International Journal of Hybrid Information Technology
Vol.8, No.9 (2015), pp.281-288
http://dx.doi.org/10.14257/ijhit.2015.8.9.26

GA Based Optimal Placement of SVC for Minimizing Installation Cost and Voltage Deviations

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Abstract

Power system under heavily loaded conditions is at high risks of consequent voltage instability problem. Voltage deviation minimization is the reliable indicators of voltage security of power networks. The aim is to minimize the voltage deviation and installation cost under increasing load condition in power system network. GA is used to solve the optimization problem in this paper which is one of the heuristic methods. Genetic Algorithm optimizes the location and size of the SVC. The effectiveness of the proposed work is tested in IEEE-30 Bus test system. It has also been observed that the proposed algorithm can be applied to larger systems and do not suffer with computational difficulties. The obtained results show that the allocation of SVC device with the proposed method considerably enhanced the voltage stability and reduce installation cost.

Keywords: *FACTS devices, Optimal Sizing, Genetic Algorithm, SVC, Installation Cost, Voltage Profile*

I. Introduction

FACTS (Flexible Alternating Current Transmission System) are generally based on power electronics which is used for increasing transmission capacity in power system. They also have the capacity to control several parameters in transmission network. FACTS devices can enhance the stability of power system network and can support voltage with better controllability of their parameters like impedance, current, voltage etc [1]. FACTS have the capability to increase the reliability of power system networks and enhance power flow control of the system. There are various methods to connect the FACTS devices such as in series, shunt, series-series and series-shunt. SVC is one of the members of shunt FACTS family which is selected as the placement and sizing in the power system network. Compared to mechanically switched capacitor banks, SVC reacts very fast and has high reliability. In this paper, Genetic Algorithm is used to optimize the placement and sizing of FACTS devices in order to minimize the voltage deviation and installation cost of the System [2].

II. Static VAR Compensator(SVC)

SVC is a shunt connected static var generator whose output is adjusted to exchange capacitive or inductive current to maintain or control specific power variable typically, the control variable is the SVC bus voltage. It provide fast reactive power and voltage regulation support. The SVC is a combination of a fixed capacitors and reactors. Thyristor switched capacitors and thyristor controlled reactors (TCR) are connected in parallel with the power system. One of the other main reasons for installing a SVC is to minimize voltage deviation and thus increase voltage profile of the system. In solving voltage regulation, applications of static var compensator are used. The suitable control of this equivalent reactance allows voltage magnitude regulation at the SVC point of connection

ISSN: 1738-9968 IJHIT

[3]. The SVC will inject or absorb its reactive power (Q_{SVC}) at a selected bus. It injects reactive power into the system if Q_{SVC}<0 and absorbs reactive power from the system if Q_{SVC} >0. Operating range of SVC is between -100MVar and 100MVar [4]. SVC is modeled as a generator or absorber of reactive power. The schematic diagram of such SVC system has been shown in Figure.1 [5].

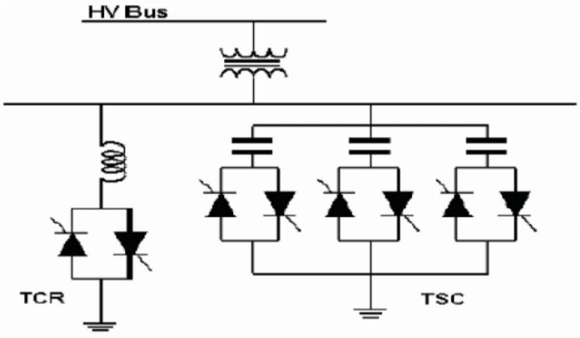

Figure 1: Basic Structure of SVC

III. Problem Formulation

Objective function- The performance of GA was studied on the SVC localization problem. The aims is to reduce voltage deviation and installation cost under increasing load condition. Hence, it is two objective optimization problem. It is calculated by the equation (1).

$$F=w_1f_1+w_2f_2 \qquad ... (1)$$

Where,
F is sum of load bus voltage deviation and cost of installation objective functions,
w1 is the weight coefficient for power loss,
w2 is the weight coefficient for voltage deviation,
w1 is varied between 0 and 1,
w2=1-w1.

Voltage Deviation:-

One of the important factor for security of power systems is voltage deviation. It is defined as a measure for the quality of service. The formula used for measuring the voltage deviation of the buses is calculated by the equation (2).

$$VD = \sum_{i=1}^{b} \left|\left(V_{iref} - V_i\right)\right| . \quad (2)$$

Where,
b is the number of buses,
V_{iref} is the reference voltage at bus i ,
V_i is the actual voltage at bus i.

Cost of Installation:-

The optimal placement and sizing of SVC considering the cost of installation of SVC has been mathematically calculated by the equation (3).

$$C_{SVC} = \sum_{k=1}^{n} 0.0003Q^2 - 0.3051Q + 127.38 \quad (US\$/kVAr) \qquad . (3)$$

Where, Q is the reactive power capacity of k^{th} SVC in MVar.

