

![Figure 1.5 Waveform representation of swell](image)

Figure 1.5 shows the waveform that represents swell of a line. Swell is an increase in voltage above 110% of its nominal value which lasts for one-half cycle to one minute. It is opposite to that of sag. It doesn’t occur frequently like sag but it can cause equipment malfunction and premature wear. Swells can be caused by shutting off loads or switching on the capacitor banks.

1.2.7 Transients

Transients are very short duration (sub cycles) events of varying amplitude. It is often referred to as “surges”. Transients are frequently visualized as tens of thousands of voltage from lightning stroke that may destroy any electric device that lies in its path. Transients occur due to equipment operation or failure or by weather phenomena like lightning. Even low voltage transients can cause serious damage to electrical equipments. The equipments are protected from the damaging effects of high voltage transients by using a properly sized industrial grade surge suppressor. Figure 1.6 shows the waveform that represents transients of a line.
1.3 HARMONIC ISSUES

Harmonics are the odd integral multiples of fundamental frequency resulting in the distortion of supply waveform due to interference by superposition. The term can also refer to the ratio of the frequency of such a signal or wave to the frequency of the reference signal or wave. At the same time harmonic order or harmonic number is a reference to the frequency of the harmonic component e.g. 3rd order harmonic component which refers to a harmonic component having frequency 3 times like that of fundamental i.e. for a 50 Hz supply 3rd order component of frequency which is 150 Hz.

Nonlinear loads drawing non-sinusoidal currents from three phase sinusoidal voltages are classified as identified and unidentified loads. When the electric utilities identify the individual nonlinear loads installed by high power consumers on power distribution systems, it is called identified harmonic-producing loads. High-power diode or thyristor rectifiers, cycloconverters and arc furnaces are typically characterised as identified harmonic-producing loads. Each of these loads can produce a large amount of harmonic current. The utilities can determine the Point of Common Coupling (PCC) of
high-power consumers who install their own harmonic-producing loads on power distribution systems. Moreover, they can determine the amount of harmonic current drawn by an individual consumer.

A single low-power diode rectifier produces a negligible amount of harmonic current whereas the multiple low-power diodes produce a significant amount of harmonic current. When diode rectifier is used as an utility interface in an electric appliance, it is considered to be an unidentified harmonic-producing load.

1.3.1 Causes of Harmonics

When the load is linear, the voltage varies sinusoidally at rated frequency. If a linear load is connected to the system it draws sinusoidal current at the supply frequency, and at the same time harmonics is not generated.

If a non-linear load is connected to the system it draws current which is not sinusoidal in nature and harmonics are generated. The current waveform can become quite complex, depending on the type of load and its interaction with other components of the system. As the current drawn from the supply remains non-sinusoidal the resultant waveform is made up of a number of different waveforms of different frequencies. Since the sum of even harmonics is less than 1% of fundamental component, they are not considered. At the same time the lower order odd harmonics constitute about 97% of total harmonic content. The following are the effects of harmonics.

1.3.2 Effects of Harmonics

- Over-heating of transformers and other electromagnetic devices such as motors, relays, and coils (due to the inductive
heating effects of eddy currents, skin effect, and hysteresis).

- Over-heating of conductors, breakers, fuses, and all other devices that carry current (because of eddy currents, skin effect, and hysteresis).

- Inductive heating of metal parts such as raceways, metal enclosures, and other iron metal parts (because of eddy currents and hysteresis).

- Voltage distortion resulting in unpredictable equipment operation because of harmonics.

- The excessive current flowing through the neutral results in equipment overheating, as it contains additive harmonic currents, excessive voltage drop, and distortion.

- Malfunction of generators and UPS due to voltage distortion resulting in unpredictable behaviour of electric variables.

1.3.3 Harmonic Elimination Techniques

The different levels of harmonics which affect the system can be eliminated using filters. Basically harmonic filters are classified into two types such as active filter and passive filter. Harmonic filters are installed at different points where power quality is affected by harmonics which are above the desirable limits as recommended by IEEE 519 standards. These filters are connected in parallel to load, so as to provide low impedance path for the flow of harmonics current. It is not necessary to install individual filters for the elimination of each harmonic component. A 3-branch filter can be used to filter 3rd, 5th and 7th harmonic components. Harmonic filters can be used in addition with capacitor compensators. Capacitor banks are traditionally used to improve power factor of load thereby avoiding financial penalty imposed by Supply Corporation. Thus there is no need to remove
capacitor banks if we desire to add harmonic filters. But capacitive compensation can also be provided using the same tuning capacitors from the filter without having additional capacitors.

