CHAPTER 2

LITERATURE REVIEW

2.1 General

The flexible AC transmission systems (FACTS) concept based on applying leading edge Power Electronics Technology to existing AC transmission systems, improves the stability to increase usable power transmission capacity to its thermal limit. A UPFC can simultaneously provide control of the transmission line impedance, phase angle and voltage.

The UPFC is constructed from two power electronic inverters which are connected together by a common DC link. Two transformers are used to isolate the UPFC and to match the voltage levels between the power system and the power electronic inverters. One of the inverters is connected to the transmission line. The series connected inverter can generate a voltage which can have adjustable magnitude and phase angle. This inverter therefore can provide both real and reactive power to the transmission line. The second inverter primarily provides the real power required by the series inverter and it can also operate as an independent VAR compensator. Therefore the UPFC can control the flow of real and reactive power in the transmission line.

The two VSIs can work independently by separating the DC side. So in that case, the shunt inverter operates as a STATCOM that generates or absorbs reactive power to regulate the voltage magnitude at the connecting point. The series inverter operates as SSSC that generates or absorbs reactive power to regulate the current flow, and hence the power flow on the transmission line is regulated.
The UPFC can be used to improve the power quality due to the separate controlling capability of real and reactive power. In this proposed work two bus system is modeled and simulated with UPFC. 14 bus system is also modeled and simulated with or without UPFC. The real and reactive power are investigated and observed. The real power increases with the increase in the angle of injection. The reactive power increases with the shunt voltage injection.

2.2 Literature Survey

From IEEE Transaction power delivery the UPFC, which was proposed by Gyugyi in 1991, is one of the most complex FACTS devices in a power system today. It is primarily used for independent control of real and reactive power in transmission lines for a flexible, reliable and economic operation and loading of power system. Until recently, all three parameters that affect real and reactive power flow on the line, i.e. the line impedance, voltage magnitudes at the terminals of the line and power angle, were controlled separately using either mechanical or other FACTS devices such as a Static Var Compensator (SVC), a Thyristor Controlled Series Capacitor (TCSC), a phase shifter etc. However, the UPFC allows simultaneous or independent control of these parameters with transfer from one control scheme to another in real time. Also, the UPFC can be used for voltage support, transient stability improvement and damping of low frequency power oscillations.

UPFC which consists of a series and shunt converter connected by a common DC link capacitor can simultaneously perform the function of transmission line's real and reactive power flow control in addition to bus voltage shunt reactive power control (Schauder et. al. 1998). The shunt converter of the UPFC controls the UPFC bus voltage/shunt reactive power and the DC link capacitor voltage. The series converter of the UPFC controls the transmission line real/reactive power flows by injecting a series voltage of adjustable magnitude and phase angle (Renz et. al. 1999). The interaction between the series injected voltage
and the transmission line current leads to real and reactive power exchange between the series converter and power / system. Under steady state conditions, the real power demand of the series converter is supplied by the shunt converter (Mihilac et. al. 1996). But during transient conditions, the series converter's real power demand is supplied by the DC link capacitor. If, the information regarding the series converter's real power demand is not conveyed to the shunt converter control system, it could lead to the collapse of the DC link capacitor voltage, and the subsequent removal of the UPFC from operation. Very little or no attention has been given to the important aspect of coordination control between the series and the shunt converter control systems (Padiyar et. al. 1998 and Round et. al. 1996).

From European Journal of scientific research, in contrast to real power coordination between the series and shunt converter control system, the control of transmission line reactive power flow leads to excessive voltage excursions of the UPFC bus voltage during reactive power transfers. This is due to the fact that any change in transmission line reactive power flow achieved by adjusting the magnitude/phase angle of the series injected voltage of the UPFC is actually supplied by the shunt converter. The excessive voltage excursion of the UPFC bus voltage is due to the absence of reactive power coordination between the series and the shunt converter control system. This aspect of UPFC control also has not been investigated (Nashiren.F; Mailah et. al. 2009).

