Optimal Location of Static Var Compensator in Power System Using Genetic Algorithm

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***Abstract*— This paper presents the optimal allocation of FACTS devices in a power system. The optimal location of FACTS devices in power system is needed, the facts controllers in the form of Static Var Compensator (SVC) is presented by evolutionary technique, i.e., Genetic Algorithms (GA) constraint violation, thus increasing the utilization of lowest cost generation in power system. The FACTS device location should be reasonably chosen based on their contribution to the general objective of power system economic generation and dispatch. The Objective Cost function consisting of the investment cost for the type of FACTS device and the generation cost is minimized**

***Index Terms*— Genetic Algorithms, FACTS, Optimal Location, Optimal Power Flow and SVC.**

I. INTRODUCTION

With the rapid development of power electronics, FACTS devices have been proposed and are used in the operation, control power systems and enhance system stability. FACTS controllers such as SVC, TCSC, STATCOM, SSSC and UPFC are used to enhance power system performance. FACTS devices are able to rapidly and smoothly supply or absorb reactive power by controlling the firing delay angles of thyristors (valves). These are used in transmission and distribution systems for voltage and reactive power control. SVC uses power electronics to control its reactive power output to regulate bus voltage. Compared to mechanically switched capacitor banks, SVC reacts very fast and has high reliability. In this paper, SVC devices optimal location can be used as a proposed method based on GAs to achieve the optimal power flow and thus to increase the utilization of the lowest cost generation in power systems and achieve voltage support.

II. Problem Formulation

The mathematical formulation of the optimal allocation of FACTS devices can be expressed as cost function and constrains.

[A] Cost function:

The generating cost function has been approximated as a quadratic function in $/Hour given by:

$f1\ (P) = aP^2 + bP + c$

Where P is a vector that represents the active power outputs of the generators in (MW) a, b and c are the generating cost coefficients in $/MW2 per hr, $/MW per hr and $ per hr.

[B] SVC cost function:

The SVC cost functions in $/KVar is given by:

$F_2 = 0.0003\ S^2 – 0.3051S + 127.38$

Where S is the operating range of the SVC devices in MVar.

The overall cost function F consists of generation costs and FACTS devices investment costs.

The objective function is to be minimized F is given as

$\min(F) = \min(F_1(P) + F_2(g))$

Where g is a vector that represents the variables of FACTS devices.

Subjected to the following constrains:

$$E(g, x) = 0$$

$$B_1(g), B_2(x) \geq 0$$

$E(g, x)$ represents conventional power flow equations

$B_1(g), B_2(x) \geq 0$ are the inequality constraints for FACTS devices:

'x' represents optimal power flow represents the operating states of the power system.

The unit for generation cost F_1 is $/Hour and for the investment costs of FACTS devices F_2 are $.The FACTS devices will be in service for many years. However, only a part of its lifetime will be employed to regulate the power flow. Here, four years is applied to evaluate the average cost function for SVC devices. The average value of investment cost function for SVC will be:

$$F_2(g) = F_2(g)/(4 \times 8760)$$

III. FACTS DEVICES

According to IEEE, FACTS, is defined as follows:

Alternating current transmission systems incorporating power electronics based on other static controllers to enhance controllability and power transfer capability. The FACTS devices enable the transmission system to obtain one or more of the following benefits:

[1] Control of power flow as ordered, ensure optimal power flow.
[2] Increase utilization of lowest cost generation.
[3] Dynamic stability enhancement. This additional function of FACTS includes the transient stability improvement, power oscillation damping and voltage stability control.
[4] Increase the loading capability of lines to their thermal capabilities, including short term and seasonal demands.
[5] Reduce reactive power flows, thus allowing the lines to carry more active power.

According to the operation principles of FACTS controllers, they are of mainly two types:

[A] Conventional Thyristor-Controlled Power System Controllers:

This type of FACTS devices consists of conventional capacitor or reactor banks and thyristors. They control on-off periods of the fixed capacitors and reactors and, thereby varying the capacitive and inductive effective impedance.

[B] Synchronous Voltage Source (SVS) Controllers:

This type of FACTS devices can generate capacitive or inductive reactive power without fixed capacitor or reactor banks.

Among of these types of FACTS controllers, SVC is selected from the Conventional Thyristor-Controlled Power System Controllers in this search.

