A Review of FACTS Devices and Optimization Algorithms for Improving Voltage Stability in Power System

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Abstract— This paper is about review of various Flexible AC Transmission System (FACTS) devices and optimization algorithms. FACTS devices are accomplished of controlling active and reactive power flows in a transmission line by controlling its series and shunt parameters. The optimal location of these devices in power system improves the power system stability, which is determined by optimization algorithms. The performance of evolutionary strategies, genetic algorithm, particle swarm optimization and artificial bee colony algorithm is also compared here. Also the performance of FACTS devices like SVC, STATCOM and UPFC is compared.

Key words: FACTS, SVC, STATCOM, UPFC, Optimization Algorithms

I. Introduction

Modern power system is a complex network comprising of numerous generators, transmission lines, multiplicity of loads and transformers. As a consequence of increasing power demand, some transmission lines are more loaded than was planned when they were construct with the increased loading of long transmission lines, the problem of transient stability after a most important error can become a transmission limiting factor [1]. Power system stability depends upon both the primary operating conditions of the system and the severity of the disturbance. Recent development in power electronics introduces the use of Flexible AC Transmission System (FACTS) controllers in power systems.

FACTS controllers are competent of controlling the network condition in a very fast manner and this feature of FACTS can be exploited to get better the voltage stability, steady state and transient stabilities of a complex power system [2]. Hingorani defined the FACTS concept and stated the broad prospects of the application in [3]. Placing appropriate FACTS device at proper location with proper sizes would tends to maximum loading margin. So it would be useful to study and compare the well known FACTS devices, namely SVC, TCSC, STATCOM, UPFC and some other devices. Moreover some techniques to provide optimal locations and sizes of these FACT devices could be a useful combination [4].

Optimal power flow problems are the important basic problems in power system operation. They are the optimization problems and their main objective is to reduce total generation cost and improving stability while satisfying the constraints in the power system. Various optimization algorithms are proposed for solving optimal location of FACTS devices. Population based optimization algorithm gives near optimal solutions to the difficult optimization problems by motivation from nature. Two important groups of population based optimization algorithms are evolutionary algorithm and swarm intelligence based algorithms. In this paper performance of evolutionary strategy, genetic algorithm, particle swarm optimization and artificial bee colony algorithm are compared.

II. Comparison of FACTS Devices

The performance of FACTS devices like SVC, STATCOM and UPFC is compared in this section

A. Static Var Compensator (SVC)

SVC is a static Var compensator which is connected in parallel to transmission line. SVC structure is composed of Thyristor Switched Capacitor (TSC) and Thyristor Controlled Reactor (TCR). Static Var Compensator with an auxiliary injection of a proper signal can considerably improve the dynamic stability performance of a power system. The structure of SVC is shown in fig.1. According to IEEE, SVC is a shunt connected static var generator or absorber to exchange capacitive or inductive current to control specific parameters in the network, generally the bus voltage [5]. SVC performs as a generator/load, whose output is tuned to exchange capacitive or inductive current so as to maintain or control specific power system parameters.

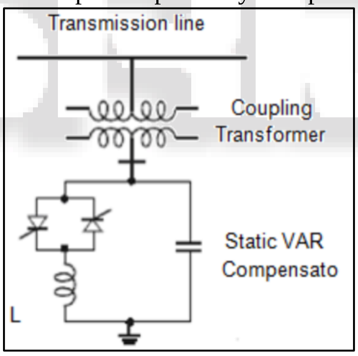

Fig. 1: Structure of SVC

B. Static Synchronous Compensator (STATCOM)

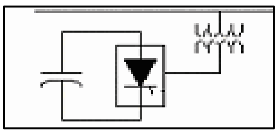

Fig. 2: Structure of STATCOM

STATCOM's are GTO (gate turn-off type thyristor) based SVC's. The basic structure of STATCOM is shown in fig.2. It is mainly based on current source or voltage source converter. According to IEEE, STATCOM is a static synchronous generator operated as a shunt-connected static var compensator whose capacitive or inductive output current can be controlled independent of the AC system voltage. STATCOM also provides dynamic voltage support in transmission and distribution network. STATCOM also act as active filter to absorb harmonics in the system. The overall performance of STATCOM is better and greater flexibility than SVC.

