CHAPTER 1

INTRODUCTION

1.1 GENERAL

Voltage instability has been a major concern in power systems, especially in planning and operation. Voltage stability is concerned with the ability of a power system to maintain acceptable voltage at all buses in the system under normal conditions and also after being subjected to a disturbance. Some of the causes of voltage instability are (i) increase in load demand; (ii) changes in system condition (iii) load centres far from generation locations; (iv) overloaded transmission lines; (v) inability to meet reactive power demand. Voltage instability is the absence of voltage stability, and results in progressive voltage decrease (or increase). In recent years, voltage instability has been responsible for several major network collapses. Several incidence of voltage collapse have been reported, in different parts of the country as is shown in Table 1.1.

Voltage collapse is the process by which the sequence of events, accompanying voltage instability, leads to a blackout or abnormally low voltages in a significant part of a power system. This will not occur at all if voltage stability can be maintained at all times.

Table 1.1 Lists of voltage instability incidents

Date	Location
September 22, 1970	New York
Sept. 22,1977	Jacksonville, Florida
Dec. 19,1978	France
March 2, 1979	Zealand, Denmark
August 10, 1981	Longview, Washington
September 17, 1981	Central Oregon
August 4, 1982	Belgium
Dec. 28, 1982 and May 17, 1985	Florida, USA
December 19, 1978 and January 12, 1987	Western French
Aug. 4, 1982	Northern Belgium
May 21, 1983	Northern California
Dec. 27, 1983	Sweden
December 27, 1983	Swedish
Aug. 22,1970, July 23, 1983 and July 23, 1987	Japan
June 11, 1984	Northeast United States
April 13, 1986	Winnipeg, Canada Nelson River HVDC link
May 20, 1986	England
May and July 1986	Miles City HVDC links
Nov. 30, 1986	SE Brazil, Paraguay, Itaipu HVDC link
July 23, 1987	Tokyo
July 20, 1987	IIlinois and Indiana
July 28, 1987	Mississippi
July 11, 1989	South Carolina
February 3, 1990 and November 1990	Western France
July 5, 1990	Baltimore and Washington
May 2, 1995	Sri Lanka
July 2, 1996	Western System Co-ordination Council (WSCC) interconnected system (North America)
December 1996	Northern Grid disturbance in Indian Power System
May 1997	Chilean power system
August 14, 2003	North American
July 12, 2004	Athens and Peloponnese peninsula
September 24, 2006	National Grid System of Pakistan

1.2 FACTS AND VOLTAGE STABILITY ENHANCEMENT

Flexible AC Transmission Systems (FACTS) was introduced in the late 1980 by the Electric Power Research Institute (EPRI), USA. FACTS is defined as a power electronic based system with other static equipment, providing control of one or more AC transmission system parameters to enhance controllability and increase in power transfer capability. FACTS has made power systems operation more flexible and secure. It has the ability to control the phase angle, the voltage magnitude at chosen buses and line impedance of transmission system in a quick and effective manner. It also controls active as well as the reactive power flow over a line.

FACTS can control the power flow, ensuring optimum power flow. It increases the loading capability of lines to their thermal capabilities and the system security through raising the transient stability limit and voltage stability limit. It limits short-circuit currents and overloads, manages cascading blackouts and dampens electromechanical oscillations of power systems and machines.

FACTS controllers enhance the voltage profile and the loadability margin of power systems by controlling impedance of the transmission line. A fundamental feature of FACTS is that the speed of response of passive power system components such as a capacitor or a reactor is enhanced. FACTS includesStatic Var Compensators (SVC), Thyristor Controlled Series Capacitors (TCSC), Static Synchronous Compensator (STATCOM), Static Synchronous Series Compensator (SSSC), Unified Power Flow Controller (UPFC) and Interline Power Flow Controller (IPFC). SVC is chosen for this research work as its feasibility and acceptable costs make it more easily usable in practical applications than other FACTS devices.

In general, FACTS controllers can be divided into four categories (i) Series controllers include TCSC and SSSC (ii) Shunt controllers include STATCOM and SVC (iii) Series-series controllers include IPFC (iv) Combined series-shunt controllers include UPFC.

This research work has chosen the biologically inspired optimization techniques such as Particle Swarm Optimization (PSO), Genetic Algorithm (GA) and hybrid PSOGA over conventional methods such as Voltage Collapse Proximity Indicator, L-index, the minimum singular value of power flow Jacobian matrix, the loading margin, minimum eigen value of reduced Jacobian Matrix because it offers a solution to the problem better than the conventional methods. Biologically inspired optimization techniques enable placing SVC device in the best possible position and also finding its susceptance rating.

In order to determine the optimal SVC settings, the voltage stability problem of a power system is modelled as a multi-objective non-linear optimisation problem. To solve this optimisation problem, biologically inspired optimization techniques such as Genetic Algorithm (GA), Differential Evolution (DE), Tabu Search (TS), Simulated Annealing (SA), Ant Colony Optimization (ACO) and Particle Swarm Optimization (PSO) etc. are envisaged by the researchers.