From IEE proceedings – Generation, Transmission and Distribution, the feasibility of achieving a dynamic voltage restoration without the use of the injection transformer is investigated by Li et. al. (2002). The injection transformer used in the conventional DVR is expensive, bulky and contributes towards losses. From the design, operation and maintenance point of view, the transformer is an added complexity to the restorer. Investigation is made into the feasibility of the DVR without the injection transformer. It shows that by introducing a separate DC
link/energy storage in each phase, and a cascaded switch/ inverter connection as well as online energy replenishing charging circuitry, the proposed transformer-less DVR can satisfactorily mitigate the voltage sag problems. The design is promising, as it indicates a less costly restorer of a more compact structure.

Hongfa Ding et. al. (2002) presented a novel DVR consisting of a conventional three phase voltage source inverter together with an emitter follower and it is applicable in unbalanced three phase four wire power distribution system. The three phase voltage source inverter is used to eliminate the adverse influences of the negative sequence components of the load voltage and to restore the load voltage to the given level, while the emitter follower is used to eliminate the zero sequence components.

The modeling aspects of the DVR working against voltage sags by simulation in the PSCAD/EMTDC have been presented by Nguyen et. al. (2004). First, a DVR using a six-pulse inverter, and a three phase Root Mean Square (RMS) voltage measurement and sine wave PWM control was described. The DVR prevents excellent performance to protect critical loads against balanced voltage sags. Then, a DVR using single-phase RMS voltage measurement, which works very well against not only balanced voltage sags but also unbalanced ones, resulting from both single line and line-line faults was presented. Finally, the study of the DVR capability and performance was examined thoroughly.

Chairs Fitzer et. al. (2004) presents and verify a novel voltage sag detection technique for use in conjunction with the main control system of a DVR. It is necessary for the DVR control system not only to detect the start and end of the voltage sag but also to determine the sag depth and any associated phase shift. The DVR, which is placed in series with a sensitive load, must be able to respond quickly to voltage sag. A problem arises when fast evaluation of the sag depth and phase shift is required, and this informer is not readily available to either user
monitoring the state of the grid or parallel controllers. Typical standard information tracking or detection methods such as the Fourier transform or phase-locked loop are too slow in returning this information. As a result of this the voltage sag detection method in this work proposes a new matrix method, which is able to compute the phase shift and voltage reduction of the supply much quicker than the Fourier transform.

Kaifei Wang et. al. (2004) described an uninterrupted three phase DVR based on three phase four wire inverter. A rectifier is used to supply the inverter of DVR and it makes the DVR compensate sag continuously. The soft phase locked loop method is used to detect the source voltage. The inverter is controlled by voltage space vector PWM algorithm that is different from the traditional method.

Hyosung Kim and seung-Ki Sul (2005) discussed the control of the compensation voltages in dynamic voltage restorers (DVR). The power circuit of a DVR system is analyzed in order to come up with control limitations and control targets for compensation voltage control. Based on this power stage analysis, a combined feed forward and state feedback control structure for the compensation voltages of DVRs is developed. Digital control systems normally have control delay from the sampling period, the switching frequency of the inverter, the sensor transmission time, etc. The control performance related with the control delay, closed loop damping factor, and the output filter parameters in DVR systems are analyzed and design guidelines are proposed for the control gains and the inverter switching frequency of DVRs.

Oscar and Prasad (2005) developed an algorithm that provides a reliable and fast detection method for voltage disturbances, such as voltage sags, swells, flicker, frequency change in the utility voltage and harmonic distortion. The algorithm is based on the theory that allows a set of three phase voltages which can be presented as DC voltages in a d-q synchronous rotating frame. In
this work, the utility input voltages are sensed and then converted to DC quantities in the d-q reference frame. Thus any disturbance at the utility input voltage will be promptly reflected as disturbances in the d-q values. The analysis, simulation and experimental results are presented for a three phase system.