C. Unified Power Flow Controller (UPFC)

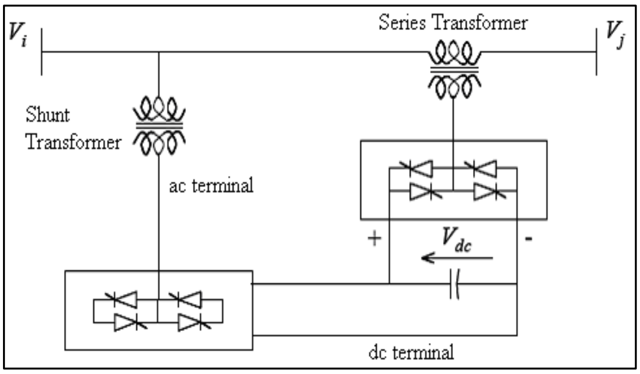

Fig. 3: Structure of UPFC

The basic configuration of a UPFC is shown in Fig. 3. The UPFC normally consists of two converters which are connected to common DC link. The series inverter united to transmission line through series transformer. The shunt inverter is coupled to transmission line through shunt transformer. The shunt inverter can produce or absorbs the reactive power and the series inverter satisfies the operating requirements It can independently able to control the both real and reactive power flows in a transmission line. The converter 1 is used mainly for supplying the real power demand of the converter 2; it drives from the transmission line. The net real power which is pinched from ac system is same or equal to the losses of the two converters. The shunt converter acts like an STATCOM regulates the terminal voltage. The series converter is used to inject a voltage phasor in series with the line. Although the reactive power is internally generated/absorbed by the series converter, the real power generation/absorption is made by the dc energy storage device (capacitor).

FACTS Devices	Load flow control	Voltage control	Transient stability	Dynamic stability
SVC	Low	High	Low	Medium
STATCOM	Low	High	Medium	Medium
UPFC	High	High	High	High

Table 1: Comparison of FACTS devices

Table 1 shows the comparison of FACTS devices. From table it is evident that the performance of UPFC is better in power system.

III. COMPARISON OF ALGORITHMS

The performance of optimization algorithms such as evolutionary strategies, genetic algorithm, particle swarm optimization (PSO) and artificial bee colony algorithm (ABC) is compared in this section

A. Evolutionary Strategies (ES)

An evolution strategy is an optimization methods based on ideas of adaptation and evolution. It belongs to the general class of evolutionary computation or artificial evolution methodologies. It use natural problem dependent representations, and primarily mutation and selection, as search operators. In general with evolutionary algorithms, the operators are applied in a loop. An iteration of the loop is called a generation. The sequence of generation is continued until a termination criterion is met. As far as actual valued search spaces are concerned, mutation is normally performed by adding a normally distributed random value to each vector component. This step size or mutation strength is often governed by self adaptation. Individual step sizes for each coordinate or correlations among coordinates are either governed by self adaptation or by covariance matrix adaptation. The steps involved in ES is given below

1) Initialize population
2) Repeat
3) Recombination
4) Mutation
5) Evaluation
6) Selection
7) Until requirements are met

B. Genetic Algorithm

Genetic Algorithm (GA) is one of the most prominent meta-heuristic optimization algorithms which is based on natural evolution and population. Genetics is usually used to achieve a near global optimum solution. In each iteration of GA (referred as generation), a new set of string (i.e. chromosomes) with improved fitness is produced using genetic operators (i.e. selection, crossover and mutation) [6]. A basic GA consists of five components. These are a random number generator, a fitness evaluation unit and genetic operators for reproduction; crossover and mutation operations. A new generation of solutions is produced with each phase of the algorithm The steps carried out in GA is presented below

1) Initialize population
2) Repeat
3) Evaluation
4) Reproduction
5) Crossover
6) Mutation
7) Until requirements are met

