Chapter 1

Introduction

1.1 General

The present power distribution system is usually configured as a three-phase three-wire or four-wire structure featuring a power-limit voltage source with significant source impedance, and an aggregation of various types of loads. Ideally, the system should provide a balanced and pure sinusoidal three-phase voltage of constant amplitude to the loads; and the loads should draw a current from the line with unity power factor, zero harmonics, and balanced phases. To four-wire systems, no excessive neutral current should exist. As a result, the maximum power capacity and efficiency of the energy delivery are achieved, minimum perturbation to other appliances is ensured, and safe operation is warranted. However, with a fast increasing number of applications of industry electronics connected to the distribution systems today, including nonlinear, switching, reactive, single-phase and unbalanced three-phase loads, a complex problem of power quality evolved characterized by the voltage and current harmonics, unbalances, low Power Factor (PF).

In recent years active methods for power quality control have become more attractive compared with passive ones due to their fast response, smaller size, and higher performance. For example, Static VAR Compensator (SVC) have been reported to improve the power factor; Power Factor Corrector (PFC) and Active Power Filters (APF) have the ability of current harmonics suppression and power factor correction; some active circuits were developed to compensate unbalanced currents as well as limit the neutral current. In general, parallel-connected converters have the ability to improve the current quality while the series-connected regulators inserted between the load and the supply, improve the voltage quality. For voltage and current quality control, both series and shunt converters are necessary, which is known as Unified Power Quality Conditioner (UPQC) and have been analyzed in this thesis. UPQC was presented during 1998. Such solution can compensate for different power quality phenomena, such as: sags, swells, voltage imbalance, flicker, harmonics and reactive currents. UPQC usually consists of two voltage-source converters sharing the same capacitive DC link. One of the converters is an active rectifier (AR) or shunt active filter while other is a series active filter (SF). Also, at the point of the load connection, passive filter banks are connected. In UPQC the series active power filter eliminates supply voltage flicker/imbalance from the load terminal voltage and forces an existing shunt passive filter to absorb all the current harmonics produced by a nonlinear load. The shunt active filter performs dc link voltage regulation, thus leading to a significant reduction of capacity of dc link capacitor. This seminar discusses various power quality problems and solutions with an emphasis on the UPQC.

1.2 Importance of Clean Power

Modern semiconductor technology is a tool for achieving productivity and profit. It is designed to run on clean electrical power. The irony is as this technology increases in sophistication, so does it's susceptibility to power disturbances because nonlinear devices, such as power electronics converters, inject harmonic currents in the ac system and increase overall reactive power demanded by the equivalent load. Also, the number of sensitive loads that require ideal sinusoidal supply voltages for their proper operation has increased. In order to keep power quality under limits proposed by standards, it is necessary to include some sort of compensation. Clean power for technology is like clean fuel for automobiles.

1.3 Introduction of Power Quality

The term electric power quality broadly refers to maintaining a nearly sinusoidal power distribution bus voltage at rated magnitude and frequency. In addition, the energy supplied to a consumer must be uninterrupted from reliability point of view. Though power quality is mainly a distribution system problem, power transmission system may also have impact on quality of power. Causes for power quality deterioration are explained in next section.

1.4 Power Quality Problems

With the ever-increasing use of sophisticated controls and equipment in industrial, commercial, institutional, and governmental facilities, the continuity, reliability, and quality of electrical service has become extremely crucial to many power users. Electrical systems are subject to a wide variety of power quality problems which can interrupt production processes, affect sensitive equipment, and cause downtime, scrap, and capacity losses. Momentary voltage fluctuations can disastrously impact production. . . extended outages have a greater impact.

Many power quality problems are easily identified once a good description of the problems is obtained. Unfortunately, the tensions caused by power problems often result in vague or overly dramatic descriptions of the problem. When power problems happen, one must try to note the exact time of the occurrence, its effect on electrical equipment, and any recently installed equipment that could have introduced problems to the system.

