A Review of Optimal Placement of Shunt FACTS Devices using Optimization Techniques

Chirag Tanti1 Dinesh Pipalava2
1Student of M. Tech 2Assistant Professor
1,2Department of Electrical Engineering
1,2L.E. College, Morbi (Gujarat), India

Abstract— This paper presents a literature survey on applications of shunt connected Flexible Alternating Current Transmission Systems (FACTS) such as Static VAR Compensator (SVC), Static Synchronous Compensator (STATCOM) for enhancement of voltage stability, minimization of the real power losses and also to provide the flexible operation & better controllability etc. Because of economic considerations, identifying the best location for installing the SVC and STATCOM is also important. The FACTS devices placement problem is commonly solved using heuristic optimization techniques. The paper also presents a review of various heuristic optimization techniques applied to determine optimal placement and sizing of the SVC and STATCOM.

Key words: FACTS, SVC, STATCOM and Optimization techniques

I. INTRODUCTION

Flexible AC Transmission Systems (FACTS) can provide benefits in increasing system transmission capacity and power flow control flexibility and speed [1]. FACTS are basically power electronics equipment which is very useful for increasing transmission capacity in the power system and have capability to control several parameters in transmission network [2]. These types of devices can enhance the stability of power system network and can support voltage with better controllability of their parameters such as impedance, current, phase angle and voltage [3]. They have ability to operate fast and effective manner to control the voltage magnitude and phase angle at chosen buses. FACTS devices include Thyristor Controlled Series Reactor (TCSC), Static Var Compensator (SVC), Unified Power Flow Controller (UPFC), and Static Compensator (STATCOM). There are several types to connect the FACTS devices such as in series, shunt, or a combination of both series and shunt. Basically static VAR compensator (SVC) and static synchronous compensator (STATCOM) are shunt connected fact devices. Shunt compensation improves the real power handling capacity of a line at a more economic cost than building other transmission line of the same as well as of higher capability. Shunt FACTS devices provide easy control and reactive power support to the transmission network system [4].

The SVC is the most widely used shunt FACTS device in power networks because of its low cost and good performance in system enhancement. It is a shunt connected static Var generator or absorber with an adjustable output, which allows the exchange of the capacitive or inductive current so as to provide voltage support. When installed at a proper location, the SVC can also reduce power losses [5]. The STATCOM is also a shunt compensator and one of the important members of the FACTS family that are increasingly being used in long transmission lines in modern power systems. Due to economic factor, it is not possible that to install the shunt controller in all buses, therefore it is necessary to find the best location and size of added compensator considering the calculation of steady state condition of the system [6].

II. CHARACTERISTIC OF SVC AND STATCOM

Shunt compensation is engaged to effects the physical electrical characteristics of transmission line of the power system to improve the steady state transmittable power. It is also helpful to control the voltage profile across the line [7]. SVC and STATCOM are very main devices for controlling the reactive power flow in the power system network. An overview of characteristics of SVCs and STATCOMs are provided in following paragraphs.

A. SVC:

The SVC is a shunt-connected static var generator/load whose output is adjusted to exchange capacitive or inductive current so as to maintain or control a specific power system variable [8]. In SVC, a traditional Thyristor is used to obtain rapid monitoring of shunt connected capacitor and reactors. SVC consists of mainly two things are to provide a permanent connected source of reactive power, fix capacitor is used. SVCs have two popular configurations. One configuration consists of a Fixed Capacitor (FC) and a Thyristor-Controlled Reactor (TCR) and the other consists of a Thyristor-Switched Capacitor (TSC) and TCR. In the limit of minimum or maximum susceptances, the SVC behaves like a fixed capacitor or an inductor. The choice of the appropriate size is one of the important issues in the application of SVCs in voltage stability enhancement [9].

B. Statcom:

The STATCOM is a voltage-source, converter-based device that converts a DC input voltage into an AC output voltage to compensate for the active and reactive needs of the system. STATCOMs have better characteristics than SVCs. The STATCOM exhibits constant current characteristics when the voltage is below the limit [8]. At the fundamental frequency, STATCOM produces a stable set of sinusoidal voltage with rapid control of amplitude and phase angle. STATCOM alter DC input voltage into AC output voltage so that compensate the active and reactive essential by the system [10].

III. APPLICATION OF OPTIMIZATION TECHNIQUES FOR OPTIMAL PLACEMENT OF SVC AND STATCOM

This section presents the basic knowledge of evolutionary computation and other heuristic optimization techniques as well as how they are combined with knowledge elements in computational intelligence systems. Applications to the
optimal placement and sizing of SVCs and STATCOMs in power networks are emphasized, and recent research is presented and discussed.

In the earlier decades several meta heuristic optimization algorithm have been introduced. These algorithms are principally inspired by nature analogy. Due to the applicability in the bulk range of problem, all the algorithms are also called as general purpose approaches. There are several optimization techniques such as [11].