The performance of a DVR in mitigating voltage sags/swells is demonstrated with the help of MATLAB. The DVR handles both balanced and unbalanced situations without any difficulty and injects the appropriate voltage component to correct any anomaly in the supply voltage to keep the load voltage balanced and constant at the nominal value. In the case of voltage sag, which is a condition of a temporary reduction in the supply voltage, the DVR injects an equal positive voltage to correct it. On the other hand, the voltage swell case, which is a condition of a temporary increase in the supply voltage, the DVR injects an equal negative voltage in all the three phases, which are anti-phase with the supply voltage. For unbalanced conditions, the DVR injects an appropriate unbalanced three phase voltage component, positive or negative, depending on whether the condition is an unbalanced voltage sag or unbalanced voltage swell (Paisan Boonchiam et al. 2006).

Bingsen Wang et al. (2006) described the detailed design of a closer loop regulator to maintain the load voltage within acceptable levels in a DVR using a transformer coupled H bridge converters. The multiloop regulator with complex state feedback decoupling is designed with an inner current loop and outer voltage loop. Detailed numerical simulation has been carried out using MATLAB to verify the power circuit operation and control scheme. A laboratory scale experimental prototype was developed that verifies the power circuit operation and controller performance. The experimental results indicate an excellence with the digital simulations.

Poh Chiang Loh et al. (2004) described a detailed analysis on Z source inverter modulation, showing how various conventional PWM strategies for
controlling a conventional VSI can be modified to switch a voltage type Z source inverter either continuously or discontinuously. Through the proper placement of shoot-through states, Z source inverter modulation can be made to reproduce the desired performance features of various reported conventional PWM strategies. The theoretical and modulation concepts presented have been verified both in simulation and also experimentally.

Mahinda Vilathgamuwa et. al. (2006) proposed a new topology based on the Z source inverter for the DVR, in order to enhance the voltage restoration property of the device. The Z source impedance network along with the shoot-through capability of the proposed inverter would ensure a constant DC voltage across the DC link, despite dwindling voltage in the storage devices connected in the DC link during the process of voltage compensation. A new topology derived from the Z source inverter enhances the capability of the DVR through better utilization of the stored energy. Moreover, it incorporates enhanced electromagnetic of the developed DVR system and its controller was tested with simulations and experiments. It was observed that the DVR compensates the disturbance caused by a sag effectively, while utilizing the stored energy fully by the use of the buck-boost capability of the proposed Z source inverter.

Liew Zhan Liu et. al. (2007) presented a dynamic Voltage Restorer (DVR) system using a three dimensional space vector pulse width modulation (3D-SVPWM). In the proposed 3D-SVPWM control scheme, the inclusion of zero-axis, in addition to conventional alpha-beta axes, enables the mitigation of zero sequence components. The two null switching vectors, which are located at the origin in alpha-beta two dimensional spaces, are now separated into two totally independent vectors in the opposite directions. It is a versatile voltage sag compensating solution that can be applied to restore fault-affected three-phase power system.
Rosli Omar and Nasrudin Abd Rahim (2008) discussed the control for DVR biased on d-q transformation. A control system is based on d-q technique in which a scaled error of the source side of the DVR and its reference for sags/swells/correction, has been presented. The DVR compensates the sags/swells quickly and provides excellent voltage regulation. The DVR handles both balanced and unbalanced situations without any difficulties and injects the appropriate voltage component to keep the load voltage balanced and constant at the nominal value.

(Chi- Seng Lam et. al. 2008) discussed Voltage swell and over voltage compensation problems in a diode bridge rectifier supported transformer-less coupled DVR. When a swell or over voltage happens, applying a conventional in phase or phase invariant boosting method causes a rapid rise in the DC link voltage, which may damage the storage capacitors and switching devices, and increase the switching loss. This work proposed a novel unidirectional power flow control algorithm with DVR maximum compensation limit consideration, which can effectively suppress problems of a continuous rise in the DC link voltage. The simulation and experimental results for unbalanced voltage swell compensation are presented.