A power quality audit can help determine the causes of one's problems and provide a well-designed plan to correct them. The power quality audit checks one's facility's wiring and grounding to ensure that it is adequate for one's applications and up to code. The auditor will check the quality of the AC voltage itself, and consider the impact of the utility's power system. The findings will be included in a report outlining problems found during the audit and recommend solutions. Many businesses and organizations rely on computer systems and other electrical equipment to carry out mission-critical functions, but they aren't safeguarding against the dangers of an unreliable power supply

1.4.1 Source of Power Quality Problems

- Disturbances can be generated external to a facility.
- Disturbances can be generated internal to a facility.

External Origins:

- Lightning
- Grid Switching
- Power Factor Correction
- Inductive Load Switching
- Utility Fault Clearing

Internal Origins:

- Internal disturbances are typically more numerous and destructive.
- They are created by all the various electrical loads in your facility.
- The disturbance sources are also closer to sensitive devices which limit the damping effect of wiring.

1.4.2 Generic Power Problems

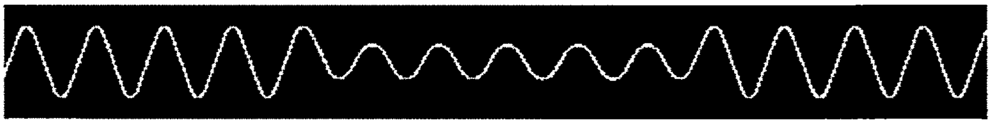
The following are the generic power problems: Blackouts & Brownouts, Sags, Surges, Impulses, Frequency Changes, Noise, Harmonics, and Power Factor Problems

1.4.3 Responsibility of utility

- Constant Voltage
- All the current needed (breaker limited)
- Protection for people and traditional loads (lights and motors) through grounding procedures.

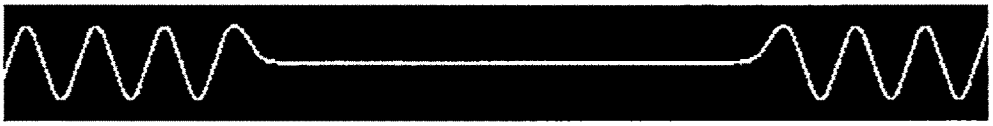
1.5 The Most Common Power Quality Problems

A. Voltage Sags



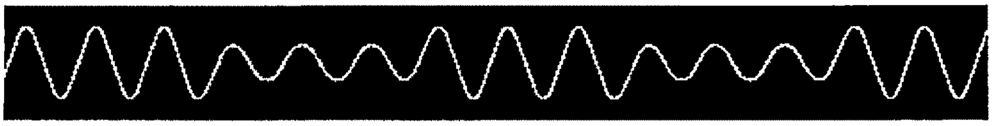
Voltage sags are the most common power problem encountered. Sags are a short-term reduction in voltage (that are 80-85% of normal voltage) [5], and can cause interruptions to sensitive equipment such as adjustable-speed drives, relays, and robots. Sags are most often caused by fuse or breaker operation, motor starting, or capacitor switching. Voltage sags typically are non-repetitive, or repeat only a few times due to recloser operation. Sags can occur on multiple phases or on a single phase and can be accompanied by voltage swells on other phases.

B. Power Interruptions



Power interruptions are zero-voltage events that can be caused by weather, equipment malfunction, recloser operations, or transmission outages. Interruptions can occur on one or more phases and are typically short duration events, the vast majority of power interruptions are less than 30 seconds [5].

C. Voltage Flicker



Voltage flicker is rapidly occurring voltage sags caused by sudden and large increases in load current. Voltage flicker is most commonly caused by rapidly varying loads that require a large amount of reactive power such as welders, rock-crushers, sawmills, wood chippers, metal shredders, and amusement rides. It can cause visible flicker in lights and cause other processes to shut down or malfunction.