1.3.4 Design of Harmonic Filters

The Harmonic filters are made up of combinations of series or parallel Inductor-Capacitor branches tuned to particular frequencies which provide a low impedance path to the particular harmonic component. Hence it is necessary to design filters in an efficient way to reduce harmonics for various load conditions. The filters are designed with electrical parameters based on the load conditions at a particular location. Thus harmonic filters are designed depending upon the locations.

1.3.5 Selection of Filters

At lower harmonic frequencies most of the waveforms have large percentage of harmonic distortion as compared to the higher harmonic frequencies. Hence, single-tuned filters are designed to suppress these lower harmonic frequencies. For suppressing the harmonics of six pulse ac to dc converter four single tuned filters are used for the elimination of 5th, 7th, 11th, and 13th harmonics, and one second order high pass filter for eliminating the higher order harmonics.

1.4 Monitoring Power Quality and Harmonics

Harmonic regulations or guidelines such as IEEE 519-1992, IEC61000, etc. are currently applied to keep current and voltage harmonic levels in check. The final goal of the regulations or guidelines is to promote better practices in both power systems and equipment design at minimum cost.
In order to obtain a solution for harmonic problems, the following steps are adopted.

- Monitoring the network according to the standard.
- Measuring a particular branch that is suspected to be the cause of the problem or the particular branch that is suffering from problems.
- Analyzing the results of above steps to achieve unique conclusion with a clear recommendation for the solution.
- Depending upon the model chosen for representing the network, proper calculation must be made for obtaining the realistic value of ohmic resistance of network components or branches in order to avoid unwanted resonance effects.
- Following the implementation of the solution, monitoring of the network must be done to compare the expected result to the real one and adjust the elements that require adjustments.

Monitoring power quality and harmonics is not as simple as measuring power quality variables. There is a need to understand power network behaviour before monitoring it, and this is not a simple task. However in today’s distribution system, from outputs the errors are calculated and rectified.

The monitoring system can identify problem conditions throughout the system before they cause complaints on the customer side, equipment malfunction, and even equipment failures. Many surveys have shown that a majority of problems are localized within the customer facilities. Given this fact, monitoring provides a key opportunity for an utility to protect its reputation and improve its relationship with the customers.
The Electric Power Research Institute (EPRI) has estimated that in 2010, 50 to 60% of the total load had been nonlinear, while by the year 2015, 70 to 80% of all loads are expected to be nonlinear. The traditional measuring equipments become helpless in measuring, as the measurements are for the nonlinear loads. For measurement in power lines true RMS parameters are being used. One of the greatest difficulties of all the organizations concerned today is to engage the engineers who are able to perform this kind of much monitoring, be able to analyze the results obtained and give a practical and economical solution fitted to the network. If the monitoring is not done properly, the wrong solution which is resorted may prove disastrous.

Today, power quality monitoring is an essential service for industrial and other key commercial customers. Because of the technology and software now available, monitoring becomes the easiest one. The network impedance varies continuously and the network has to be monitored using the models that take this into consideration. Without a relevant representation of the impedance, the results of the monitoring will be worthless.

IEEE 1159-1992 standard provides the steps for monitoring a network and the guidelines for understanding the results obtained.

1.5 MOTIVATION

The power quality problem is defined as “any occurrence manifested in voltage, current, or frequency deviations that result in damage, upset, failure, or mal-functioning of end-use equipment.”

The power quality problem can be solved by load conditioning in which the equipment can operate under severe voltage problems. The equipment is less sensitive to a faulty atmosphere. But this is not advisable as it is not certain that the equipment will always operate properly in the worst
situations. Hence the line-conditioning equipments such as filters are used to eliminate power quality problems. The filters installed in the system may reduce harmonic currents in the system.