Chellai Benachaiba and Brahmin (2008) describe principles of DVR and voltage restoration methods at the point of common coupling. The problem of voltage sags and swells and its severe impact on sensitive loads are well known. One of those devices used to solve this problem is the Dynamic Voltage Restorer (DVR), which is the most efficient and effective modern custom power device used in power distribution networks. Its appeal includes lower costs, smaller size, and fast dynamic response to the disturbance.

Ahmed A. Helal and Mohamed H. Saied (2008) presented a DVR based on a new firing control strategy for the three six switch VSI. In this firing control strategy, one of the three- inverter legs is to be intentionally opened, one
per time in a pre-planned sequence. This strategy combines the commonly used 180° and 120° conduction modes to generate a new operating mode, defined as the 150° conduction mode. Thus, the inverter primarily obtains a seven level, 12 step output voltage waveforms, which resemble the sinusoidal wave shape.

Naidu and Fernandes (2009) described the closed loop control of a four leg VSC based DVR. The three phase input variables are resolved into positive, negative and zero sequence components using a weighted, recursive, least square estimator. A laboratory model of the restorer has been constructed and its performance has been tested by simulation using MATLAB and experiments.

Sasitharan and Mahesh K. Mishra (2009) proposed a filter structure for improving the performance of switching band controller based DVR. The control method of the VSI inherits merits, such as fast dynamic response, robustness, zero magnitude/phase errors and ease of implementation. The proposed filter structure and the adaptive band controller for the DVR are presented by carrying out PSCAD simulation studies.

Ahad. Kazemi and Ali Azyhadast (2009) described the design and operation of a three phase DVR, including control strategies which are evaluated through simulation studies. The simulation results show that the proposed voltage sag compensator is able to protect sensitive loads against short term voltage disturbances, and can be an attractive alternative to low short term voltage disturbances, and also can be an attractive alternative to low voltage Uninterruptible Power Supply. Compared with the conventional DVR topologies, the voltage sag compensator considered here, presents the advantages of reduced switch count, no energy storage systems and the smaller ratings of the power converters. The use of converters with a reduced number of switches, however, increases the overall rating of the DC link capacitor bank.
Jowder (2009) proposed a DVR which can compensate deep and long duration voltage sag and simultaneously compensate steady state harmonics. The DVR consists of shunt and series converters connected back-to-back through a DC to DC step-up converter. The presence of the DC to DC converter permits the DVR to compensate deep voltage sags for a long duration. The series converter is connected to the load side. With this configuration, there is no need for large DC capacitors. A design procedure for components of the DVR is presented under a voltage sag condition. The control system of the proposed DVR is based on hysteresis voltage control. Besides voltage sag compensation, the capability of compensating load voltage harmonics has been added to the DVR to increase the power quality benefits to the load, with an almost negligible effect on the sag compensation capability. The proposed DVR is modeled and simulated using the MATLAB/SIMULINK package.

The modeling and simulation of a DVR using PSCAD/EMTDC has been presented by Rosli Omar and Nasrudin Abd Rahim (2009). The efficiency of the DVR depends on the efficiency of the control technique involved in switching the inverter. The DVR handled both balanced and unbalanced situations without any difficulty, and injected the appropriate voltage component to correct rapidly any anomaly in the supply voltage to keep the load voltage balanced and constant at the nominal value. The results of the PSCAD/EMTDC simulation also verify the proposed control algorithm based on the space vector modulation technique to generate the pulses.

Pedro et. al. (2009) proposed a repetitive controller which has a fast transient response and ensures zero error in the steady state for any sinusoidal reference input and for any sinusoidal disturbance whose frequencies are an integer multiple of the fundamental frequency. To achieve this, the controller has been provided with a feed forward term and a feedback term. The design has been carried out by studying the stability of the closed loop system including possible
modeling errors, resulting in a controller which possesses very good transient and steady state performances for various kinds of disturbances. Only one controller is required to eliminate three pq disturbances, namely, voltage sags, harmonic voltages and voltage imbalances. The well developed graphical facilities available in the PSCAD/EMTDC are used to carry out all modeling aspects of the repetitive controller and test system. The simulation results show that the control approach performs very effectively and yields excellent voltage regulation.