IV.SVC MODELING

The SVC consists of a TCR in parallel with a bank of capacitors. SVC behaves like a shunt-connected variable reactance, which either generates or absorbs reactive power in order to regulate the voltage magnitude at the point of connection to the AC network. It is used to provide fast reactive power and voltage regulation support. The firing angle control of the thyristor enables the SVC to have almost instantaneous speed of response. A schematic diagram of the SVC is shown in Figure 1.

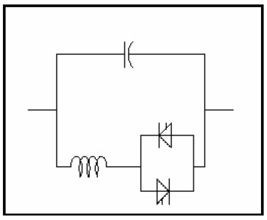

Figure 1. Schematic diagram of FC-TCR

The TCR whose reactive impedance is XL, with a bidirectional thyristor valves.

The controllable reactance of the TCR part is Xv, which is defined by:

$$X_v = X_L \frac{\pi}{2\pi - 2\alpha + \sin(2\alpha)}$$

where α is the firing angle of the thyristor.

The effective susceptance B of the FC-TCR is given by:

$$B = \frac{X_{V+}X_C}{X_V X_C}$$

where X_C is the capacitive impedance of the fixed capacitor.

V. Optimization Algorithms

In conventional OPF algorithms, the objective is to minimize the overall generation function, which includes generation cost of power plants and investment cost of SVC devices. The optimization algorithms simulate an evolutionary process where the goal is to evolve solutions by means of crossover, mutation, and selection based on their quality (fitness) with respect to the optimization problem of interest. Evolutionary algorithms are highly relevant for industrial applications, because they are capable of handling problems with non-linear constraints, multiple objectives, and dynamic components that frequently appear in real-world problems.

In this area of computation, heuristic methods may be used to solve combinatorial optimization problems. These heuristic methods are called ‘intelligent’, because the movement from one solution to another is done using rules close to the human reasoning .The most important advantage of heuristic methods lies in the fact that they are not limited by restrictive assumptions about the search space like continuity, existence of derivative of objective function, etc.

Several heuristic methods exist, such as Tabu Search method (TS), Simulated Annealing (SA), Genetic Algorithms (GAs), and Particle Swarm Optimization (PSO) algorithms.

In this paper, a proposed method based on GAs to achieve optimal allocation of FACTS has been used.

VI. Genetic Algorithms

Heuristic methods may be used to solve complex optimization problems. Based on the mechanisms of natural selection and genetics, genetic algorithms are global search techniques. They are able to search several possible solutions simultaneously and they do not require any prior knowledge or special properties of the objective function. Moreover, they always produce high quality solutions and, therefore, they are excellent methods for searching optimal solution in a complex problem. GAs starts with random generation of initial population which represent possible solutions of the problem. Then the fitness of each individual is evaluated and new populations are generated by genetic operators (Reproduction, Crossover and Mutation) until the maximal number of generation is reached. Figure.2 depicts the Outline of GAs for optimization problems.

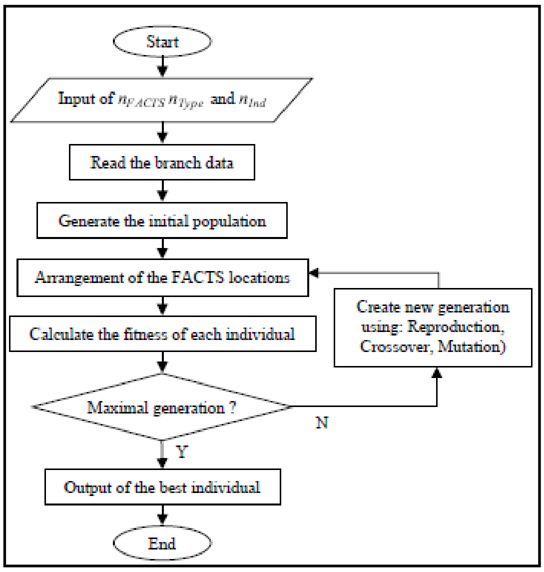

Figure2: Genetic algorithms flowchart

The GAs differs from other optimization and search procedures in four ways:

1- GAs work with a coding of the parameter set, not the parameters themselves. Therefore GAs can easily handle the integer or discrete variables.

2- GAs search from a population of points, not a single point. Therefore GAs can provide globally optimal solutions.

3- GAs use only objective function information, not derivatives or other auxiliary knowledge. Therefore Gas can deal with the non-smooth, non-continuous and non differentiable functions which are actually existed in a practical optimization problem.

4- GAs use probabilistic transition rules, not deterministic rules.

