ABSTRACT

Presently the increasing industrialization, urbanization of life style has lead to more dependency on the electrical energy. This tends into fast growth of power systems. The rapid growth has resulted into few uncertainties. Power disruptions and individual power outages are one of the major problems that affect the economy of a country. In contrast to the rapid changes in technologies and the power required by these technologies, transmission systems are being pushed to operate closer to their stability limits and at the same time reaching their thermal limits due to the fact that the delivery of power have been increasing. The major problems faced by power industries in establishing the match between supply and demand are to meet the electric demand without exceeding the thermal limit. In large power systems, instability problems causing power disruptions and blackouts are leading to huge losses. These constraints affect the quality of power delivered. However, these constraints have to be minimized by enhancing the power system control. With the advent of power electronics technology, the most widely used device which has wide application is Flexible AC Transmission System (FACTS). Using FACTS controllers, the utilities are able to control power flow, increase transmission, line stability limits, improve security of transmission systems and enhance utilization of the existing power system.

The power systems of today are mechanically controlled. There is a widespread use of microelectronic computers and high speed communications for control and protection of present transmission systems. However, when operating signals are sent to the power circuits, where the final power control action is taken, the switching devices are mechanical there by resulting in slow response. Another problem with mechanical devices is that control cannot be initiated frequently, because these mechanical devices tend to wear out very quickly compared to static devices. In effect, from the point of view of dynamic and steady state operation, the system is really uncontrolled. These limitations can be easily overcome by resorting to the application of FACTS technology on a selective basis. The FACTS technology is essential to alleviate some but not all of these difficulties by enabling utilities to get the most service from their transmission facilities & enhance grid reliability. FACTS technology opens up new opportunities for controlling power & enhancing the usable
capacity of present, as well as new and upgraded lines. Relatively recent development & the use of FACTS controllers in power transmission systems have led to many applications of these controllers to improve the power systems stability.

FACTS devices should be used for controlling transmission voltage, power flow, reducing reactive losses and damping of power system oscillations for high power transfer levels. Thyristor controlled shunt/series connected compensating devices also have to be used for dynamic power compensation and enhancement of real power transmission capacity. FACTS controllers in power systems should be installed at appropriate places for better controllability. A better utilization of the existing power systems to increase their capacities and controllability by installing FACTS devices becomes imperative. FACTS devices are cost effective alternatives to new transmission line construction.

However, the cost of transmission lines and losses, as well as difficulties encountered in building new transmission lines, would often limit the capacity of lines. As power transfers grow, degree of complexity in power system increases and leads to the reduction in security level of the system. In addition, it may lead to large power flows with inadequate control, excessive reactive power in various parts of the system, large dynamic swings between different parts of the system and other bottlenecks. Thus, the full potential of transmission interconnections cannot be utilized.

The system performance can considerably improved by controlling the power flows without generation rescheduling or topological changes. Furthermore, if the thermal limits are not violated, losses are minimized, and the stability margin increases. The potential benefits of FACTS equipment are nowadays widely recognized by the power systems engineering community. However, the current challenge is now to obtain the maximum benefit from these devices by locating them at proper places with minimum cost.

Electric power systems have been forced to operate to almost their full capacities due to the environmental and/or economic constraints to build new generating plants and transmission lines. The amount of electric power that can be transmitted between the locations through a transmission network is limited by security and stability constraints. Power flow in the lines and transformers should not
be allowed to increase to a level where a random event could cause the network collapse because of angular instability, voltage instability or cascaded outages. Hence, economic operation of power system along with the assurance of refined quality of power supply to consumers is a challenging task. Due to the introduction of deregulation in electricity market, installation of FACTS devices has become inevitable. Because of the economical considerations, installation of FACTS controllers in all the buses & lines in a system is not feasible. Thus, it is required to find the optimal location of FACTS devices to overcome both economical & technical barriers in accomplishing the objective. Use of Thyristor Controlled Series Capacitor (TCSC) as Flexible AC Transmission System (FACTS) device brings a number of benefits for the user of the grid, all contributing to an increase of the power transmission capability of new as well as existing transmission lines. These benefits include improvement in system stability, voltage regulation, reactive power balance, load sharing between parallel lines and reduction in transmission losses. Optimal location of TCSC is a major challenge & an important factor in the accomplishment of objectives of FACTS devices. There are several conventional based methods for finding optimal locations of FACTS devices in power systems described. Based on the literature survey it is seen that with conventional methods co-ordinate with artificial intelligence techniques to relieve congestion are not been carried out based on the priority location of FACTS devices. Hence the present thesis concentrates on one of the important aspects of FACTS controller in transmission system. The optimization problem selected for the thesis work based on three aspects: finding the optimal location of the device in the network, finding its optimal size/value, and optimizing its controller parameters such that the maximum benefit can be obtained in both steady state and dynamic operation. Considering these three aspects, the problem becomes a multi-objective optimization problem that involves a very complex formulation. On the other hand, the power system itself is a highly nonlinear and non-stationary system, subject to uncertainties. The conventional methods in solving optimization problem in power systems suffer from several limitations due to necessities of derivative existence, providing suboptimal solutions, etc. Hence, modern heuristic methods are required to cater to the above multi objectives. This thesis presents an overview of intelligent learning controllers which have the ability to deal with large scale computations. Some iterative heuristic methods used in this research for location of TCSC are Genetic Algorithm (GA),
Particle Swarm Optimization (PSO) and are presented together with a brief description of its algorithms. Introduction of co-ordinate FACTS devices at right location increases the loadability, optimal power flow and heuristic methods can be effectively used for this kind of optimization. The present research work is focused on the application of Robust Optimization Techniques like Genetic Algorithm, Particle Swarm Optimization to meet the objectives of loss reduction and enhancement of power flow by placing suitable FACTS devices on the standard IEEE test systems and also on a part of practical power network of Karnataka 220 KV Indian system.

