CHAPTER-II

REVIEW OF LITERATURE

2.0 INTRODUCTION

This chapter covers the literature review on UPFC at length in the following subsections.

Section 2.1 deals with general limitations of loadability of transmission lines. Section 2.2 discusses on the practical constraints faced in the industries regarding operation of conventional voltage source converter based UPFC. Section 2.3 reviews the literature survey on matrix converter based UPFC. Section 2.4 has reviewed on the topology of Z source impedance circuit coupled to matrix converter. Section 2.5 details the review done on various advanced steady state power flow models of UPFC. Section 2.6 has extensively covered the literature review on different methods of voltage stability assessment and analysis with FACTS controllers using evolutionary optimization techniques.

2.1 LINE LOADABILITY LIMITATIONS

The loading capability of a transmission line apart from taking into account of the contingency conditions is also subject to thermal stability, dielectric stability, steady state stability, transient stability, dynamic stability and voltage stability.

The thermal capability of a line may vary by a factor of 2 to 1 depending on the ambient temperature and weather conditions. The nominal rating of a line is usually decided by the worst ambient
environment, which is very rare. Therefore in reality, the lines do have a considerable margin. There are offline and online monitoring programs to assess the real time loading capability based on ambient temperature and recent loading history. During planning stage, normal loading of lines takes into account, the evaluation of losses also. Another important point to remember is, increasing rating of transmission lines depends on loading capability of transformers also. Structural upgrading of transmission lines involves changing of conductor size to higher current rating or conversion to double circuit lines.

Regarding dielectric stability an increase of 10% voltage on the nominal voltage rating is possible provided the transient or dynamic overvoltage is within limits [Hingorani et al., 2001].

The UPFC with adequate converter rating and suitable control strategy is capable of maximizing the power transfer at its rated limits, taking into consideration the contingency conditions. The present research studies focuses on voltage stability limited power transfer using UPFC. The rating of the converters is only a fraction of the throughput rating of the line. The maximum voltage drop experienced in a line of 200 km long at full load voltage drop of 1 % for every 10 km amounts to 20%. Assuming equal voltages at the sending end and receiving end of a line with the reactance of 0.3 p.u the value of phase angle difference is 0.3 radians. The rating of the compensative device even for 100% compensation is normally only a fraction of the nominal rating of the line, around 10 to 20%. The power flow along the line can
be controlled by the driving voltage i.e. the voltage magnitude difference, voltage phase angle difference or the reactance.

2.2 PRACTICAL CONSTRAINTS OF VSC - UPFC OPERATION

[Gyugi.L et al. 1995\textsuperscript{22}] presented the basic voltage source model (VSM) with two GTO converters, a shunt connected ac-dc converter and series connected dc-ac converter connected through a large dc link storage capacitor. The equivalent circuit is represented by two voltage sources and leakage admittance of the coupling transformers connected to the transmission line.

[Schauder C.D et al., 1998\textsuperscript{48}] In actual high power and practical installation of UPFC, gate turn-off thyristors (GTOs) with a rating as large as 6000 V and 6000 A have been used for the inverter configuration. The first installation of a large scale UPFC has been implemented for American Electric Power. The paper has detailed the fundamental operating constraints. At the shunt inverter side, a vector control scheme controls the current delivered to the line. The reactive part of current regulates the ac bus voltage and the real part of current regulates the dc bus voltage. The limit on shunt reactive current is a function of the real power passed through the dc bus. At the series inverter side, a vector control scheme regulates the real and reactive line current, based on the comparison of real power and reactive power specified with measured values. The magnitude of the series injected voltage is limited by the maximum voltage rating of the inverter. Hence the series inverter and the coupling transformer are
designed to operate at a specified maximum voltage. When the dc voltage is reduced, the maximum injected voltage is also reduced accordingly. The UPFC is installed at the substation, where \( V_1 \) is the regulated substation bus voltage and \( V_2 \) is the outgoing line voltage. The maximum injected voltage is always below the maximum at any phase angle resulting in \( V_2 = V_1 + V_{\text{inj}} \). The series transformer has leakage reactance \( X_{\text{series}} \) and hence the injected voltage is only \( V_{\text{inj}} - jI_{\text{line}} X_{\text{series}} \). This clearly illustrates the terminal line voltage is decided not only by the inverter rating, but also by the prevailing line current i.e. \( V_2 = V_1 + V_{\text{inj}} - jI_{\text{line}} X_{\text{series}} \). The UPFC is capable of increasing or decreasing the voltage magnitude by 50%. This induces large voltage stress on the line, especially when the line is tapped. Therefore it becomes highly necessary to impose limits on the injected voltage magnitude. Hence the UPFC is restricted to operate within the allowable upper and lower limits of \( V_2 \) and its achievable range. The achievable range depends on the line current and its drop across \( X_{\text{series}} \).