As mentioned earlier, the problem with a passive filter is resonance and filters concentrate for the elimination of single harmonics. Due to its promising features the Shunt Active Filter (SAF) finds a valuable place in reducing the power quality problems in the distribution lines. Also it compensates the current and voltage disturbance in the lines. The compensating current produced by the SAF cancels the harmonic current in the lines. Hence the SAF is considered in this research work for power quality improvement.

1.5.1 Power Filter Topologies

Depending on the application or electrical problem to be solved, active power filters can be implemented as shunt type, series type, or a combination of shunt and series active filters (shunt-series type). These filters can also be combined with passive filters to create hybrid power filters.

Series active power filters were introduced in 1980s as they could operate mainly as a voltage regulator and as a harmonic isolator between the nonlinear load and the utility system. The series-connected filter protects the consumer from an inadequate supply voltage. This type of approach is especially used for the compensation of voltage imbalances and voltage sags from the ac supply and for low-power applications. The series filter is an economic alternative to UPS. But as it has no energy storage battery, the overall rating of the components is reduced in a series filter. Since the series active filter injects a voltage component in series with the supply voltage, it is regarded as a controlled- voltage source. It is mainly used for compensating voltage sags and swells on the load side. Mostly the series filter is used along
with LC filter as a hybrid filter. If passive LC filters are connected in parallel to the load, the series active power filter operates as a harmonic isolator, forcing the load current harmonics to circulate mainly through the passive filter rather than the power distribution system. The main advantage of this scheme is the rated power of the series active filter is a small fraction of the load kVA rating, typically 5%. However, the apparent power rating of the series active power filter may increase in the case of voltage compensation. Also it is very tedious to introduce a series filter as the topology is very complex.

The shunt-connected active power filter, with a self-controlled dc bus, has a topology similar to that of a Static Compensator (STATCOM) used for reactive power compensation in power transmission systems. SAF compensates load current harmonics by injecting equal-but opposite harmonic compensating current. In this case the SAF operates as a current source injecting the harmonic components generated by the load but it is phase-shifted by 180°. The SAF involves multilevel inverters which prove to be an efficient performance in providing a multi stepped waveform. Hence the SAF becomes popular in enhancement of power quality.

Comparing the above two filters, the promising features of SAF motivate to consider the device for improving power quality issues and reduce power losses in the distribution lines. Hence, in this research work SAF is taken for study and analyzed with various control techniques.

1.6 THEORY OF FILTERS

As filters are efficient in suppressing the harmonics a detailed study is made. The filters are basically classified into active filters and passive filters.
1.6.1 Passive Filters

The passive filter uses resistors, inductors, and capacitors and they do not rely upon any type of external power source. It does not depend on any active components. The inductors block high frequency signals and allow low frequency signals. The capacitors block low frequency signals and allow high frequency signals.

Passive filters are the oldest type of electronic filters. They are generally quite simple, with just resistors, capacitor and inductors. The simple filters started developing in the 1880s for telegraphs but in those early years they were not exactly successful. Also their performance was not so satisfactory. On continuous evolvement, better filters were found. There are different types of passive filters. They are classified as follows.

- Band Pass Filters.
- Power Line Filters.
- Surface Acoustic Wave Filters.
- Signal Filters.
- Sinusoidal Filters.

1.6.1.1 Band-pass filters

Band-pass filters are circuits that let signals from two different frequencies pass. However, it will not let other frequencies pass. This type of filter is often used for wireless receivers and transmitters.
1.6.1.2  Power line filters

The basic function of a power line filter is removing harmonics in AC supply. They make the system more sinusoidal. They are most prevalent in audio and video devices.

1.6.1.3  Surface acoustic wave filters

A surface acoustic wave filter is operated at radio frequency. This is nothing but a piezoelectric filter which is operating at 3 GHz.

1.6.1.4  Signal filters

Signal filters are those which remove some type of unwanted signal or component. This usually means that some of the frequencies are removed by keeping other frequencies to improve performance and to remove background noise. One of the drawbacks of this type of filtering is the loss of information during the process.