D. Power Surges

A power surge takes place when the voltage is 110% or more above normal. The most common cause is heavy electrical equipment being turned off. Under these conditions, computer systems and other high tech equipment can experience flickering lights, equipment shutoff, errors or memory loss [1][5].

E. High-Voltage Spikes

High-voltage spikes occur when there is a sudden voltage peak of up to 6,000 volts. These spikes are usually the result of nearby lightning strikes, but there can be other causes as well. The effects on electronic systems can include loss of data and burned circuit boards.

F. Switching Transients

Switching transients are extremely rapid voltage peak of up to 20,000 volts with duration of 10 microseconds to 100 microseconds. Switching transients take place in such a short duration that they often do not show up on normal electrical test equipment. They are commonly caused by machinery starting and stopping, arcing faults and static discharge. In addition, switching disturbances initiated by utilities to correct line problems may happen several times a day. Effects can include data errors, memory loss and component stress that can lead to breakdown.

G. Frequency Variation

A frequency variation involves a change in frequency from the normally stable utility frequency of 50Hz.This may be caused by erratic operation of emergency generators or unstable frequency power sources. For sensitive equipment, the results can be data loss, program failure, equipment lock-up or complete shut down.

H. Electrical Line Noise

Electrical line noise is defined as Radio Frequency Interference (RFI) and Electromagnetic Interference (EMI) and causes unwanted effects in the circuits of computer systems. Sources of the problems include motors, relays, motor control devices, broadcast transmissions, microwave radiation, and distant electrical storms. RFI, EMI and other frequency problems can cause equipment to lock-up, and data error or loss.

I. Brownouts

A brownout is a steady lower voltage state. An example of a brownout is what happens during peak electrical demand in the summer, when utilities can't always meet the requirements and must lower the voltage to limit maximum power. When this happens, systems can experience glitches, data loss and equipment failure.

J. Blackouts

A power failure or blackout is a zero-voltage condition that lasts for more than two cycles. It may be caused by tripping a circuit breaker, power distribution failure or utility power failure. A blackout can cause data loss or corruption and equipment damage.

1.6 An Overview of Power Problems, Their Causes and Effects

There are number of power quality problems and each problem create significant effect. The overview of problem and their effects is summarized in following table

Table 1.1: Overview of Power Problems, Their Causes and Effects

Power Problems	Causes	Effects
Voltage Spikes and Surges	Lightning, Utility grid switching, Heavy industrial equipment	Equipment failure, System lock-up, Data corruption, Data loss
Electrical Noise	Arc Welders etc..., Switch mode power supplies, Fault clearing devices, Ground not dedicated or isolated	Data corruption, Erroneous command functions, Loss of command functions, Improper wave shapes etc...
Harmonics	Switch mode power supplies, Nonlinear loads	High neutral currents, Overheated neutral conductors, Overheated transformers, Voltage distortion, Loss of system capacity
Voltage Fluctuations	Brownouts, Unstable generators, Overburdened distribution systems, Start-up of heavy equipment	System lock-up, System shutdown, Data corruption, Data Loss, Reduced performance, Loss of system control
Power Outage & Interruptions	Blackouts, Faulted or overload, conditions, Back-up generator start-up	System crash, System lock-up, Power supply damage, Lost data, Complete shutdown loss of control
Stable AC from DC source	DC power plant available, Remote areas	Unavailable AC power

Emergency power source transfer, Peak shave power	Back-up generator start-up, Power interruption transfer of utility source	System crash, System lock-up, Power supply damage, Lost data, Complete shutdown loss of control
Distribution Systems and Power quality questions	Lack of understanding of system problems or coordination	Unstable distribution system, Lost productivity and profitability.
High energy cost / Power factor correction	Need for energy savings and pay back for equipment investment.	Lost profits increased cost.