VII. DEVELOPMENT OF THE PROPOSED METHOD

In this paper, the process of determining the optimal allocation and ratings of SVC is introduced using GAs. They are developed to obtain efficiently a high quality solution within practical power system operation.

The goal of the optimization is to find the best location of SVC devices in the power systems. The configuration of SVC is defined with two parameters, the location and rated values.

In order to take into account the two aforementioned parameters in the optimization, a particular coding is developed. An individual is represented with two strings. The first string corresponds to the location of SVC. It contains the numbers of buses where the SVC are to be located. The second string of the individual represents the values of the SVC. It can take discrete values contained between 0 and 1; 0 corresponding to the minimum value that the device can take and 1 to the maximum. According to the model of the SVC, the real value of the device Vreal is calculated with the relation:

$$V_{real} = V_{min} + (V_{max} - V_{min}) * V$$

Where Vmin and Vmax are the minimum and maximum setting value of the SVC, and V is its normalized value. The rated values of SVC are between -100 MVar and 100 MVar. The location of FACTS device has been done for IEEE-14 bus system. Figure 3 shows the single line diagram for IEEE-14 bus system.

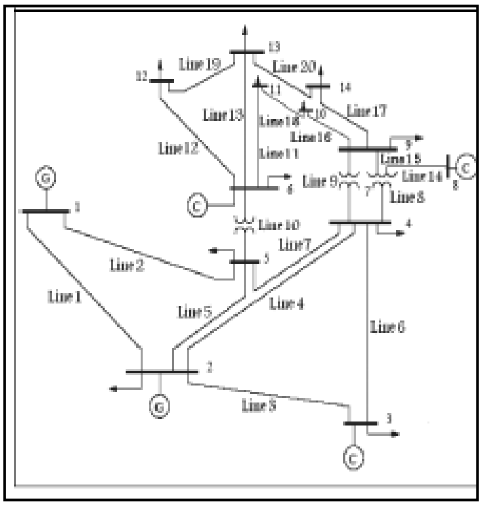

Figure3: Single Line Diagram of IEEE-14 Bus

The creation of an individual is done in the following stages. First,a set of buses of the network that can locate SVC at it, in the first string. The second step consists of the attribution of the characteristics of the device. Setting values of SVC are finally randomly chosen among the possible values. Then, the objective function is computed for every individual of the population. It has to be elaborated so as to favor the reproduction of good individuals without preventing reproduction of interesting others.

The move to a new generation is done from the results obtained for the old generation according to the values of the objective function of it. After that, the operators of reproduction, crossover and mutation are applied successively to generate the offsprings. These three operations are repeated until the number of desired offsprings is created. The objective function is then calculated for every offsprings and the best individuals among the entire pool, comprising parents and their offsprings, are kept to constitute the new generation. By this way, the objective function of the best individual of the new generation will be the same or higher than the objective function.

VIII. SIMULATION RESULTS

In this paper the main objective is to find the best locations of SVC in a network using GAs. By re-dispatching of the load flows in power systems, the total generation costs can be minimized by optimal SVC allocation. Therefore, the objective is to minimize the overall cost function, which includes the generation costs of power plants and the investment costs of SVC devices.

In these proposed methods, Newton Raphson method has been used for power flow. GAs is used for handling the optimization problem. The software was written in MATLAB.

In order to verify the effectiveness of the proposed method, IEEE 14-bus test system is used. After the optimization, for the considered power system, SVC at bus 5 is the best location. For implementing the GA in this problem, population size of 100 was taken and the maximum number of generations was taken as 100.

Table 1 depicts the fuel cost with GA for the IEEE-14 bus system.

	IEEE-14 bus system without placing Static Var compensator	IEEE-14bus system placing Static Var compensator
Fuel Cost($/hr)	1073.69	529.14

Table 1: Fuel Cost with GA for IEEE-14 Bus

The rating of the FACTS Device to be placed is of the value 51.31 MVAR (Injected MVAR –Load MVAR). The Load MVAR is greater at the 5th bus.

CONCLUSION

In large power systems, the selection of proper location for FACTS devices is the first and important step in designing FACTS controllers. Based on the FACTS locations, the design and coordination of their controllers can be carried out. FACTS devices includes improvement of system stability, enhancement of system reliability and reduction of operation and transmission investment cost. In practical operation, the main concern for the allocation of FACTS devices is the economic effect. The proposed GA method is a general method for allocating of SVC from FACTS devices in large power systems.

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