GTO thyristors are absolute limited by turn off peak current other than continuous current which is based on its thermal rating. In the shunt inverter the current delivered to the line is regulated such that the sum of the real power component and the reactive component does not exceed the continuous maximum current rating of the inverter. In the series inverter the line current keeps flowing through it. The limit of the line current is restricted by the maximum injected voltage, but it is only a fraction of the line voltage.
The above observations clearly tell us that the MVA rating of the UPFC is designed for peak continuous current and peak continuous voltage whether they occur simultaneously or not.

A range of achievable operating points are set for the practical limits of the UPFC under prevailing system conditions. The UPFC depending on the reference inputs tracks to offset the deviation by control of gating signals until the limit is reached. Top priority is given for maximizing real power. These limitations and practical constraints have given a call for high level Line Optimization Control which sets optimum values for UPFC parameters. Another important feature is providing self protection, under fault conditions to avoid destruction of the devices.

2.3 MATRIX CONVERTER BASED UPFC

Kazerami M and B.T Ooi (1993)\textsuperscript{26}, (1995)\textsuperscript{27} explored into new type of ac to ac PWM voltage source converter. The dc bias voltage has to be maintained constant or the anti parallel diodes start conducting each time the dc link passes through the negative half cycle. A theoretical model of matrix converter based UPFC is developed.

Boon Tech Ooi B T and M.Kazerami (1995)\textsuperscript{10} has detected waveform distortion which could not be filtered because of operation at different frequencies – at the shunt end, dc or 0 frequency, and a different frequency at the series end. He introduces a three phase cancellation of unwanted frequencies using transformers.
Boon Teck Ooi et al., (1996)\textsuperscript{11} This paper has shown that the voltage source matrix converter is capable of not only satisfying the UPFC specifications but also excel in other advantages. Step down voltage transformers with a novel wye connection prevented dc or low harmonic current entering into the secondary of transformer at ac side. Hence the power systems at different frequency standards are possible to be linked. The range of variation of the phase angle shift is a wide 360 degree. The synchronizing power with the series capacitor compensation is surpassed when compared to the conventional VSC UPFC model.

The theory adaptations has been implemented in a laboratory model with 3 units of 3 phase voltage source converters consisting of BJT, each rated at 1 kVA at a switching frequency of 1260 Hz with two step down transformers. For achieving bidirectional power flow, the charging of dc capacitor to provide the dc bias voltage posed a problem. Similar to SVC control using the phase angle adjustment, modification has been demonstrated by reversing the polarity of the error signal in the dc voltage regulation.

Strzelecki M et al., [2001]\textsuperscript{59} has investigated on the output voltage of the matrix converter UPFC obtained through modulation coefficient to verify its full range of power flow control.

Wei Lixiang and Thomas A Lipo (2001)\textsuperscript{64} has analyzed on a novel matrix converter topology which has a simple commutation circuit and reduced number of switches.
Bernet Steffan et al., (2002)\(^9\) compares a matrix converter and a dc voltage link PWM converter. This paper has proved that the matrix converters' losses are less at full load operation. A 30\% reduction of the device current rating of the matrix converter followed by reduction in thermal stress also has been illustrated. The design of the dc link capacitor in the VSC depends on the voltage ripple, control hardware, and the current through the capacitor. Minimum capacitance value is fixed by the current rating, temperature and lifetime specifications.