- Evolution strategies (ES)-1965,
- Genetic algorithm (GA)-1975,
- Simulated annealing (SA)-1983,
- Ant colony optimization (ACO)-1992
- Particle swarm optimization (PSO)-1995,
- Harmony search algorithm (HSA)-2001
- Bee colony optimization (BCO)-2004,
- Gravitational search algorithm (2009)

A. Evolution Strategies:
The ES optimization technique was introduced in the early 1960s and developed further in the 1970s by Rechenberg and Schwefel at the University of Berlin in Germany. It was originally created to solve technical optimization problems, and its first application was in the area of hydrodynamics [12]. Nowadays, the ES is recognized as a very strong optimization method capable of solving large scale, multimodal, highly constrained, nonlinear problems [13]. The main search procedure in the ES is the mutation operator that generates random samples around search points (solution candidates) selected from a population of different search points.

Jordehi et.al was applied an Evolution strategy to obtain ideal location of FACT devices with the objective of increased system load ability. Enhancement of system load ability is depends on location and setting of FACTS devices. SVC, TCSC, and UPFC were considered for this purpose. Effectiveness of this approach was checked on IEEE 30-bus test system [14].

Santiaigo et.al proposed an approach based on Evolution strategies for optimal placement of FACTS devices with the objective of enhancing system load ability with better controllability of security limits of power system. Mainly three crucial aspects were considered for the optimization purpose- types of installed FACTS, their placement, and corresponding control setting. Effectiveness of this algorithm is checked on IEEE-30 bus test system. Result shows that when different types of FACTS were applied simultaneously, it was maximize the system load ability [15].

B. Genetic Algorithm:
The GA is an evolutionary computation technique that patterns itself after Charles Darwin’s “survival of the fittest” concept. Through selection of parents, crossover between members of the current population, and mutation of the offspring, the population evolves and after a number of generations it approaches an optimal fitness. After the population data is initialized, the fitness of each individual is evaluated through the use of a fitness function. The fitness function value quantitatively compares each individual of the current generation to obtain a fitness ranking (ordering) of all the members. Higher ranking individuals have fitness values that are closer to the optimal fitness value and vice versa for lower ranking individuals. After the fitness of each individual has been assessed, a subgroup of individuals is selected to become the parents for the next generation. Once the two parents are chosen, crossover between them will produce two offspring. The crossover operator applies to the parents according to a pre-defined crossover probability. If the crossover is not allowed, then the two offspring will be identical to the parents. On the other hand, if crossover is allowed, a portion of each parent’s genes goes to one child and the rest to the other. In this way, two individuals containing the same number of genes are produced[16,17].

Pisica et.al used GA that offers to distinguish best placement and sizing of SVC. A multi criteria function was evolved consisting of mainly operational objectives and investment cost. The computer program was operated on a 13-nodes test system. Enhancement in voltage profile and reducing power losses was calculating by a computer program [18].

Talebi et al. [19] used GA for SVC placement with the objective of load balancing during a specific period of time. The unbalanced treatment of some real samples of the feeders was studied and the effect of SVC application was simulated. Simulation results demonstrated that optimal use of the SVC can balance load current and decrease unfavourable effects considerably. Financial analysis showed that this technique is optimal from the economic point of view.

Preethi et.al was offered an application of GA for power system voltage stability enhancement using several FACTS devices. In this paper traditional Newton Raphson method was used to obtain load flow analysis considering several types of loading condition. For the purpose of simulation matlab coding was required [20].

A GA based optimization procedure has been implemented to find the best placement, type, and size of selected FACTS devices for reducing total financial losses in the network caused by voltage sags [21]. Three types of FACTS devices were considered, namely, SVC, STATCOM, and Dynamic Voltage Restorer (DVR). Farsangi et al. [22] used power system stability as an index for optimal allocation of the controllers.

Parizad et.al was proposed an application of GA for finding the optimal location of fact devices to enhance the voltage stability and reduce losses. For this purpose, three types of FACTS devices have been considered. In first step TCPAT, UPFS and SVC installed only in transmission line and indices have been calculated. After that two types of following devices effort to enhance parameter randomly. This method effort to gives superior voltage stability index and reduced losses by consideration of all above devices cumulatively. These processes were performed on 34-bus test system [3]. A messy GA-based optimization scheme for voltage stability enhancement of power systems under critical operation conditions was presented in [23].

Whel -min line et.al has been presented the application of Ant colony optimization (ACO) + GA with ECI (equivalent current inject) model in a power system. This algorithm was applied to find the best location and capacity of a new STATCOM with the objective of voltage security enhancement. In this paper GA was improved the quality of ants by optimizing themselves to develop a
superior result. Finally simulation was performed on IEEE 30-bus test system [24].