Wijekoon et. al. (2003) proposed a new concept of the Interline Dynamic Voltage Restorer where two or more DVRs in different feeders are connected to a common DC link, while one of the DVR compensates the voltage sag, the other DVR connected to a common DC link replenishes the DC link energy storage. The proposed multiloop feedback control system is identical for both voltage regulation and the real power control modes. The only difference is the way in which the reference signal is generated, and it depends on the mode of operation. In the real power flow control mode the reference is generated according to the real power requirement demanded by the faulty line. The analysis shows that the two line IDVR system can mitigate about 40% voltage sag for a long duration, which appears in one of the lines. The limiting factor of the amount of real power that can be transferred from one line to the DC link as the load power factor. The power transfer capacity from the healthy lines to the DC link can be further increased if the number of DVRs connected to the DC link are increased.

The concept of the IDVR in which several DVRs are connected to a common DC link energy storage is proposed (Mahinda Vilathgamuwa et. al. 2004). The capability of a particular DVR to compensate long duration voltage sag depends mainly on the amount of energy stored within the DVR. This work has proposed a new concept of the IDVR which can minimize the DC link energy storage connecting two or more DVRs to a common DC link. One of the DVRs replenishes the DC link energy storage to maintain the DC link voltage. A current
mode voltage regulator has been used for controlling the converters of the IDVR system in both the modes, voltage sag compensation and power flow control. The reference signal for the power flow control mode is generated using the instantaneous active current calculated from the DC link error signal, while software PLL incorporating the Kalman filter is used to derive the reference signal for the voltage sag compensation mode. The simulation results are presented to verify the efficacy of the proposed IDVR design. The limiting factor of the proposed IDVR system is that the amount of real power that can be transferred to the DC link energy storage depends on the load power factor.

The concept of the IDVR, which is an economical approach to improve multiline power quality is proposed (Mahinda Vilathgamuwa et. al. 2006). As the voltage restoration process involves real power injection into the distribution system, the capability of a particular DVR topology, especially for compensating long duration voltage sags, depends on the energy storage capacity of the DVR. The IDVR consists of several DVRs, which are electrically far apart, connected to a common DC link. When one of the DVRs compensates the voltage sag appearing in that feeder, the other DVRs in the IDVR system work in the power flow control mode. The control scheme for the IDVR includes a multiloop feedback control system, which is identical for both voltage compensation and real power control. The experimental results are shown to improve quality.

The concept of Inter line Dynamic Voltage Restorer is discussed. This device consists of two conventional DVRs which are installed in two different distribution feeders and in the DC link capacitor. DVR which is installed in low voltage feeder operates in voltage sag compensation mode. A novel control technique minimizes the energy flow from DC link capacitor to this feeder. The DVR, which is installed in medium voltage feeder, controls the voltage of DC link capacitor. The proposed device and its new control strategy have been modeled
and simulated by PSCAD/EMTDC. The results verify the effectiveness of IDVR and the suggested control method (Banaei et. al. 2006)

The design strategy for optimizing the total rating of an IDVR is presented (Karshenas and Moradiou 2008). An IDVR, which is two DVRs installed in two feeders with a common DC bus, has the ability of active power exchange between two DVRs, and thus the energy storage device is not an issue. Therefore, the design criteria for the selection of the rating of an individual DVR is not applicable to the IDVR obtained. A new step-by-step design procedure is proposed with the objective of the optimum selection of the rating for an IDVR structure.

A mathematical model of the IPFC in the steady state has been developed (Diez-Valenica et. al. 2002). The model was used to investigate the operating limits based on the controllability of the power flow in the transmission line due to the initial loading levels in the network. It is shown that the range of power flow control could be maximized using special control strategies.