C. Particle swam optimization (PSO)

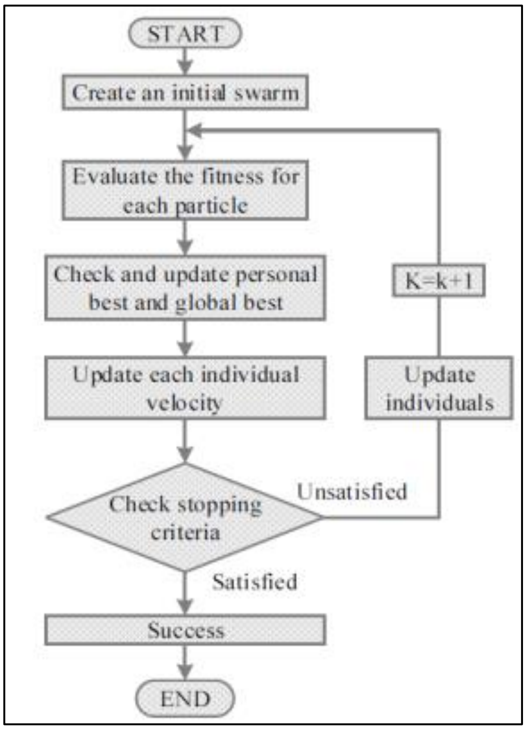

Fig.4. Flowchart for PSO algorithm

Particle swarm optimization has been used to solve many optimization problems Developed by Kennedy and Eberhart. A population based optimization technique stimulated by social behavior of bird flocking or fish schooling, PSO consists of a swarm of particles. Each particle exists in at a position in the search space. The fitness of each particle represents the quality of its position. The particles fly larger than the search space with a certain velocity. The velocity (both direction and speed) of each particle is dependent on its own best position found so far and the best possible solution that was found so far by its neighbors. The steps involved in PSO is given below

1) Initialize population
2) Repeat
3) Calculate fitness values of particles
4) Modify the best particles in swarm
5) Choose the best particle
6) Calculate the velocities of particles
7) Update the particle positions
8) Until the requirements are met

D. *Artificial Bee Colony Algorithm (ABC)*

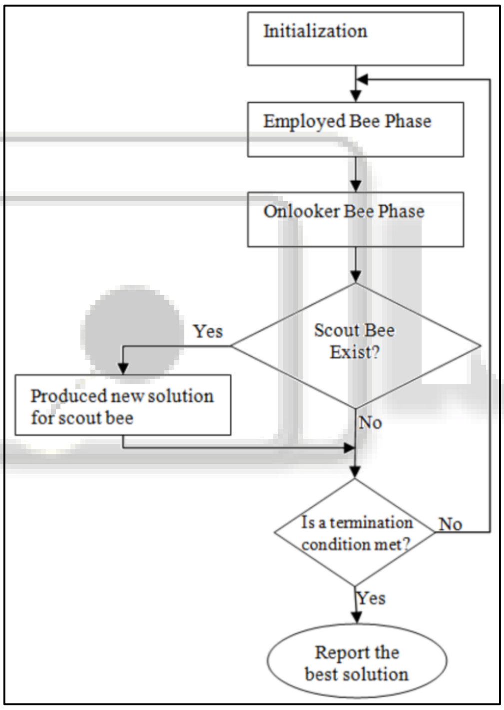

Fig. 5: Flowchart for ABC algorithm

Artificial Bee Colony (ABC) algorithm is introduced by Karaboga in 2005 [7]. The ABC algorithm was formed by monitoring the activities and behavior of honey bees while they are looking for the nectar sources and sharing the information about nectar sources with other bees. The colony of honey bees consists of three groups of bees namely employed bees, onlooker bees and scout bees. The employed bees wait above the nectar source and keep the neighboring sources in memory while the onlooker bees obtain that data from the employed bees and make a resource choice to collect the nectar and the scouts are very much responsible for calculation. The number of employer bees and onlooker bees is always equal. Procedure involved in ABC algorithm is summarized below.

1) Initialize population
2) Repeat
3) Fix the employed bees on their food source
4) Place the onlooker bees on the food source depending on their nectar amounts
5) Send the scouts to the search area for discovering new food sources
6) Memorize the best food source found so far
7) Until requirements are met

Initially a random food source is selected by employer bees and the amount of nectar present in source is evaluated. Then the bees return to the hive and share the information with other bees which is waiting in dancing area. This dance is referred as waggle dance. After sharing the information employed bee moves for another nectar resource area. Then the onlooker bee prefers the source with more nectar by comparing each food source in direct. In next step, when the food source is abandoned by bees then the scout bee randomly chooses the next source by replacing the abandoned source.

Algorithm	Convergence speed	Time	No. of iteration	No. of control parameters	Accuracy
Evolutionary strategy	Slow	Very high	more	4	Accurate
Genetic algorithm	Slow	Very high	More	5	Highly accurate
Particle swarm optimization	Slow	High	Less	5	Accurate
Artificial bee colony algorithm	Fast	Less	Less	3	Highly accurate

Table 2: Comparison of algorithm

Table.2 shows the performance comparison of various optimization algorithms. They are compared based on the speed of convergence, number of iterations, time and their complexity. Artificial bee colony algorithm shows better performance when compared with other techniques.

IV. CONCLUSION

In this paper comparison of FACTS controllers and optimization algorithms is presented. From the comparison table it is evident that the performance of UPFC and artificial bee colony (ABC) algorithm is better when compared to other devices and algorithms respectively. So the combination of UPFC along with artificial bee colony algorithm can be utilized for the power system stability improvement.

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