Casedei D et al., (2004)\(^12\) has proposed a novel modulation strategy for matrix converters with reduced switching frequency based on output current sensing.

Schafmeister F et al., (2005)\(^47\) has made an analytical calculation on the switching and conduction losses of the conventional matrix converter and sparse matrix converter.

Monteiro J et al.,(2005)\(^40\) has designed UPFC without dc bus using matrix converter.

Joalo Ferreira and Pinto S (2008)\(^24\) has developed a UPFC model based on ac to ac converters with minimum storage requirements i.e. sparse matrix converter topology to reduce energy storage equipment, aiming at reduction of power losses and lifetime increase of UPFC. The system controllers are designed for a good steady-state and dynamic response.

Geethalakshmi B and Dananjayan P (2009)\(^19\) has investigated on the performance of UPFC without dc link capacitor
Monteiro J et al.,(2011)\(^{41}\) has modelled the matrix converter connected to transmission line through two coupling transformers. The simplified ideal equivalent circuit of matrix UPFC is represented as a controllable voltage source of voltage magnitude and a phase angle.

### 2.4 Z SOURCE MATRIX CONVERTER TOPOLOGY

Fang Z Peng (2003)\(^{81}\) has proposed an impedance fed power converter capable of controlling dc to dc, ac to ac, dc to ac and ac to dc power conversion. In this novel power conversion circuit, the converter is coupled to the power source through a unique impedance network. The Z source converter has been proved to overcome the conceptual theoretical barriers and limitations of conventional voltage source or current source converter.

Keping You and Rahman M F (2006)\(^{28}\) presents the analytical calculation of conduction and switching losses for a novel Z source matrix converter and a conventional voltage source converter respectively using PWM modulation strategy. Z-source converters offer less conduction and switching losses in dc-ac inversion compared to VSC in certain range of modulation indices. For ac-dc rectification the novel Z source matrix converter promises less conduction and switching loss than the conventional VSC.

Tang Yu et al.,(2007)\(^{61}\) introduces a new family of Z-source voltage fed ac-ac converters with buck-boost ability. The single-phase topology consists of four switches and the three-phase topology, six
switches. Compared to traditional ac-ac converters, they have unique features like a larger range of output ac voltage with buck-boost, reversing or maintaining phase angle, reducing in-rush and harmonic current. Safe commutation strategies, without snubber circuit has been proposed.

**Minh-Khai Nguyen et al.,(2009)**\(^{37}\) deals with single-phase ac-ac buck-boost matrix converter that can provide a wider range of output voltage in-phase/out-of-phase with the input voltage. Snubber less commutation has been adopted.

**Kiwoo Park et al.,(2009)**\(^{30}\) has proposed a novel Z-source matrix converter structure with a unity voltage transfer ratio. Though the merits of traditional matrix converter over a dc linked back-to-back converter have been established, it could not become popular in the industry owing to its reduced voltage ratio (max. 0.866). The new Z-source network has been introduced to overcome the low voltage transfer ratio.

**Weizhang Song and Yanru Zhong (2008)**\(^{65}\) have discussed on the disadvantages of classic matrix converter having low voltage ratio (max. 0.866) and hence proposed new z-source indirect matrix converter (ZSIMC) and z-source direct matrix converter (ZSDMC) based on construction topology.

**Kiwoo Park et al., (2009)**\(^{3}\) proposes a novel Z-source sparse matrix converter using zero-current commutation method with reduced number of switches to overcome low voltage transfer ratio inherent in the traditional matrix converter.
Xiong Liu et al.,(2010)\textsuperscript{68} has discussed on optimal modulation theory applied to indirect ac –dc- ac matrix converter with Z source impedance inserted at its intermediate dc-link. Buck-Boost flexibility, minimum commutation count and ease of implementation, in addition to sinusoidal input and output quantities are no doubt important for ac-ac energy conversion. But this is achieved only at the cost of passive components. Bringing forth these advantages by unveiling related optimal modulation theories is a relevant investigation.