To improve the energy quality in distribution systems, many different solutions have been implemented like Active filters, the Unified Power Flow Controller (UPFC), the Unified Power Quality Conditioners (UPQC) and the IPFC. The IPFC concept using a probabilistic approach to the distribution system decreases the power rating of the parallel active filters when it is a component of the IPFC (Ryszard Strzelecki et. al. 2002).

An integrated approach of the radial basis function neural network and fuzzy scheme with a genetic optimization of their parameters has been developed to design intelligent adaptive controllers for improving the transient stability performance of power system (Mishra et. al. 2002). This concept is applied to a simple device, such as the Thyristor Controlled Series Capacitor (TCSC) connected to the IPFC, connected in a multi machine power system. By combining
both the intelligent techniques, the control strategy becomes less mathematical, and hence, it is faster in computation. The new neuro-fuzzy based control scheme adapts itself to generate a suitable variation of the control signals, depending on the operating condition of the power system, and hence, a superior performance in comparison to the linear PI controllers is used for the IPFC and TCSC.

The use of fuzzy logic in order to achieve a better coordination between the inverters that constitute the IPFC to improve their capability to track reference signals, has been presented (Menniti et. al. 2002). The proposed IPFC controller consists of a conventional controller based on the linear quadratic regulator technique, and a non-conventional controller based on fuzzy logic. Some simulation cases are considered to compare the performance of the proposed controller with respect to that of other conventional controllers. For this investigation an Electromagnetic Transients Program is used as a study tool.

Mathematical models of the IPFC and Generalized UPFC and their implementation in the Newton power flow have been presented (Zhang 2003). Numerical results based on the IEEE 30-bus, 118-bus and 300-bus systems are presented to demonstrate the performance of the Newton power flow algorithm with the incorporation of the IPFC and UPFC. In the test, some extreme power flow control cases for blocking the reactive power flow by the FACTS controllers have also been investigated. The blocking capability of the reactive power flow will be helpful in operating the networks efficiently, while reducing the active power losses.

A new dispatch strategy for an IPFC operating at rated capacity is proposed (Xuan Wei et. al. 2004). When an IPFC operates at its rated capacity, it can no longer regulate the line active power flow set points or the reactive power flow set points or both. In such cases, the dispatch strategy switches to a power circulation set point control to co-optimize both series VSCs, without exceeding
one or both the rated capacities. The concept is used to generate PV curves associated with the voltage stability analysis for maximizing power transfer. The modeling and computation are performed using a Newton-Raphson load flow algorithm. The voltage stability curves for two test systems are shown to illustrate the effectiveness of this proposed strategy.

An optimal power flow control in electric power systems incorporating the IPFC is presented (Jun Zhang and Akihiko Yokoyama 2006). The injection models of both the IPFC and the transmission lines embedded in the IPFC, which can be easily incorporated in load flow programs and optimal power flow programs, are developed.

A new, simple approach based on a quadratic equation and its solution to model and analyze the series connected multiline VSC based FACTs controllers, namely, the Generalized Interline Power Flow Controller (GIPFC) and the IPFC have been presented (Leon Vasquez-Arnez et. al. 2007). The model and the analysis developed are based on the converter’s power balanced method which makes use of the d-q orthogonal coordinates.

The regulation modes of an IPFC and its control strategies at rated capacity are discussed'(Xia Jiang et. al. 2007). Based on this, the voltage stability limited IPFC dispatch on a 20 bus system is investigated. The dispatch results show that the IPFC can improve the power transfer in the system. A model decomposition approach is proposed to select the best damping control input signals. Damping control signals are selected based on two indices derived from effective control actions. Dynamic simulations show the damping effect of the controller designs, using selected signals.

A novel power injection model of the IPFC, suitable for power flow analysis, is described (Yankui Zhang et. al. 2006). In this model, the impedance of
the series converter coupling transformer and the line charging susceptance are all included, while the original structure and symmetry of the admittance matrix can still be retained. Furthermore, the model can take into account the practical constraints of the IPFC. The power flow control capability and the constraints enforcement of the IPFC are also detailed.