1.7 Power Quality Solutions

- Surge Suppressors
- Voltage Regulators
- Generators
- Filters

1.7.1 Surge Suppressors

Transient voltage surge suppression (TVSS) provides protection against transient surges, which can happen so quickly that they do not register on normal electrical testing equipment. Surge suppressors or surge protectors are the most basic form of power protection. A surge suppressor is often used to shield important, but less critical or highly sensitive equipment. It is also used as a complement to more comprehensive power protection solutions. They are passive electronic devices that protect against transient high-level voltages.

Transients are often the cause of "unexplained" equipment problems, computer lock-up, data loss, and other "gremlins" inside a facility. Transient voltage surge suppressors can be incorporated into voltage regulators, power conditioners, and UPS for added protection. Depending on the components involved, surge suppressors offer limited protection against power surges. In the case of frequent high voltage spikes, a high quality surge suppressor is a good choice. When large equipment like AC motors are turned on and off, they create large, fast voltage changes (switching transients). However, low frequency surges (slow changes at 400 Hz or less) can be too great for a surge suppressor attempting to clamp that surge.

1.7.2 Voltage Regulators

A voltage regulator maintains the input voltage to the facility or system within a narrow range. Regulators provide excellent protection against sags, brownouts, surges and spikes, and moderate noise attenuation, but do not protect against blackouts. There are five types of voltage regulators:

- Ferro resonant
- Tap Switching Transformer
- Limited Range Variable Transformer
- Buck-Boost
- Hybrids

A. Ferro resonant Regulators

Ferro resonant constant voltage regulators use a capacitor in series with a transformer coil, and tend to be high impedance devices that are sensitive to load changes, and therefore, do not handle high inrush loads well. They can interact with switch mode power supplies to produce transients and electrical noise on the output. Their resonant circuits make them particularly sensitive to frequency changes. Applied carefully, Ferro resonant regulators can provide ±2% - ±5% output regulation, load isolation, and noise attenuation

B. Tap Switching Transformer Regulator

Regulators based on tap-switching transformers monitor output voltage and use solid-state switching circuits for changing the transformer taps. Typically these units provide ±3% - ±5% output regulation. These regulators are extremely fast, but their fast response can sometimes cause problems with switch mode power supplies and can produce harmonics and radio frequency interference.

C. Limited Range Variable Transformer Regulator

Limited range variable transformer regulators use variable transformers to directly control the output voltage of the regulator. This places the transformer's brush assembly directly in the power path of the regulator, which could cause premature regulator failure. Limited range regulators provide excellent regulation, from ±1% - ±3%.

D. Buck-Boost

The buck-boos regulator consists of three basic components: a motorized variable transformer, a buck-boost transformer, and a controller. These regulators are very reliable and provide from ±1% - ±3% voltage regulation. The controller monitors the output voltage and then uses the feedback signals to determine drive commands for the transformers.

E. Hybrid Regulators

Ideally, a voltage regulator will combine two or more of these technologies in order to maximize the regulator's stability and output regulation. Called hybrid regulators, these units bring voltage regulation up to a power conditioning level, providing comprehensive power conditioning features such as harmonic suppression.

1.7.3 Generators

Generators are machines that convert mechanical energy into electrical energy. They are usually used as a backup power source for a facility's critical systems such as elevators and emergency lighting in case of blackout. However, they do not offer protection against utility power problems such as over voltages and frequency fluctuations, and although most can be equipped with automatic switching mechanisms, the electrical supply is interrupted before switching is completed, so it cannot protect against the damage that blackouts can cause to expensive equipment and machinery.

1.7.4 Filters

- Passive filters
- Active power filters

A. Passive filters

Passive filters have been most commonly used to limit the flow of harmonic currents in distribution systems they are usually custom designed for the application. However, their performance is limited to a few harmonics and they can introduce resonance in the power system.

The passive filters use reactive storage components, namely capacitors and inductors. Among the more commonly used passive filters are the shunt LC filters and the shunt low pass LC filters. They have some advantages such as simplicity, reliability, efficiency and cost. Among the main disadvantages are the resonances introduced into the ac supply; the filter effectiveness, which is a function of overall system configuration; and the tuning and possible detuning issues. These drawbacks are overcome with the use of active power filters.