Minh-Khai Nguyen et al., (2010)\textsuperscript{38} propose a novel single-phase Z-source buck-boost matrix converter capable of step-changed frequency output. In addition, the converter does not need a snubber circuit. The performance has been verified with a prototype model rated at 40 V\textsubscript{rms} at 60 Hz , connected to a passive RL load.

Park K et al., (2011)\textsuperscript{45} proposes a novel Z-source sparse matrix converter (ZSSMC) and a fuzzy logic controller to compensate unbalanced input voltages. The ZSSMC is developed to reduce the number of switches and employs a Z source network to overcome the limitation of low voltage transfer ratio of conventional matrix converters. ZSSMC is a two-stage converter, connected through a Z source network designed with smaller passive components as its purpose is to boost the voltage.

Hosseini S H et al.,(2011)\textsuperscript{23} has investigated on the capability of the single phase Z source matrix converter on ac-ac power conversion with a wide range of frequency . The topology uses only four switches resulting in lower loss and higher efficiency. Furthermore novel
switching pattern is applied to achieve better performance. This method is achieved by combining PWM and PAM methods.

**Xupeng Fang et al., (2011)** proposes a novel three-phase ac–ac matrix converter based on Z-source concept providing buck-boost voltage at varied frequency. Compared to earlier voltage source based ac-dc-ac converter, it uses fewer switching devices. And compared to traditional matrix converter, is capable of providing better voltage regulation range at higher input-output voltage transformation ratio.

### 2.5 POWER FLOW MODELS OF UPFC

**Hingorani N G and Gyugi L (1995)** has presented the basic voltage source model (VSM) with two GTO converters, a shunt connected ac-dc converter and series connected dc-ac converter connected through a dc link storage capacitor. The equivalent circuit is represented by two voltage sources and leakage admittance of the coupling transformers connected to the transmission line. The controllable parameters are the shunt and series voltage magnitude and phase angle. The voltage magnitude is subject to upper and lower limits and is a function of the converter ratings. The phase angles variation is between 0 to 2π radians. The converter is assumed to have no power loss and so no real power is drawn or sent to the line. The dc voltage is kept constant by the operation of converters. The real power equality constraint is satisfied. The transfer admittance linking current and voltage is not a square matrix.
Nabavi-Niaki et al., (1996)\textsuperscript{43} has proposed the sequential and the decoupled UPFC power flow model in which the power flowing from node m to k and the voltage magnitude at node k can be regulated. A lossless UPFC is assumed. The UPFC and coupling transformers is modeled as a generator at one end and a load at the other end. The UPFC’s sending end is changed into a PQ load bus and the receiving end is converted into a PV bus. The real power P and reactive power Q at the load bus is controlled by UPFC. The voltage magnitude at the sending end is controlled. A standard power flow solution is obtained using the presented model. The UPFC parameters are updated using additional non linear equations. Hence the UPFC limits cannot be checked during the iterative process. Another disadvantage of this method is that the UPFC cannot control one or two variables but only all the parameters simultaneously.

Handshin and Lehmkoster (1999)\textsuperscript{85} are the first to introduce the Power Injection Model of UPFC. It has resulted from the conventional VSM in the lossless case by interpreting the power injections of the shunt and series sources as real and reactive node injections. This model lets control of one or two UPFC variables. This paper has described the method of incorporating the PIM model of UPFC into NR power flow algorithm.

Fuerte C.R et al., (2000)\textsuperscript{17} has done a critical comparison of different Newton -Raphson algorithms with UPFC in power flow studies. He has presented the simulation results of various power
flow models of UPFC. He has also simulated to quantify the interaction between UPFC and other FACTS devices.

Angelo L’ Abbate (2002) has done a detailed comparative study of various UPFC steady state models for implementing in Newton Raphson power flow algorithm. Two voltage source models, power injection model (PIM) and the new shunt admittance model (SAM) are detailed at length. The SAM-UPFC is represented as a π section with two shunt admittances. The significant feature of SAM is that the real and reactive node power injections are not the controllable variables of UPFC. The shunt admittances in a closed loop implementation regulate the power flow. Quick quadratic convergence to a tolerance of $10^{-12}$ in less than 6 iterations has been ensured using these models in the power flow equations.