From IEEE Transactions on power delivery, Padiyar and Nagesh Prabhu (2007) present the modeling of the IPFC of the IPFC with 12-pulse, three-level converters, and investigate the sub synchronous resonance characteristics of the IPFC at different operating modes. The application of the D-Q model is validated by the transient simulation of the three-phase model of the IPFC. It is observed that the D-Q model is quite accurate in predicting the system performance. The effectiveness of the various operating modes of the two VSCs comprising the IPFC in damping sub-synchronous resonance has been investigated.

A modified control strategy for UPFC (Jason Yuryevich and Kit Po Wong 1999) has been described. This indicates that broad study of UPFC is progressing accordingly to further explore its application, modeling and control strategy. Determination of UPFC parameters can also alter the solution in power flow. This is termed as optimal power flow, required optimization technique considering a particular objective function. Evolutionary programming was used to solve optimal power flow.

The voltage profile improvement using UPFC approach based on Artificial Immune System (AIS) optimization engine is developed (Ismail Musirin et. al. 2008). The voltage profile improvement which utilized UPFCs as control variables embedded into the system's data. Implementation on the IEEE reliability test system considering several variations in the AIS properties indicated AIS potential in solving voltage control problems.
Injection of the wind power into an electric grid affects the power quality. The performance of the wind turbine and thereby power quality are determined on the basis of measurements and the norms. The influence of the wind turbine in the grid system concerning the power quality measurements are the active power, reactive power, variation of voltage, flicker, harmonics, and electrical behavior of switching operation are measured to demonstrate the power quality problem due to installation of wind turbine with the grid. In this proposed scheme STATic COMpensator (STATCOM) is connected at a point of common coupling with a battery energy storage system (BESS) to mitigate the power quality issues. The battery energy storage is integrated to sustain the real power source under fluctuating wind power. The STATCOM control scheme for the grid connected wind energy generation system for power quality improvement is simulated using MATLAB/SIMULINK in power system block set. The effectiveness of the proposed scheme relieves the main supply source from the reactive power demand of the load and the induction generator.(Sharad et. al. 2010)

(Yan Zhang and Jovica V. Milanovic 2010) presents an approach to optimally select and allocate flexible AC transmission (FACTS) devices in a distribution network in order to minimize the number of voltage sags at network buses. The method proposed is based on the optimization of a preselected objective function using simple and niching genetic algorithms (GA). The objective of the optimization is to achieve the improvement in overall system sag performance of the network. Using proposed GA-based optimization, the location, the type and the rating of six (in total) FACTS devices are optimized simultaneously. Three types of FACTS devices are implemented in this study, namely, static var compensator, static compensator, and dynamic voltage restorer.

(Khadkikar et. al. 2006) presents a new, simple and effective approach to estimate the required quadrature injected voltage during utility voltage sag
condition. This approach helps in voltage sag compensation through reactive power control using series part of unified power quality conditioner, generally termed as UPQC-Q. Thus utility sag compensation can effectively be done without utilizing any active power from source or from the inverter side. Moreover, this quadrature voltage injection during voltage sag compensation also helps to improve the source side power factor, which results in reduced shunt active power filter (APF) loading. The voltage harmonic compensation based on d-q transformation simultaneously with voltage sag compensation is also presented.

One of the comparative structures of the electric power is back to back converter. In respect to controlling structure, these converters may have various operations in compensation. For example, they can operate as series or shunt active filters for compensating the load current harmonics and voltage oscillation (Akagi et al., 2007). This is called Unified Power Quality Conditioner (UPQC) (Areadas and Watanabe, 1995).

UPQC is greatly studied by Akagi and Fujita, (1995), (Fujita and Akagi, (1998), (Fujita and Akagi, (1998) as a basic device to control the power quality. The duty of UPQC is to reduce perturbations which affect the operation of sensitive loads. UPQC is able to compensate voltage using shunt and series inverters. In spite of this issue, UPQC is not able to compensate voltage interruption and active power injection to grid, because in its DC link, there is no energy source.