1.8 Active Power Filters

Active power filters are basically of two types i.e. shunt active power filter and series active power filters.

1.8.1 Shunt Active Filter

The shunt 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. Shunt active power filters compensate load current harmonics by injecting equal but opposite harmonic compensating current. In this case the shunt active power filter operates as a current source injecting the harmonic components generated by the load but phase shifted by 180°.

1.8.2 Series Active Power Filters

Series active power filters were introduced by the end of the 1980s and 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 quality. This type of approach is especially recommended for compensation of voltage unbalances and voltage sags from the ac supply and for low power applications and represents economically attractive alternatives to UPS, since no energy storage (battery) is necessary and the overall rating of the components is smaller. The series active filter injects a voltage component in series with the supply voltage and therefore can be regarded as a controlled voltage source, compensating voltage sags and swells on the load side.

1.8.3 Series-Shunt Active Filters

As the name suggests, the series-shunt active filter is a combination of series active filter and shunt active filter. The shunt-active filter is located at the load side and can be used to compensate for the load harmonics. On the other hand, the series portion is at the source side and can act as a harmonic blocking filter. This topology is called as Unified Power Quality Conditioner. The series portion compensates for supply voltage harmonics and voltage unbalances, acts as a harmonic blocking filter and damps power system oscillations. The shunt portion compensates load current harmonics, reactive power and load current unbalances.

1.9 Harmonic Standards

Different standards that are followed are listed below

- IEEE 519: Harmonic control Electrical power systems [24].
- IEEE Harmonic's working group.
- IEC Norm 555-3, prepared by the International Electrical commission.
- IEC Power quality standards- numbering system (61000-1-X - Definitions and methodology; 61000-2-X - Environment (e.g. 61000-2-4 is compatibility levels in industrial plants); 61000-3-X - Limits (e.g. 61000-3-4 is limits on harmonics emissions); 61000-4-X - Tests and measurements (e.g. 61000-4-30 is power quality

measurements); 61000-5-X - Installation and mitigation; 61000-6-X - Generic immunity & emissions standards; IEC SC77A: Low frequency EMC Phenomena -- essentially equivalent of "power quality" in American terminology).

- US Military Power Quality Standards (MIL-STD-1399, MIL-STD-704E).
- EN 50 006, "The limitation of disturbances in electricity supply networks caused by domestic and similar appliances equipped with electronic devices," European standard prepared by CENELEC.
- West German Standards VDE 0838 for household appliances, VDE 0160 for converters, and VDE 0712 for fluorescent lamp ballasts.

In the thesis IEEE – 519 standards is taken for comparison with the obtained results from simulation and practical. This is common standard which is used, briefly the total harmonic distortion of current drawn must be below 5% and individual harmonic components shouldn't be greater than 3%. This also imposes restriction on supply voltage harmonics which are to be maintained below 3% by the utility or supplier.

1.10 State of Art

Unexplained computer network failures, premature motor burnouts, humming in telecommunication lines, and transformer overheating are only a few of the damages that quality problems may bring into home and industrial installations. Studies by the Canadian Electrical Association indicate that power quality problems, including voltage sags and surges, transients, and harmonics, are estimated to cost Canada about $1.2 billion annually in loss production. Most of the cost of harmonics is not incurred in the power system itself but rather within the customer's facility [1-2-3].