2.6 VOLTAGE STABILITY ANALYSIS

The rising events of voltage collapse in power systems are continuing to draw a lot of researchers in the area of voltage stability analysis. Although several methods have been used in voltage stability analysis, successful avoidance of power collapse depends on accuracy, rapid indications and very low computation time.

2.6.1 Voltage Stability Assessment Methods

The literature review on different methods of static voltage stability assessment has been covered in the following areas.

1. Evaluation of voltage stability margin using PV and QV curve
analysis, L-index and line stability methods, singular decomposition method, point of collapse method, static bifurcation analysis, small signal analysis or modal analysis etc.

2. Identification of voltage control areas and coherent buses having similar VQ curve minima.

3. Various sensitivity based methods like generator sensitivity and reactive power injection sensitivity etc.

4. Voltage stability analysis using different power flow models like CPF, RPF, OPF etc.

All these conventional methods are time consuming thus limiting its use for online applications. Recent methods like ANN approach have decreased the computational burden significantly. These networks are trained offline in the determination of voltage stability margin and applied in any online environment.

Weedy B M and B R Cox (1968) submitted the first paper on voltage stability. The voltage stability though has been known for a long time, active contributions started only in eighties.

Kessel P and Glavitsh (1986) propose the L-index method for detecting the voltage instabilities. The stability index at each bus bar is determined. It varies from 0 (no load) to 1 (voltage collapse point).

Kwatny et al., (1986) has showed that at the static bifurcation with respect to voltage collapse, the load voltages are highly sensitive to parameter variation.
Schlueter R. A et al., (1989, 1991) has introduced the general phenomenon of voltage collapse at the load end, and the induction motor has been taken as the critical component of system loads. The active power and reactive-power versus voltage characteristics of power-system loads are represented for the analysis of radial lines. The static PQ and PV stability and controllability methods are proposed.

Obadina et al., (1990) has identified critical buses based on the change in bus voltage from an initial operating state to the voltage stability limit.

Flatabo N et al., (1990) has proposed a sensitivity method based on the limits imposed by reactive power generation from the distance to the voltage collapse point in terms of MVAR.

Gao B et al., (1992) has evaluated the stability criterion based on modal analysis and participation factor.

Chebbo et al., (1992) has examined the concept of voltage collapse at load buses based on maximum power transfer between two buses using Thevinin’s equivalent circuit. The stability index is the ratio of Thevinin’s impedance to load impedance, which is maximum 1.0 when both are equal. Less than unity, the system is said to be stable.

Lof P A, Smed T et al., (1992) has presented the eigenvalue decomposition technique known as modal analysis and their associated eigenvectors are determined to find the bus participation
factors to find the critical bus.

Mansour Y (1989)\textsuperscript{36} and Awad (1989)\textsuperscript{5} have used the classic PV and QV curve analysis to identify the variations in critical bus voltages based on voltage stability limit.

Schlueter R A, et al., (1993)\textsuperscript{50} establishes lack of reactive supply or insufficient reactive resources as one of the main cause of voltage collapse.

Moghavvemi et al., (1997)\textsuperscript{39} proposes a line stability index calculation $L_{mn}$. The system is reduced to a single line network. If the value exceeds 1 the system loses stability.

Schlueter R.A et al.,(1998)\textsuperscript{49} determines the voltage control areas i.e. bus groups having similar VQ curve minima and a similar set of exhausted generators at this minima, called as reactive reserve basin (RRB) for effective reactive compensation.

Kubokawa, J et al., (2000)\textsuperscript{31} uses the difference between current operating condition to the collapse point as an index of voltage stability robustness. The additional reactive load that can be increased is looked into. The developed OPF is capable of obtaining the optimal operating point with sufficient loadability margin for contingency conditions also.

Craig Aumuller and Saha T (2003)\textsuperscript{13} have made some improvements on the sensitivity method, based on the determination of coherent bus groups. The original Schlueter method used computation of VQ curves at several buses.
Musirin, I Rahman, T.K.A et al., (2002)\textsuperscript{42} has focused on line outage contingencies in this paper for voltage stability analysis. The contingency ranking is based on fast voltage stability index (FVSI).