Electrical power generation in a country has a bigger challenge to meet the growing demands for more power. The demand is increasing due to rapid industrialization, urbanization and increase in population of the developing countries. As a measure to meet the increasing demand ensuring adequate availability and reliability, private participation is being encouraged. Because of this, the power trading, grid maintenance etc., become complex issues. Among them congestion management is a prime issue. When the generation and consumption of electric power causes the transmission system to operate beyond stability limits, the system is said to be under congestion. Congestion is the most fundamental transmission management problem. Congestion management is the process to avoid or relieve the congestion. In a broader sense, congestion management is considered as a systematic approach for scheduling and matching generation and loads in order to reduce congestion. Installation of FACTS devices at proper places can handle issues related to congestion management.

In general, two paradigm methods can employ to relieve congestion in transmission lines. One is cost free method and the other is non-cost free method where the former include actions like outage of congested lines or operation of transformer taps or phase shifters or FACTS devices. These means are termed as, ‘cost free’ because the marginal costs (and not the capital costs) involved in their usage, are nominal. Non-Cost free methods include re-dispatch of generation and curtailment of pool loads and/or by curtailment of bi-lateral networks. The former method relieves congestion technically, while the latter being related more with economics.
Among the above two main techniques, cost free means do have advantages such as not involving economical matters, so generation companies and distribution companies will not be involved. Hence, optimal operation of FACTS devices is one such technology, which can reduce the transmission congestion and leads to better usage of the existing grid infrastructure, along with many other benefits. Besides, using FACTS devices gives more opportunity to independent system operators (ISO). Various issues associated with the usage of FACTS devices are, their optimal location, appropriate size, setting, cost and modeling. This thesis deals with the optimal location of TCSC, for congestion management in competitive power markets. Up to now, the sensitivity factor method has used to find the location to enhance the static performance of the system. However, there are some disadvantages for this method such that it may not capture the non-linearity associated with the power system. The objective of this thesis is to develop an algorithm to relieve congestion by optimally locating a thyristor controlled series capacitor in a transmission line. A line utilization factor is derived to determine the level of congestion in the transmission line. Sensitivity parameters for the total system losses have been derived as a function of the real power at the individual load points in the presence of thyristor controlled series capacitor. These sensitivity parameters are used in comparing the alternative locations available for generation capacity and percentage of congestion.

A fuzzy logic controller is proposed to control active power flow for congestion management. The proposed algorithm is tested successfully on the IEEE 14-bus system. The fuzzy based results have been compared with the solution given by sensitivity method. This comparison confirms the efficiency of the proposed method, which makes it promising to solve congestion problem in a power system network by suitably placing a Flexible Alternative Current Transmission System device. Placement of series FACTS device is based on the priority table specified in the thesis and is discussed based on the results obtained. The results obtained after the optimization process has revealed that a significant reduction in the congestion of the system had been carried out based on the priority method with minimum economical impact. Hence Fuzzy technique is used in the research work to relieve the congestion in the overloaded lines which in turn improves the stability of the power system.

Computational Intelligence methods play an important role in determining the optimal solutions for multi objective functions. Thus, a combinatorial analysis
problem in power systems can be tackle by modern heuristic methods in finding optimal solution. The present research thesis has demonstrated the two different heuristic methods applied to power systems. In that, stability improvement by Genetic Algorithm (GA) and Particle Swarm Optimization (PSO) approaches has been used for sizing and location of a FACTS device in a power system.