C. Simulated Annealing:
Simulated Annealing is one of the most important common probabilistic meta-heuristic for the global optimization problem. Metropolis was described this technique in 1950 as a model of crystallization process. After that this technique was freely stated by Scott Kirkpatrick, C. Daniel Gelatt and Mario P. Vecchi in 1983 and by VladoCerny in 1985 [25]. Simulated annealing was mainly introduced to settle mixed problem by adapting the process of crystallization modal. Simulated annealing emulates the physical gradual cooling process (known as -annealing) to generate high quality crystal [26]. SA locates an ideal approximation to the universal optimum of given function in a huge search space [25]. Actually this technique mocks the behavior of this dynamical system to obtain the thermal equilibrium at a predefined temperature. SA has appreciable ability of escaping from the local minima by accepting or rejecting new solution candidates according to a probability function.

Ghitizadeh and Kalantar proposed an approach based on SA and Sequential Quadratic Programming (SQP) in the optimization process for optimally locating TCSC and SVC [27]. The problem was formulated according to the SQP problem in the first stage to accurately evaluate the static security margin with the congestion alleviation constraint in the presence of FACTS devices, and in the next stage an SA based optimization technique was used to find an optimal solution. The simulation results showed that this placement approach reduced congestion in the transmission lines and enhanced distance of the voltage collapse point without the use of procedures with a high computational burden such as the CPF method.

D. Particle Swarm Optimization:
Particle swarm optimization (PSO) is an evolutionary computation technique developed by Russell Eberhart and James Kennedy in 1995, which is inspired by the social behavior of bird flocking and fish schooling. PSO has its roots in artificial life and social psychology as well as in engineering and computer science. It utilizes a "population" of particles that fly through the problem hyperspace with given velocities. At each iteration, the velocities of the individual particles are stochastically adjusted according to the historical best position for the particle itself and the neighborhood best position. Both the particle best and the neighborhood best are derived according to a user defined fitness function. The movement of each particle naturally evolves to an optimal or near-optimal solution.

Ravi et.al has implemented a modified PSO approach for best location of FACTS devices in order to reduce power system losses and improve voltage profile was known as enhanced particle swarm optimization algorithm. In this algorithm SVC and STATCOM selected for optimal location and sizing in the power system. Enhanced PSO technique obtains optimal setting for current infrastructure as well as ideal location sizes and control setting for STATCOM unit. An IEEE 30-bus test system was presented as an instance to illustrate this approach. Computational results were shown the enhancement of reliability of the power system and efficiency of this modern technique [28].

Hernandez et al. [29] demonstrated the feasibility of applying the PSO technique in solving optimal allocation of a STATCOM in a 45-bus section of the Brazilian power system. The technique was able to find the best location for the STATCOM in order to optimize the system voltage profile with a low degree of uncertainty. Another approach for optimal placement of STATCOMs in power systems was proposed using simultaneous application of PSO and CPF in order to improve the voltage profile, minimize the power system’s total losses, and maximize the system load ability with respect to the size of the STATCOM [30].

Sakhtivel et.al was proposed PSO technique for the optimal location and sizing of SVC to enhance the voltage stability under the most critical line outage contingency in a power system. The other objective of this technique was to minimize the line loss by providing reactive power support with svc under single line outage contingency condition. In this modern technique the line outage severity was measured by considering the amount of enhanced reactive power generation. The performance of this work was checked on IEEE-30 bus test system [31].

Another PSO based techniques has been proposed for minimization of transmission loss considering voltage profile and cost function. SVC was selected as the compensation controllers. It was designed as a reactive source compiled at the bus. Computational simulation was investigated on the IEEE 30-bus test system [32].

Laifa et.al was proposed a multi objective particle swarm optimization technique to obtain ideal allocation of SVC with the objective of solving a mixed continuous-discrete multi objective optimization problem in order to obtain the best location of facts. Several objectives were used such as voltage stability enhancement, reduction of real power losses and voltage deviation. Performance of this algorithm was checked on IEEE 14-bus test system for ideal location and size of fact devices [33].

To find the optimal location and sizing of a STATCOM in a power system for voltage profile improvement, different variations of the PSO techniques have been applied. From among the various PSO techniques, namely, the classical PSO, PSO time varying inertia weight, PSO random inertia weight and PSO time varying acceleration coefficients (PSO-TVAC), the PSO-TVAC model was found to be superior in terms of computational speed and accuracy of solution [34]. The effect of population size and initial and final values of acceleration coefficients was also investigated in this paper.

IV. CONCLUSION
This paper provides a review on reported work in literature on optimal placement and sizing of shunt FACTS devices using above mentioned heuristic optimization technique. Summary of mentioned optimization techniques is also presented. The paper also presents a broad overview and a list of published references as necessary recommendation for the research on optimal location and sizing of shunt FACTS devices.

REFERENCES