Craig Aumuller and Saha T (2003)\textsuperscript{13} determines the sensitivity of the reactive power flow in a line to the reactive power injection at a bus. The power produced by a generator is nothing but the flow in the system through transformer or the generator branch. The injection of reactive power produces a change in the load. The proposed method is an improvement on the sensitivity analysis technique.

Kataoka, Y et al., (2006)\textsuperscript{25} proposes a new VMPI (voltage margin proximity index) considering voltage limits, especially lower voltage limits. In traditional methods, the stability indices point towards a critical point.

Sharma Chandrabhan et al., (2007)\textsuperscript{54} has done the comparison of common steady-state methods for voltage stability analysis and a dynamic approach to it. Modal analysis is focussed in this paper providing a relative proximity of the system to instability, and also identifies contributing factors to instability.

Subramani C et al., (2009)\textsuperscript{60} discusses on the weak area clustering techniques like voltage stability analysis and line outage contingency analysis. This analysis identifies the most critical lines during stress conditions. A pre-developed voltage stability index has been utilized as an indicator of stability.
Yang Zhang et al., (2010) identifies the weak areas with respect to reactive power deficiency. The critical contingency conditions and voltage stability margin is determined using practical methods. The experiences gained during the study of voltage stability analysis of a large power system are shared and discussed.


Yanfang Wei et al., (2011) uses the MATLAB Voltage Stability Toolbox to study power flow, singularity based analysis, eigenvalue analysis, static and dynamic bifurcation analysis and time domain simulation.

2.6.2 Voltage Stability Analysis with FACTS Controllers using Optimisation Techniques

Sobierajski M and Fulczyk M (2001) has applied PQ curve analysis since bus voltage violation is more important. PQ curve for the critical bus has been drawn to estimate the probability of the critical voltage violation for uniformly distributed active and reactive power at a given load bus. The PQ curve is drawn based on the bus impedance.

Li Hongzhong et al., (2005) has presented improved particle swarm optimization (IPSO) for reactive power planning. The voltage stability margin index (VSI) is used to rank the load buses and to install reactive power compensators on the weak buses. Maximization
of voltage stability margin is included in the objective function of reactive power planning.

**Sode-Yome A et al., (2005)** has investigated on voltage stability assessment with STATCOM, TCSC and SSSC. Continuation power flow (CPF) has been used for static voltage stability study. Static voltage stability margin has shown enhancement using STATCOM, TCSC and SSSC.

**Baghaee H.R et al., (2008)** has dealt with improvement of voltage stability margin using FACTS devices. Optimal placement using GA algorithm considering cost function of FACTS devices and power system losses has been presented in this paper leading to line flow control at minimum acceptable voltage levels and significant improvement in voltage stability margin.

**Yingni Mao and Maojun Li et al., (2008)** has studied on optimal reactive power planning where in voltage stability margin and voltage level are given priority in this paper. The most critical bus has been identified using singular value decomposition method. The bus location and the amount of reactive compensation have been obtained using fuzzy and SA-PSO method. The proposed method has significant improvement in decreasing network loss, improving voltage stability and voltage quality of the whole power system.

**Benabid R et al., (2009)** has proposed Non-Dominated Sorting Particle Swarm Optimization (NSPSO) method for optimal location of multi type FACTS devices. Fuzzy-based rules have been employed for
selecting the best solution from the pareto front. NSPSO has been used to find the optimal location and setting of TCSC and SVC for maximizing static voltage stability margin, reducing losses and load voltage deviation.

**Gupta, S et al., (2010)** have been in vogue since 1970s for dynamic compensation. This paper has detailed the latest research and developments in the voltage stability improvement using FACTS controllers. Technical problems related to location of FACTS have been highlighted with respect to voltage stability analysis. In addition, real-world installations have also been summarised.

**Whei-Min Lin et al., (2009)** has compared ant colony (ACO) and genetic algorithm (GA) based optimisation for the placement and rating of STATCOM with equivalent current injection model to increase the voltage stability margin.