Power quality problems such as voltages Sag/Swell, flickers, harmonics, asymmetric of voltage have become increasingly serious. The voltage quality may contain amplitude errors, harmonics, phase unbalance, sag/dips, swells, flicks, impulses and interrupt voltage. As far as the current quality is concerned harmonics, reactive component, unbalance, excessive neutral zero-sequence current are the main issues [4-5-6]

While system solutions are being searched and even power quality markets are being formulated in the present deregulated environments, the solution starts at the individual industrial and commercial facilities. With the risks and costs of pollution in mind, researchers and equipment manufacturers are looking for alternatives for protection, while industry and businesses are increasingly investing in sophisticated and innovative devices to improve power quality.[7-8]

Nowadays power quality problems are solved primarily with different Active Power Filter. Research into active power filter for medium voltage range is ongoing [9-10-11] The control strategies applied to active power filters play a very important role on the improvement of the performance and stability of APF; with the development of control strategies. The method used for current reference generation is simple by using newly proposed algorithm. The method used is indirect method of estimation but in other reference frame change the 3 phase supply in to 2 phase supply [12-13]. APF algorithm also compensate harmonics and reactive power separately. It is mainly based upon the desired capacity of the APF. Various simulation results are presented with ideal and distorted mains voltage and compared with other algorithms. [14-15]

APF is designed with controlled voltage source power converter as active power filter to generate a compensating voltage that is converters into compensating current via the series connected inductor and capacitor set. This is nothing but a hybrid topology to improve the performance of the active power filter. Performance of different topologies with hybrid topology is compared, in proposed topology they claim that the size of the inductor and capacitor are reduced.[16-17-18]

The shunt active power filter (STATCOM), used for reactive power compensation in power transmission systems. Shunt active power filters compensate load current harmonics by injecting equal but opposite harmonic compensating current[19-20]. In this case the shunt active power filter operates as a current source injecting the harmonic components generated by the load but phase shifted by 180^{o}. The STATCOM is a solid-state synchronous voltage generator, which consists of a multi-pulse, voltage-sourced inverter connected in shunt with the transmission line.

The shunt active filter has proved to be useful device to eliminate harmonic currents and to compensate reactive power for linear/nonlinear loads. This reference presents a novel approach to determine reference compensation currents of the three phases shunt active power filter (APF) under distorted and/or imbalanced source voltages in steady state. The proposed approach is compared with three reviewed shunt APF reference compensation strategies.[9-21-22-23]

The STATCOM is superior in that it provides greater speed of response, does not increase short circuit current in the system and can provide symmetrical leading or lagging reactive current[8]. The smooth continuous control of the STATCOM minimizes source, compensating voltage sags and swells on the load side[24-25].

According to Industrial customer Voltage sag is the most sever power quality problem Voltage sag is common reasons for malfunctioning in production plants. According to IEEE standard 1159 voltage sag is "a decrease in RMS voltage between 10 to 90 % at a power frequency for durations from 0.5 cycles to 1 minute" [5]. off large load. The effect of voltage swell is control delay tripping, overheating and many times destruction in electrical equipments [3].

One of the most efficient method is to mitigate voltage sag/swell DVR (Dynamic Voltage Restore). DVR inject an appropriate voltage magnitude with an appropriate phase angle dynamically [4]. Dynamic compensating signals are determine based on the difference between desired and actual values [5]. Main components of DVR are voltage source converter, injecting transformer, passive filter, and energy storage device. The performance of DVR depends on the efficiency control technique of switching of voltage source inverter (VSI). In this paper *abc* to *dq0* based simple control method is used to compensate voltage sag/swell. The proposed control technique is modeled based on MATLAB/ SIMULINK. [26-27-28]

Series active power filter working as a sinusoidal current source, in phase with the mains voltage. The amplitude of the fundamental current in the series filter was controlled through the error signal generated between the load voltage and a pre-established reference. The control allows an effective correction of power factor, harmonic distortion, and load voltage regulation. Compared with previous methods of control developed for series active filters, this method is simpler to implement, because in this approach the only thing required is to generate a sinusoidal current, in phase with the mains voltage, the amplitude of which is controlled through the error in the load voltage[29-30].
In different approach The main circuit of the APF consisted of voltage source inverter with a space vector modulation and high pass filter connected in parallel t o the power system. The proposed system had a function harmonic isolation between source and load, voltage regulation, and unbalance compensation. Therefore, the source current is maintained as a nearly sinusoidal waveform and the load voltage is regulated with a rated voltage regardless of the source variation condition. [31-32-33]