SVC is a shunt-connected static var generator or absorber whose output can be automatically adjusted according to whether capacitive or inductive current is required in order to maintain or control specific parameters of the electrical power system (typically bus voltage). It is modelled as an ideal reactive power injection or absorption at the load end. Variable shunt susceptance model of SVC has been used in this research; this is shown in Figure 1.1.

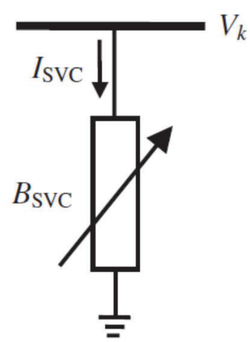

Figure 1.1 Variable shunt susceptance model

The current drawn by the SVC is given in Equation (1.1)

$$I_{SVC}=jB_{SVC}V_k \quad (1.1)$$

The reactive power drawn by the SVC, which is also the reactive power injected at bus k, is given in Equation (1.2)

$$Q_{SVC} = Q_k = -V_K^2 B_{SVC} \quad (1.2)$$

where B_{SVC} is the susceptance of SVC and V_k is the voltage at bus k.

1.3 BIOLOGICALLY INSPIRED OPTIMIZATION TECHNIQUES

Biologically inspired technique is a new multidisciplinary field which includes fuzzy logic, neuro-computing, evolutionary and genetic computing, and probabilistic computing. The applications of biologically inspired technique have proved two main advantages. First, it made solving nonlinear problems, in which mathematical models are not available. Second, it introduced the human knowledge such as cognition, recognition, understanding and learning into the fields of computing. This resulted in the possibility of constructing intelligent systems such as autonomous self-tuning systems, and automated designed systems.

There are several biologically inspired optimization techniques such as Genetic Algorithms, Differential Evolution, Tabu Search, Simulated Annealing, Ant Colony Optimization and Particle Swarm Optimization. Each of these algorithms has its own best features. PSO and GA are very efficient and well known population based optimization techniques.

PSO is a population based stochastic optimization technique developed by Eberhart and Kennedy in 1995, inspired by the social behaviour of bird flocking or fish schooling. The technique is based on the food-searching behaviour of birds with help from the global level of information to determine the birds' direction. The global and local best positions are computed at each iteration and the output is the new direction of search. Once this direction is detected, it is followed by the cluster of birds.

GA was developed by John Holland, University of Michigan during the 1970's; it is an iterative procedure, which maintains a constant size population of candidate solutions. During each iteration step, three genetic operators such as reproduction, crossover and mutation are performed to generate new population and the chromosomes of the new population are evaluated via the value of the fitness. Based on these genetic operators and the evaluations, the better new population of candidate solutions are formed. If the search goal has not been achieved, GA creates offspring strings again through three operators and the process is continued until the search goal is achieved.

In this research work biologically inspired optimization techniques of PSO, GA and hybrid PSOGA have been applied to solve the multi-objective optimization problem of finding the optimal placement and rating of SVC device to improve voltage stability in the power system. This multi-objective optimization problem has five objective functions such as minimization of voltage stability index, total power loss, load voltage deviation, cost of generation and cost of SVC device and subjected to the operational constraints. The proposed algorithm is verified with IEEE 14 bus, IEEE 30 bus, IEEE 57 bus and IEEE 118 bus power systems.

1.4 OBJECTIVES OF THE STUDY

The objectives of this thesis is

1. To model the voltage stability problem as a multi-objective optimization problem with constraints.
2. To apply biologically inspired optimization techniques to enhance voltage stability by finding the optimal location and the size of the SVC devices.
3. To determine the effect of the proposed methods through IEEE 14 bus, IEEE 30 bus, IEEE 57 bus and IEEE 118 bus power systems with different load scenarios.
4. To compare the results obtained by GA, PSO and hybrid PSOGA with L index—one of the conventional methods and other researcher results.

1.5 ORGANISATION OF THE THESIS

The literature survey about identification of weakest bus by different voltage stability analysis techniques, enhancement of voltage stability margins and loadability by locating FACTS device in the power system and optimal location of FACTS device using PSO, GA and hybrid PSOGA to maximize the voltage stability margin are reviewed in Chapter 2.

Chapter 2 also presents (a) mathematical model of PSO, parameters of PSO, proposed algorithm and flowchart for PSO, (b) genetic algorithm, various operation of GA, parameters of GA, proposed algorithm and flowchart for GA and (c) hybrid PSOGA, proposed algorithm and flowchart for hybrid PSOGA.

The problem formulation in Chapter 3 presents problem formulation, multi-objective optimization problem considering the minimization of voltage stability index, cost of generator units, real power loss, load voltage deviation and cost of SVC device. The equality constraints, inequality constraints and fitness function evaluation are also discussed.

In Chapter 4 the results for optimal location and rating of SVC device using PSO, GA and hybrid PSOGA which minimize the multi-objective functions for IEEE 14 bus, IEEE 30 bus, IEEE 57 bus and IEEE 118 bus systems for different load scenario. Results obtained from biologically inspired optimization techniques are compared with L index method and other researcher results.

The conclusions arrived at from the results of the applied techniques are discussed in Chapter 5. The scope for future research work is also indicated.