**Xiaohua Huang et al., (2010)** Superconducting magnetic energy storage (SMES) system improves the stability of a power system. Location of SMES in multi-nodes power network plays a significant role for the stability improvement level. The voltage stability index is used as the fitness function in GA. The GA mathematic parameters and optimal flow chart are presented. The proposed algorithm is tested in an IEEE 14-bus system. Simulation results show that the SMES is settled on the best site through GA optimization.
Al-Hajri M T and Abido M A (2010)\(^3\) has assessed the voltage stability indices using GA optimisation.

Preethi V A et al., (2011)\(^{46}\) presents the optimal placement of SVC and TCSC using GA technique. In this paper, Newton-Raphson algorithm is used for the power flow analysis. Different loading conditions are considered and MATLAB coding is developed for simulation.

G Selvi et al., (2011)\(^{53}\) has chosen the maximum loading point i.e. the margin from the operating point as the index for voltage stability. Determination of this margin is formulated in differential evolution optimisation. DE algorithm has faster convergence with a few control parameters only.

2.7 OBSERVATIONS FROM LITERATURE REVIEW

To summarize the review of research done on UPFC, the following observations noted are listed below.

1. Extensive research has been carried out on the various construction models of UPFC, but very few studies compares in detail with matrix converter based UPFC model. The Z source topology coupled with the matrix model of UPFC has not been taken up so far.

2. The conventional matrix converter has the disadvantage of low transfer ratio (0.866). The buck boost effect in Z source converter topology can offset the converter switching losses incurred using
matrix converter. Hence unity or even higher voltage transfer ratio can be achieved now.

3. The power injection model of UPFC can bypass the presence of converter voltage source thus proving to be more advantageous when compared to other steady state power flow models. Their effect is taken into account by UPFC’s power injections at the two nodes. These power injections are represented by the controllable variables. The required UPFC parameters can be chosen and controlled for the target specified power under all operating conditions.

4. The PIM model of UPFC is incorporated into NR power flow algorithm. A symmetric transfer admittance matrix is possible with this model. In the conventional VSC-UPFC model, the two voltage sources have to be modeled and to obtain a square admittance matrix, two fictitious nodes are needed. The UPFC parameters combined with the system state variables are automatically adjusted for a unified power flow solution. The quadratic convergence of NR algorithm is retained with this model.

5. The voltage stability analysis has been investigated in detail. Lots of papers on improving voltage stability margin with other FACTS devices like STATCOM, TCSC etc are available but only one or two papers with UPFC has been analyzed. The various methods like sensitivity analysis though takes less computation time, cannot determine the loadability of a bus or a line, which is the deciding
factor for maximum power transfer. Hence the most popular method in the power industries still remains as PV curve analysis.

6. Though a number of recent evolutionary optimization algorithms is available, real coded GA Optimization Tool is more reliable and efficient.

7. UPFC is more applicable for tie line power transfer. The application of UPFC may be tried in active power flows from surplus generation areas to the deficit areas through parallel paths, that are possible corridors of several lines (Hingorani and Gyugi 2001). With adequate UPFC control, the transmission line can be made capable of carrying power to its full thermal capacity with proper selection of converter ratings, assuming lossless converters.

2.8 PROPOSED RESEARCH WORK

The present research work is a motivation to construct a converter with minimum loss and minimum storage capacity based UPFC with unity or higher voltage transfer ratio. Hence a novel model of UPFC has been proposed using the Z source impedance circuit coupled to the matrix converter. ZSMC based UPFC has not been taken up so far.

In order to achieve a closed loop unified power flow control in large interconnected power systems for the specified power, advanced Power Injection Model (PIM) of UPFC which is capable of bypassing the presence of matrix converter has been taken up with the available literature.
To achieve maximum power transfer the UPFC is operated at its rated limits. To achieve the target or specified power a dispatch strategy controlling the power circulation between the converters has been implemented.

Location of a reactive compensating device plays a significant role in voltage stability limited power transfer. Hence various methods of voltage stability analysis are investigated to identify critical areas before arriving at the location of UPFC. Very few papers have dealt with voltage stability enhancement using UPFC.

Development of a modified real coded genetic algorithm has also been taken up with the available literature, to provide a global optimal solution.