Equality Constraints:-

The typical load flow and power flow balance equations are represent by the equality constraints which are as follows:

$$P_{Gi} - P_{Li} = V_i \sum_{k=1}^{n} \left(V_k \left[G_{ik} \cos\left(\theta_i - \theta_k\right) + B_{ik} \sin\left(\theta_i - \theta_k\right)\right]\right) \quad (4)$$

$$Q_{Gi} - Q_{Li} = V_i \sum_{k=1}^{n} \left(V_k \left[G_{ik} \sin\left(\theta_i - \theta_k\right) + B_{ik} \cos\left(\theta_i - \theta_k\right)\right]\right) \quad (5)$$

Where,
P_{Gi} and Q_{Gi} are the generated active and reactive powers at node i,
P_{Li} and Q_{Li} are the load active and reactive powers at node i,
G_{ik}, B_{ik} are the conductance and susceptance.

Inequality Constraints:-

The power flow limit and bus voltage limits are represented by the inequality constraints which are as follows:

$$S_I \leq S_{I\ max} \quad \ldots (6)$$

Where,
$S_{l\ max}$ is the thermal limit of the line or bus in steady-state operation.

$$V_{imin} \leq V_i \leq V_{imax} \quad \ldots (7)$$

Where, V_i is the bus voltages which must be maintained around the nominal value [6].

IV.Proposed Methodology

Genetic Algorithm is an evolutionary computing method. It is an excellent method for searching optimal solution in a complex problem. Holland proposed this algorithm in the 60's and 70's. It is a global search algorithm that is based on concepts from natural genetics and the Darwinian survival-of-the-fittest code.

GAs simulate the survival of the fittest among individuals over consecutive generation for solving a problem. Each generation consists of a population of character strings that are analogous to the chromosome that we see in our DNA. Each individual represents a point in a search space and a possible solution. The individuals in the population are then made to go through a process of evolution. It is better than conventional AI in that it is more robust. Unlike older AI systems, they do not break easily even if the inputs changed slightly, or in the presence of reasonable noise. Also, in searching a large state-space, multi-modal state-space, or n-dimensional surface, a genetic algorithm may offer significant benefits over more typical search of optimization techniques.

GAs starts with random generation of initial population which represents possible solutions of the problem. Meta-heuristic algorithm- based engineering optimization methods, including GA, have occasionally overcome several deficiencies of conventional numerical methods. This algorithm helps us to reach to a near global optimum solution. A new set of string (i.e. chromosomes) is produced in each iteration of GA with improved fitness by using genetic operators. The operators used are selection, crossover and mutation.

Reproduction-

It is a process where the individual is selected to move to a new generation according to their fitness. The biased roulette wheel selection is employed in this process. The probability of an individual's reproduction is proportional to its part on the biased roulette wheel.

Crossover-

The main aim of crossover is to reorganize the information of two different individuals and generate a new one. A single point crossover is implemented and probability of crossover is selected as 1.

Mutation-

Mutation is used to introduce some sort of artificial diversification in the population to avoid premature convergence to local optimum solution. The above-mentioned operations of selection, crossover and mutation are repeated until we found the best individual.

There are four ways which makes GAs differs from other optimization:

1) GA is working with a coding of the parameter set.
2) GA search from a population of points, not a single point so it can provide globally optimal solutions.
3) GA use only objective function information, not derivatives or other auxiliary knowledge so it can deal with the non-smooth, non-continuous and non differentiable functions.
4) GA uses probabilistic transition rules, not deterministic rules [7].

The figure shows the general flowchart of GA for placement of SVC.

Steps involved in the process of genetic algorithm are:

1) Randomly initialize population(t)
2) Determine fitness of population(t)
3) Repeat
    a. select parents from population(t)
    b. perform crossover on parents creating population(t+1)
    c. perform mutation of population(t+1)
    d. determine fitness of population(t+1)
4) Until best individual is good enough.