1.6.1.5  Sinusoidal filters

This type of filter is commonly used in AC supply particularly in motors, and when applied properly, it can offer number of benefits. It could help increase the life of the motor by reducing the harmonics and reducing the current. It can also ensure that there is less heating, which can improve the condition of the motor, especially over a long period. This helps in reducing the amount of noise and eliminating voltage spikes.

1.7  SHUNT ACTIVE FILTER

International standards concerning electrical energy consumption impose that electrical equipments should not produce harmonic contents
greater than specified values. Meanwhile it is mandatory to solve the harmonic problems caused by those equipments already installed.

Passive filters have been used as a solution to solve harmonic current problems, but they present several disadvantages as follows.

- The passive filters are tuned for a particular frequency. Hence for suppressing different harmonics, different filters are needed to be presented. This increases the cost and bulkiness of the system.
- Resonances can occur because of the interaction between the passive filter and other loads with unpredictable results.

To overcome these disadvantages of the passive filters, recent efforts have been concentrated on the development of the active power filters. Their main characteristics are the following.

- Dynamic power factor correction.
- Dynamic compensation of any harmonic currents with frequencies up to about 5 kHz.
- Dynamic zero-sequence current compensation.
- Flexible microcontroller-based implementation.
- Only one power converter and inverter with just a capacitor on the DC side.
- IGBT power stage capable of compensating harmonics in three-phase systems and low cost system.

The other efficient way to maintain power quality is achieved by compensating the deficit of reactive power needed by the distribution lines. In
transmission lines, STATCOM is placed, which is similar to SAF. Since SAF is a shunt-compensating device, the basics of shunt compensation are explained in the following section.

1.7.1 Shunt Compensation

The shunt device acts as a controllable current source. There are two types of shunt compensation techniques which are classified as shunt capacitive compensation and shunt inductive compensation. The Shunt capacitive compensation is used to improve the power factor of the line. Whenever an inductive load is connected to the transmission line, power factor lags because of lagging load current. To compensate, a shunt compensating device is connected, which draws a current leading the source voltage. The Shunt inductive compensation method is effective for the low level of loads at the receiving end. Under lightly loaded conditions, the receiving end voltage will be higher than the sending end voltage and to compensate, shunt inductors are connected across the transmission line. The power transfer capability is also thereby increased.

The characteristics of shunt compensation are as follows.

- Shunt capacitors do not affect current or power factor beyond their point of application.
- The reactive power supplied by the shunt capacitor banks is directly proportional to the bus voltage.

1.7.2 Voltage Source Converters

The SAF is associated with the Voltage Source Converters (VSC). The output of the converter is connected to a capacitor which maintains a constant DC voltage. Even though general schemes are there, Pulse Width Modulation (PWM) technique finds it suitable for dynamic performance of
the system. In PWM technique the DC voltage is chopped to get the required ac output. There are different PWM topologies present for synthesizing the waveform. The inverters are classified as Current Source Inverter (CSI) and VSI. In practical applications, VSI is used for the following reasons.

- Efficiency is high and there is low initial cost compared to CSI.
- The rating can be increased by connecting more switches in parallel.
- The individual switching times are independent and we can decide the switching pattern. Hence higher order harmonics can be easily eliminated.

![Diagram of Voltage source converter topology for SAF](image)

**Figure 1.7 Voltage source converter topology for SAF**

Figure 1.7 shows the Voltage source converter topology for SAF. Three phase inverters are used for high power application such as ac motor drives, induction heating and UPS. A three phase inverter changes DC input
voltage to a three phase variable frequency and variable voltage output. The
input DC voltage can be from a DC source or a rectified AC voltage. A three
phase bridge inverter can be obtained by combining three single phase half
bridge inverters. In the figure, the converter block consists of six switches
with six associated freewheeling diodes. The switches are made on/off
periodically in the proper sequence to produce the desired waveform. The rate
of switching determines the output frequency of the inverter. There are two
possible schemes for gating the devices. In one scheme each device conducts
for 180°, and in another scheme each device conducts for 120°. But in both
schemes gating signals are applied and removed at 60° intervals of the output
waveforms.

There are different gate triggering schemes. In this design Sub
harmonic elimination method is used, which is explained as follows.