A protection scheme for series active power filters is presented and analyzed in this reference. The proposed scheme protects series active power filters when short-circuit faults occur in the power distribution system. The principal protection element is a varistor, which is connected in parallel to the secondary of each current transformer. After a few cycles of short-circuit currents flowing through the varistor, the gating signals applied to the active power filter switches are removed and the pulse-width-modulation (PWM) voltage-source inverter (VSI) is short circuited through a couple of anti parallel thyristors. [34-35-36-37]

STATCOM is mainly used for current harmonics and reactive power compensation and DVR used for voltage harmonics mitigation. The new method is combined system of series and shunt active filter been proposed. A new control method, which enables application of the combined system to compensation for cycloconverters, is proposed.

The relations between the harmonic current extraction circuit and the compensation characteristics have been developed. As a result, the combined system can be considered suitable for harmonic compensation.[38-39]

As the name suggests, the series-shunt active filter is a combination of series active filter and shunt active filter.. The shunt-active filter is located at the load side and can be used to compensate for the load harmonics. On the other hand, the series portion is at the source side and can act as a harmonic blocking filter. This topology is called as Unified Power Quality Conditioner. The series portion compensates for supply voltage harmonics and voltage unbalances, acts as a harmonic blocking filter and damps power system oscillations. The shunt portion compensates load current harmonics, reactive power and load current unbalances. In addition, it regulates the dc link capacitor voltage. The power supplied or absorbed by the shunt portion is the power required by the series compensator and the power required to cover Unified Power Quality Conditioner (UPQC) The UPQC gives power system operators the flexibility to overcome many of the transmission restraints facing the industry today.[40-41]

A UPQC equipped transmission line can independently control real and reactive flow to maximize line utilization and system capability. It also can be used to minimize reactive current flow, enabling users to reduce system losses. The UPQC provides simultaneous, real-time control of all three basic power transfer parameters (voltage, impedance and phase angle) in any combination to optimize the transmitted power. It can handle such conventional functions as reactive shunt compensation, series compensation and phase shifting. The UPQC allows the power delivery system operator to set and independently control the real and reactive flow on a specific power transmission line[13-14-16]].

Unified Power Quality Conditioner (UPQC), which is a combination of series APF and shunt APF. A control strategy based on unit vector template generation is discussed in this paper with the focus on the mitigation of voltage harmonics present in the utility voltage [42-43].

Then this reference proposes an approach of One Cycle Control (OCC) for UPQC which can deal with most of the problems identified above as a whole. This proposed OCC-UPQC consists of a serial three-phase three-leg and a parallel three-phase four-leg converter. The OCC-UPQC has the advantages of no reference calculation that results in simplicity, vector operation for reduced losses, modular approach with the flexibility to work in both three-wire or four-wire systems. The proposed UPQC provides a multifunctional, high performance, cost effective, and reliable solution for total power quality control[44].

Power quality of sensitive loads can be improved by a unified power quality conditioner (UPQC) which consists of back-to-back connected series and shunt active filters, and is modeled using state-space-averaging technique to analyze its behavior. The UPQC is modeled with reference to a synchronously rotating d-q-0 reference axes. Compared to the traditional low pass filtering methods, the proposed method is seen to result in a more rapid dynamic response. The proposed UPQC used to compensate for various voltage disturbance of the power supply, to correct any voltage fluctuation and to prevent the harmonic load current from entering the power system. The proposed direct compensation control method used in the series active filter and the moving window current calculation method used in the shunt active filter make the UPQC response very quickly to any sudden voltage change.[45-46]

A unified power quality conditioner (UPQC) that consists of two three-phase current-source converters connected on the same inductive DC link has faster phase voltage control loop than its voltage-source converter based counterpart, as well as the inherent short circuit protection capability[47].