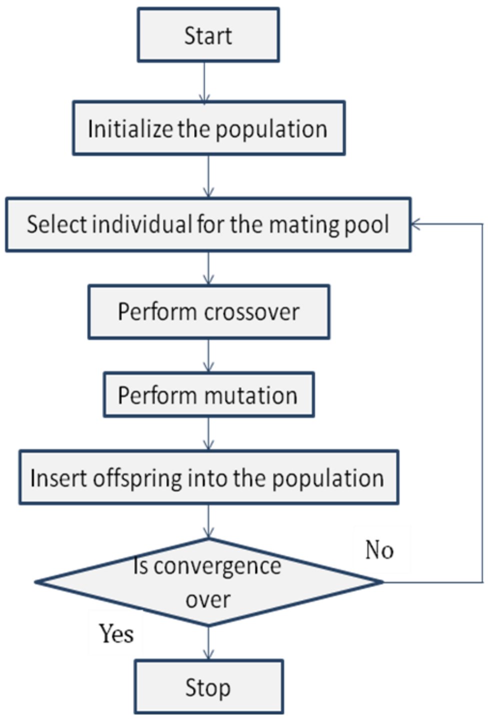

Figure 2: Flowchart of GA

V. Results

The proposed method is implemented on IEEE 30-bus system shown in Figure 5. The test bus system consists of 1 slack bus, 5 generator buses, 24 load buses. To determine the optimal location and size of SVC devices in the network, the proposed genetic algorithm has been implemented. Table.1 shows the various objective functions after installation of the SVC devices. It is observable from table.1, that the SVC placement by using the genetic algorithm lead to lower SVC cost and slightly less voltage deviation. The SVCs of different ratings and their respective optimal location as computed from the developed GA program are shown in Table 1. After placing SVC at their respective optimal location the load bus voltage deviation and installation cost are obtained which are also shown in Table 1. The computed value of voltage deviation is 0.4475 and cost of SVC is 27,214 at the optimal location 28. The graph of generation and cost is shown in fig.3 . Figure 4 shows the characteristics for voltage deviation.

Table.1

Optimal location	Voltage deviation (P.u.)	SVC cost($)
28	0.4475	27,214

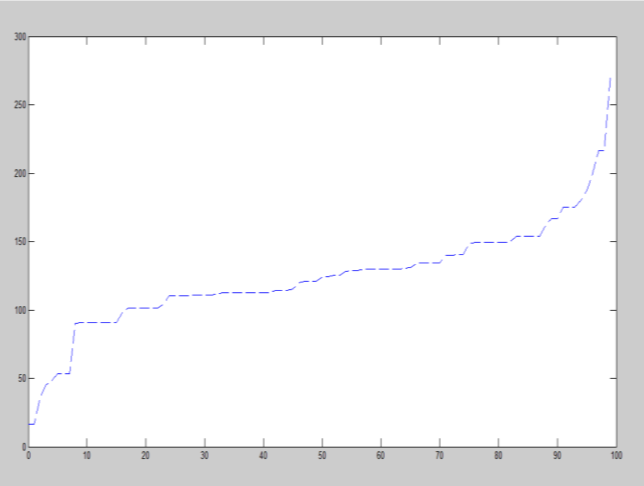

Figure 3

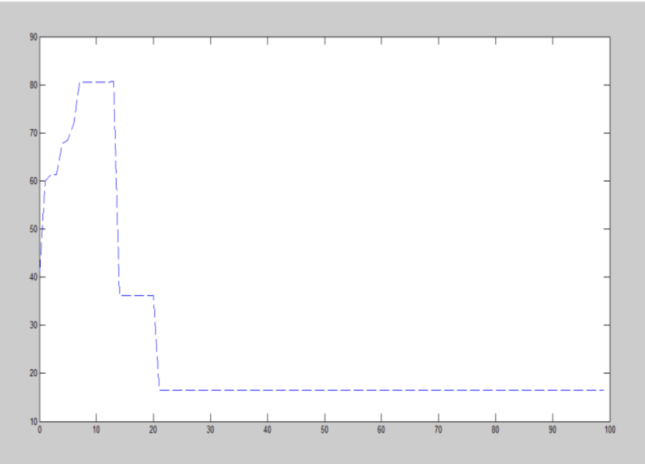

Figure 4

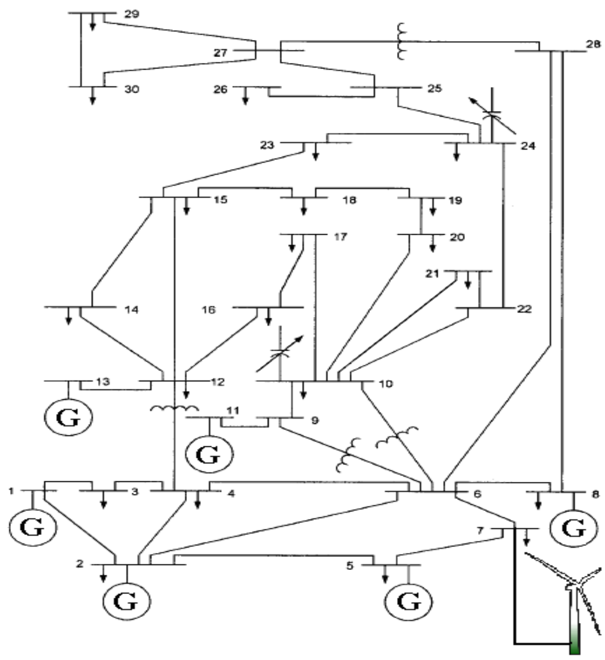

Figure 5: IEEE-30 Bus System

VI.Conclusion

In this paper an algorithm for minimizing voltage profile and installation cost has been proposed. The application of the genetic algorithm as a meta heuristic optimization method for determining the optimal location and size of SVC devices in a bus system has been presented. The proposed multi-objective genetic algorithm has been validated on the IEEE 30-bus system and the obtained results showed that the genetic algorithm gives greater reduction in voltage deviation and total SVC costs. The results clearly indicate the efficiency of the proposed genetic algorithm while it determines the optimal location and sizing of the SVC devices. This algorithm is practical and easy to implement in large-scale power systems.

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