POWER SYSTEM VOLTAGE PROFILE IMPROVEMENT AND POWER LOSS REDUCTION IN TRANSMISSION SYSTEM BY USING MULTI-TYPE FACTS DEVICES AND GA ALGORITHM

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ABSTRACT

The power system is one of the most significant concepts of power system stability. Nonlinearity characteristics, high complexity and time varying behaviour of power systems have considered widespread challenges to stability of the power systems. There are different problems in maintaining the stability of power systems. At present many of the existing transmission lines could not cope with increasing power demand, the problem of voltage stability and voltage collapse has also become a major concern in planning and operation of deregulated power systems. So control of power flow in order to have more efficient, reliable, and secure system is in the interest of the Transmission System Operator (TSO). To overcome this problem, Flexible AC Transmission System (FACTS) devices are introduced. This paper presents a Genetic Algorithm (GA) based allocation algorithm for FACTS devices and reduced power system losses. Proposed algorithm is tested on IEEE 30 bus system.

KEYWORDS: Flexible Alternative Current Transmission System (FACTS), Thyristor Controlled Series Capacitor (TCSC), Static VAR Compensator (SVC), Unified Power Flow Controller (UPFC), Voltage Stability Index, Genetic Algorithm.

INTRODUCTION

At present many of the existing transmission lines could not cope with increasing power demand, the problem of voltage stability and voltage collapse has also become a major concern in planning and operation of deregulated power systems. So control of power flow in order to have more efficient, reliable, and secure system is in the interest of the Transmission System Operator (TSO). To overcome this problem, FACTS devices are introduced. FACTS devices can regulate the active and reactive-power control as well as adaptive to voltage magnitude control simultaneously by their fast control characteristics and their continuous compensating capability and so reduce flow of heavily loaded lines and maintain voltages in desired level. Besides, FACTS devices can improve both transient and small signal stability margins. Controlling [1] the power flows in the network, under normal and abnormal
conditions of the network, can help to reduce flows in heavily loaded lines, reduce system power loss, and so improve the stability and performance of the system without generation rescheduling or topological changes in the network.

FACTS technology opens up new opportunities for controlling power and enhancing the usable capacity of present as well as new and upgraded lines. The possibility that current through a line can be controlled at a reasonable cost enables a large potential of increasing the capacity of existing line with larger conductors and use of one of the FACTS controllers to enable corresponding power to flow through such lines under normal and contingency conditions.

The power flow study, also known as load-flow study, is an important tool involving numerical analysis applied to a power system, for planning future expansion of power systems as well as in determining the best operation of existing systems. The principal information obtained from the power flow study is the magnitude and phase angle of the voltage at each bus, and the real and reactive power flowing in each line.

Genetic algorithm is one of the most famous meta-heuristic optimization algorithms which are based on natural evolution and population. It is usually used to reach to a near global optimum solution. Each iteration of GA, the population string is improved using genetic operators like selection, crossover and mutation. Proposed method is tested on IEEE 30 bus system and results are presented.

**FACTS DEVICES MODEL**

In this paper, three different FACTS devices have been selected to place in suitable location to improve voltage stability margins in power system. These are: [3]TCSC (Thyristor Controlled Series Capacitor), SVC (Static VAR Compensator) and UPFC (Unified Power Flow Controller). These are shown in Fig. 1.
TCSC

TCSC can act as a capacitive or inductive compensator by modifying the reactance of the transmission line. The operating range of TCSC is -0.7Xl to 0.2Xl. The TCSC is assumed to be connected between sending end and receiving end in a transmission line, where the TCSC is presented like a continuously controllable capacitive reactance. By inserting a TCSC modifies the equivalent reactance of the line, and the active power flow can also be varied. The capacitor is inserted into the line if the corresponding thyristor valve is turned off, otherwise it is bypassed. A thyristor valve is turned off in an instance when the current crosses zero.

SVC

Static VAR Compensator is “a shunt-connected static VAR generator or absorber whose output is adjusted to exchange capacitive or inductive current so as to maintain or control specific parameters of the electrical power system (typically bus voltage)”. SVC is based on thyristors without gate turn-off capability. The operating principal and characteristics of thyristors realize SVC variable reactive impedance. SVC includes two main components and their combination: (1) Thyristor-controlled and Thyristor-switched Reactor (TCR and TSR); and (2) Thyristor-switched capacitor (TSC). TCR and TSR are both composed of a shunt-connected reactor controlled by two parallel, reverse-connected thyristors. TCR is controlled with proper firing angle input to operate in a continuous manner, while TSR is controlled without firing angle control which results in a step change in reactance.
UPFC

The UPFC is a combination of a static compensator and static series compensation. It acts as a shunt compensating and a phase shifting device simultaneously. The UPFC consists of a shunt and a series transformer, which are connected via two voltage source converters with a common DC-capacitor. The DC-circuit allows the active power exchange between shunt and series transformer to control the phase shift of the series voltage. The series converter needs to be protected with a Thyristor bridge. Due to the high efforts for the Voltage Source Converters and the protection, an UPFC is getting quite expensive, which limits the practical applications where the voltage and power flow control is required simultaneously.

VOLTAGE STABILITY INDEX

In power system, the stability level of all buses and the weakest bus among them are identified with the help of the stability indices. Voltage stability Index (L-Index) is one among them.

The minimum singular value of the power flow Jacobian matrix has been used as a static voltage stability index, indicating the distance between the studied operating point and the steady-state voltage stability limit. Operators can use the index to know how close the system to voltage collapse, or how much power that the system can supply to loads. This index should be use on-line or off-line to help operators in real time operation of power system or in designing and planning operations. [2]By using the load flow results obtained from Newton- Raphson Technique, the Voltage Stability index (L index) for load buses can be computed as

\[ L_j = I - \sum_{j=1}^{g+1} \frac{F_{ji}}{V_j} \] ........................(1)

Where \( g \) is the no of generators connected in the system. And \( j=g+1\ldots n \). Where \( n \) is the total number of buses.