A new control design of UPQC for harmonic compensation in a power distribution system is introduced and the topology of this UPQC is based on two three phase voltage source inverters (VSIs) which share two dc link capacitors with midpoint grounded. The extraction circuit using an artificial neural network (ANN) controller with improved weights updating algorithm is proposed. The equivalent single phase representation of the

ANN with hysteresis controlled UPQC Besides eliminating the harmonic components successfully, it can also correct the power factor of the supply current and mitigate. However, the proposed design concept still needs to be validated by experimental results in the future[48-49]

1.11 The Motivation

Modern concept of FACT devices is an effective solution for power quality problems. One of the fact device is static compensator (STATCOM) used for reactive power compensation in power transmission systems. Shunt active power filters compensate load current harmonics by injecting equal but opposite harmonic compensating current [3][4]. In this case the shunt active power filter operates as a current source injecting the harmonic components generated by the load but phase shifted by 180^{o}. Same way for series compensation FACT device used is Dynamic Voltage Restore (DVR). DVR inject an appropriate voltage magnitude with an appropriate phase angle dynamically [5].DVR effectively mitigates voltage sag/swell. Dynamic compensating signals are determine based on the difference between desired and actual values[6].

The present technique used for power quality solution is useful either for current issue or voltage power quality issue. At the Same time it is very complex and very costly. The control technique used decides the response of STATCOM and DVR[7].

Three phase combination of shunt and series FACT devises is very rarely and lately introduce. It is combination of shunt and series devices. It is known as Unified Power conditioner (UPQC). UPQC is a combination of fact devices. The design of UPQC is made up with STACOM and DVR [8][9] with innovative technique. This unique combination device able to reduce current and voltage related power quality issue effectively

The motivation behind the work presented in this thesis are :

1. Simulate the fast response STATCOM to eliminate the current harmonics
2. Using innovative technique design a DVR to mitigate voltage sags and swells

3. Main task is combine both device and used appropriate fast response control technique to filter out current and voltage harmonics.
4. Explore different control technique for UPQC to get optimum response
5. Simulate different types of loads like R- L and DC machine
6. To study the effectiveness of optimal adjustment of control circuit

1.12 Organization of the Thesis

Chapter 1: In this chapter the background of power quality issues, power quality problems and the available solutions are discussed briefly. Also certain active power filters topologies have been briefly discussed. Moreover, this chapter includes the brief details of references which have been referred for this thesis work.

Chapter 2: In this chapter the shunt active power filter is discussed in detail. In this the basic compensation principle of shunt active power filter, power flow, estimation of reference source current, control scheme, design of dc link capacitor, selection of reference capacitor voltage, selection of filter inductor, PI controller and hysteresis controller have been discussed. Also the operation of simulation model has been discussed briefly. The Voltage Source Inverter (VSI) based The Static Synchronous Compensator (STATCOM) is used for eliminating current harmonics and compensating reactive power. This VSI draw or supply a compensating current from the utility such that it cancels current harmonics on the AC side.

Chapter 3: In this chapter the series active power filter has been discussed in detail. In this the basic compensation principle of series active power filter, estimation of reference voltage and control scheme and brief operation of simulation model has been discussed. The DVR restores constant load voltage and voltage wave form by injecting an appropriate voltage. Present novel structure improves power quality by compensating voltage sag and voltage swells.

Chapter 4: In this chapter the unified power conditioner (UPQC) has been discussed in detail. In this the Mathematical Modeling, Operating Principle and Control scheme of the

UPQC have been discussed in detail. Using innovative control technique combine series and shunt combination

Chapter 5: In this chapter the simulation blocks and their respective results of shunt and

series active power filters and unified power quality conditioner have been shown. A very simple hysteresis current controller based control technique with help of unit vector template is proposed for STATCOM. DVR is simulated with abc to dq0 base new control algorithm to generate the pulse Phase Locked Loop (PLL) is used to generate unit sinusoidal wave in phase with main voltage. The combination of shunt and series Fact devices test on the RL load and DC machine

Chapter 6: This chapter gives the main outcomes of the thesis and scope of the future works