The attention to Distributed Generating (DG) sources is increasing day by day. The reason is the important roll they play in the future of power system (Blaabjerg et al., 2004; Barker and De Mello, 2000). Recently, several studies were accomplished in the field of connecting DGs to grid using power electronic converters. Here, grid’s interface shunt inverters are considered more where the
reason is low sensitive of DGs to grids parameters and DG power transferring facility using this approach. Although DG needs more controls to reduce the problems like grid power quality and reliability, Photovoltaic array (PV) energy is one of the distributed generation sources which provides a part of human required energy nowadays and will also provide it in the future. The greatest shares of applying this kind of energy in the future will be its usage in interconnect systems. Nowadays, European countries have shown inter – connected systems development in their countries by choosing supporting policies. In this study, UPQC and PV combined system have been presented. UPQC introduced by (Chen et al., 2000), has the ability to compensate voltage sag and swell, harmonics and reactive power.

2.3 Scope of present investigation

The above literature does not deal with modeling of UPQC based eight, fourteen, thirty and fifty bus systems using MATLAB / SIMULINK. This work proposes models for 14, 30 and 50 bus systems employing UPQC. The effects on real power, reactive power and voltage are investigated.

This work deals with the control of real and reactive power in power system using UPQC. The above mentioned papers do not deal with the use of multiple UPQCs in thirty/fifty bus systems. This work proposes multiple UPQCs for medium scale power systems to improve the power quality.

2.4 Research problem

Line data and load of multibus system are specified. It is required to model and simulate multibus system using the blocks of Simulink. The following equations are used for calculating the real and reactive powers.
\[ P_{ik} = \frac{V_i V_k}{Z_{ik}} \sin(\delta_i - \delta_k) \]  

\[ Q_{ik} = \frac{V_i}{Z_{ik}} (V_i - V_k) \cos(\delta_i - \delta_k) \]  

It is required to improve the voltage by using an inverter that can inject voltage with minimum harmonics.

It is also required to improve the voltage profile of the line. In order to improve the voltage profile, multiple UPQC systems are attempted.

### 2.5 Solution Methodology

The proposed work deals with modeling and simulation of two, fourteen, thirty and fifty bus systems with and without UPQC. This work also covers the variation of real power with variation in the angle of injected voltage. The effect of variation of reactive power with the variation in the magnitude of voltage is studied.

All the cases are modeled and simulated using MATLAB simulink version 7.9.(Sim Power Systems). The MATLAB uses state space modeling to solve the currents, voltages and powers in the network.

### 2.6 Organization of the Thesis

The work reported in the thesis is organized into six chapters.

Chapter 1: This chapter provides the complete and detailed review of the literature surveyed. This chapter also explains the motivation for taking up the research problem and objectives of the research carried out.
Chapter 2: This chapter describes the basic concepts and theory of Flexible AC Transmission System Controllers, Power quality improvement and the concept of UPQC.

Chapter 3: This chapter deals with modeling and simulation of two bus system. Variation of reactive and real powers with the variation in the magnitude and angle of injected voltage is presented.

Chapter 4: This chapter deals with the modeling and simulation of eight bus system and the power quality improvement in eight bus system using UPQC.

Chapter 5: This chapter discusses the modeling and simulation of fourteen bus system and the power quality improvement with UPQC. This chapter also presents voltage sag compensation in 14 bus system using UPQC.

Chapter 6: This chapter deals with use of multiple UPQCs in thirty bus system. The effect of UPQC on real & reactive powers are studied.

Chapter 7: This chapter deals with modelling and simulation of fifty bus system.

Chapter 8: This chapter summarizes the major contributions of research presented in various chapters. The conclusion of the research work presented. This chapter also provides the direction for future work and possible extensions.

2.7 Summary

This chapter deals with literature survey, scope and outline of the present investigation.