The present research work starts with Genetic Algorithm, a wing of evolutionary computation encapsulated with heuristic approach for finding the optimal location of TCSC. The thesis presents Genetic Algorithm (GA) based approach for the allocation of FACTS (Flexible AC Transmission System) devices for the improvement of Power transfer capacity in an interconnected Power System. In the research work carried out, reactance of TCSC has been considered as a variable parameter. The GA based approach is applied to IEEE standard test bus systems and also to real time System. FACTS devices are installed in the different locations of the power system and system performance has been observed with and without FACTS devices. First, the locations, where the FACTS devices are to be placed are determined by calculating active and reactive power flows in the lines. Genetic Algorithm is then applied to find the amount of magnitudes of the parameter of the FACTS devices. This approach of GA based placement of FACTS devices has a significant benefit both in terms of performance and economy and this is seen from the results obtained.

IEEE 5, 14 and 30 bus systems are considered to test the credibility of this algorithm and the results obtained are subjected to analysis to determine the optimal location. It can be observed from the results obtained for 5bus system that using Genetic Algorithm method, TCSC could be optimally placed in the branch 6 with 36% degree of compensation. The effect of placing TCSC in branch 6, results in loss reduction in the lines. The total loss was effectively reduced from 3.0556MW to 3.002 MW resulting in a loss reduction of 1.73% and also it increases the 11.2% power transfer capability of the line. Hence this method has been extended to other standard IEEE test systems and a part of the practical systems with more number of buses. The results found were quite encouraging.

The proposed Particle Swarm Optimization (PSO) methodology has been applied to an IEEE 5, 14 and 30 bus systems. From the simulation results, it can
inferred that TCSC has been optimally located in one of the branches where minimum loss occurs rather than locating in all the branches, which in turn reduces the cost. It was noticed that the insertion of the TCSC found by PSO method into the system has resulted in the reduction of total power loss by 1.8%, real power flow increases by 89% and reactive flow also changes. Hence, this method has also been extended to other standard test systems and a part of the practical system with more number of buses. The results were found satisfactory.

The present research work carried out has two strategies – Conventional method called sensitivity method & computational intelligence technique (Genetic Algorithm and Particle Swarm Optimization) for optimal location of series FACTS controller. This research presents an effective comparison of conventional method and evolutionary method for locating TCSC - a series FACTS device. The work also emphasizes the line flows and line losses in both the cases. It can be observed from the result that TCSC can be optimally located for any IEEE standard bus system using GA and PSO methods. The effect of placing TCSC in particular branch, results in loss variation in the lines. The total loss effectively reduces and it increases the power transfer capability of the line. The comparison of proposed GA and PSO methods for standard test systems clearly indicated that the GA method validates the superior performance than other PSO or Conventional methods.

A practical 220kV, 14 bus system a part of Karnataka Power System Network, in India for optimal location of FACTS device, has been considered to test the credibility of the two strategies. The results obtained are quite encouraging & will be useful in electrical restructuring.

Simulation studies have been carried out on a 220kv Basthipura real system. The most sensitive lines have been identified using conventional reactive power loss index method. TCSC has been effectively placed among the identified sensitive line using GA and PSO methods. It has been observed from results that the reactive power loss reduces by placing TCSC in the most sensitive line and the power flows in the line has been enhanced by 32%. In this case also GA performed more superior than PSO.

Shunt controllers like Static Var compensator (SVC) and Static Synchronous Compensator (STATCOM) are capable of effectively controlling the voltage profile by dynamically adjusting the reactive power output at the point of connection.
However, these controllers are very expensive and, hence, their optimal locations in the network must be ascertained. Among these two FACTS controllers, SVC is more popular due to its lesser cost/size as compared to the STATCOM. Shunt Flexible AC Transmission System (FACTS) devices, when placed at the mid-point of a long transmission line, plays an important role in controlling the reactive power flow to the power network and hence controls system voltage fluctuations and improves transient stability. This thesis also deals with Impact of Shunt Facts Controllers on Transient System Stability of Power System using Matlab blockset simulink models. With different shunt FACTS devices, namely SVC and STATCOM in a long transmission line for a 3 bus system has been tested using the simulink model. It has been observed from the simulation results that by locating the STATCOM at the midpoint of the transmission line, transient stability has been enhanced compared to SVC. Self tuning regulator has also been adopted in the present research work by locating TCSC optimally at a specific bus for a 5 bus system and verified the parameters like voltage, current and power using simulink blockset models and results found to be satisfactory during normal and contingency conditions, which shows that stability has been improved.

Finally using conventional and heuristics methods for location of FACTS devices, the stability of the system has been improved and congestion in the overloaded lines has also been reduced, which in turn improved stability of the power system.