In Sub harmonic elimination method of m-level inverter, (m-1)
carriers with the same frequency \( f_c \) and the same amplitude \( A_c \) are disposed in
such a way that the bands they occupy are continuous. The reference
waveform has peak to peak amplitude of \( A_m \), the frequency of \( f_m \), and is zero-
centred in the middle of the carrier set. The reference is continuously
compared with each of the carrier signals. If the reference signal is greater
than the carrier signal, the active device corresponding to that carrier is
switched off.

1.8 OBJECTIVE OF THE THESIS

In modern electrical distribution systems, there has been a sudden
increase or decrease of single phase and three-phase non-linear loads. These
non-linear loads employ solid state power conversion and draw non-sinusoidal currents from AC mains. Thereby they cause harmonics and reactive power burden and excessive neutral currents that result in pollution of power systems. They also result in lower efficiency and interference to nearby communication networks and other equipments. SAF have been developed to overcome these problems.

The objective of this thesis is to analyze the performance of SAF for

- Improving the power quality of transmission system.
- Harmonics suppression.
- Improving the power factor which improves the efficiency of the system.
- Analyzing the effect of SAF in real time system.

In this research, transmission line with and without SAF is tested. To analyze the performance, a test system of 4.16 kV is considered. In order to compensate the reactive power and suppress the Total Harmonics Distortion (THD) drawn from a Non-Linear Diode Rectifier Load (NLDRL), SAF is implemented in the test system. Sub-Harmonic Pulse Width Modulation (SHPWM) technique is used for triggering gate pulses of converter. The techniques that are used to generate the desired compensating current are based on the instantaneous extraction of compensating currents from the distorted current signals in time domain.
Harmonics are measured for the system without SAF. The system is implemented with SAF and the performance is studied. The PI controller is used for triggering the VSI. The d-q reference frame theory is used for modeling the system. The SHPWM pattern generation is used as control for the switches of Cascaded Five Level Inverter (CFLI).

As a means of further improvement, fuzzy logic and ANFIS controlled shunt active power filter for the harmonics suppression and reactive power compensation of a nonlinear load are implemented. The performance of all the types of controllers with similar conditions is studied. The advantages of intelligent controllers over conventional controller are analysed. The work process is simulated with MATLAB.

1.9 REAL TIME IMPLEMENTATION

The Tamil Nadu Electricity Board (TNEB) distribution network at SALEM is taken for the study. It is a 110kV/440V distribution system. SAF is inserted in this system. The energy meters were installed by TNEB in the vicinity of Salem region for loss calculation in the distribution line. The real losses are calculated, and the effect of SAF is studied, which is taken up for discussion later.

1.10 ORGANISATION OF THE THESIS

This thesis is of seven chapters. Introduction of the research work with objective, motivation are discussed in this chapter. The overall organization of the rest of the chapters is as follows:
Chapter 2 describes the detailed literature survey made on general concepts of power quality, harmonic issues, SAF, Voltage Source Inverters (VSI) and intelligent control techniques.

Chapter 3 outlines the various switching techniques for VSI. The Modelling of SAF with a PI controller using SHPWM technique is discussed in detail. A comparison is made with and without SAF. The performance of SAF is analyzed in steady state and transient state.

Chapter 4 deals with intelligent control techniques as it draws more attention in the research area. A fuzzy logic controller is designed to work with SAF. The various parameters are analyzed by implementing Fuzzy logic controller, which is being discussed and compared with PI controller.

The Neural Network (NN) is based on predictions and it is not much suitable for controller design. The Adaptive Neuro Fuzzy Interference System (ANFIS) is a combination of Fuzzy and NN. It is the fusion of the above two and takes the outstanding features of Fuzzy logic and NN. Hence, the ANFIS controller for the SAF is designed and discussed in Chapter 5. A comparative study is made between PI, fuzzy and ANFIS based controllers.

Real time simulation with the Salem distribution system is modelled and discussed in Chapter 6.

Conclusion and future scope are given in Chapter 7.
1.11 SUMMARY

In this chapter various power quality problems and need for improving them are discussed. The importance of eliminating the harmonics in the line is dealt with. As filters play an important role in eliminating the harmonics, different types of filter are discussed. Due to the promising features of SAF, it is taken in this work. The objectives of the proposed research work and organisation of the thesis have been presented in this chapter.