The values of \( F_{ji} \) can be obtained from Y bus matrix.

\[ F_{ji} = [YLL]^{-1}[YLG] \] .................(2)

Where YLL, YLG are corresponding portions of the Y-bus matrix. The L-indices for a given load condition are computed for all load buses and the maximum of the L indices gives the proximity of the system to voltage collapse. The range of L value is [0,1].When L approaches to 1, power system will approach voltage collapse. Distance between L and 1.0 is system stability margin.
PROPOSED ALGORITHM

Genetic Algorithm is a search heuristic that mimics the process of natural selection. This heuristic is routinely used to generate useful solutions to optimization and search problems. Genetic algorithms belong to the larger class of evolutionary algorithms (EA), which generate solutions to optimization problems using techniques inspired by natural evolution, such as mutation, selection, and crossover.

The Genetic Algorithm (GA), developed by John Holland and his collaborators in the 1960s and 1970s. Holland was the first to use the cross over and recombination, mutation, and selection in the study of adaptive and artificial systems. [4]These genetic operators from the essential part of the genetic algorithm as a problem-solving strategy.

The implementation of GA is as follows

Step 1:

Initial population of \([nop \times n]\) number of real numbers is generated randomly within the limits, where \(nop\) is the initial population size and \(n\) is the number of FACTS devices. Each row represents one possible solution to the optimal FACTS devices sizing problem. Iteration count is set to one.

Step 2:

By placing all the \(n\) FACTS devices of each chromosome at the respective candidate locations and load flow analysis is performed using the branch current load flow method to find the total real power loss \(PL\). The same procedure is repeated for the ‘\(nop\)’ number of chromosomes to find the total real power losses. Fitness value corresponding to each chromosome is evaluated. Fitness value corresponding to each particle is evaluated using the equation (3.1) for maximum loss reduction. Fitness function for maximum loss reduction (considering the FACTS) is given by

\[
\text{Fitness } F_A = PL - P_L^D \tag{3.1}
\]

The FACTS devices sizes corresponding to maximum loss reduction are required. For any one chromosome, the negative \(FA\) value indicates that savings are negative and \(FA\) is fixed at \(FA\) (minimum) and FACTS devices sizes corresponding to that chromosome are fixed at minimum.
Step 3:

The population is arranged in the descending order according to their fitness values. Maximum fitness and average fitness values are calculated. Error = (maximum fitness - average fitness) \( \text{---(3.2)} \)

Error is calculated using the equation (3.2). If this error is less than a specified tolerance then go to step 9.

Step 4:

The best chromosomes are directly copied to the next generation population to perform the elitism with a probability of Pe.

Step 5:

Parents are selected in pairs by using the roulette wheel selection technique based on their fitness values.

Step 6:

Crossover is performed using arithmetic crossover operators

**ARITHMETIC CROSSOVER:**

Arithmetic crossover technique linearly combines two parent chromosomes to produce two new offspring. Two offspring are created according to the following equations.

\[
\text{Offspring}_1 = a \times \text{Parent}_1 + (1-a) \times \text{Parent}_2 \quad \text{---(3.3)} \\
\text{Offspring}_2 = (1-a) \times \text{Parent}_1 + a \times \text{Parent}_2 \quad \text{---(3.4)}
\]

Where ‘a’ is a random number between zero and one, which is generated before each crossover operation.

Step 7:

The iteration count is incremented and whether this iteration count is greater than iteration maximum or not is checked. If it is greater than iteration count then go to step 9.

Step 8:

After performing the elitism and crossover operators, the new population is generated from the old population. In this present work mutation operator is eliminated. Go to step 2 to repeat the same procedure.
Step 9:

Stop the procedure and print the results.

The following figure represents the flow chart representation for Genetic Algorithm operation which consisting the all above steps.

The process is continuing up to maximum number of iterations or up to convergence. Finally it gives the ratings of TCSC and SVC, Loss reduction after placing FACTS devices, Voltage profile before and after placing FACTS devices.

Figure 4 Genetic algorithm

SIMULATION RESULTS

Simulation studies were done for different scenarios in IEEE 30 bus system

Scenario 1: power system normal operation (without FACTS devices installation).
Scenario 2: TCSC-GA operation
Scenario 3: SVC-GA operation
Scenario 4: UPFC-GA operation

The first scenario is normal operation of network without installation any device. In second TCSC-GA was installed. And finally SVC-GA, UPFC-GA was installed. By comparing Scenario2&3&4 was given best improvement and reduces the losses.

Table 1: power losses with and without FACTS device

<table>
<thead>
<tr>
<th>SCENARIOS</th>
<th>TOTAL POWER LOSSES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without FACTS</td>
<td>28.33</td>
</tr>
<tr>
<td>TCSC-GA</td>
<td>24.91</td>
</tr>
<tr>
<td>SVC-GA</td>
<td>26.33</td>
</tr>
<tr>
<td>UPFC-GA</td>
<td>23.09</td>
</tr>
</tbody>
</table>

Figure 5: Voltage profile with and without FACTS devices
CONCLUSION

In this paper a novel approach for optimal placement of FACTS devices based on Genetic algorithm (GA) is presented. Simulation of IEEE 30 bus test system for different scenarios shows that the placement of Multi-type FACTS devices leads to improve in voltage stability margin of power system and reduce losses.

REFERENCES