International Journal of Electrical and Electronics Engineering (IJEEE)
ISSN(P): 2278-9944; ISSN(E): 2278-9952
Vol. 3, Issue 1, Jan 2014, 1-8

International Academy of Science, Engineering and Technology
Connecting Researchers; Nurturing Innovations

PERFORMANCE IMPROVEMENT OF TRANSMISSION SYSTEM USING UPFC BY GA AND PSO ALGORITHMS

RAMPRASAD KANNEMADUGU[1] & A. LAKSHMI DEVI[2]

[1]M.Tech Student, Department of EEE, SV University, Tirupati, Andhra Pradesh, India

[2]Professor, Department of EEE, SV University, Tirupati, Andhra Pradesh, India

ABSTRACT

Power losses and voltage instability are major problems in present power systems. It has become more complex day by day due to less security and reliability. Flexible AC transmission systems (FACTS) controllers have been mainly used for solving various power system steady state control problems. Flexible AC transmission systems or FACTS are devices which allow the flexible and dynamic control of power systems and enhancement of system stability using FACTS controllers. Based on PSO algorithm is an effective method for finding the optimal choice and location of FACTS controllers. It also increases load ability of the line and minimizes losses. This paper presents comparative study of GA and PSO algorithms for one of the FACTS controller i.e., UPFC device. The suggested algorithm has been applied to IEEE-30 bus system.

KEYWORDS: Voltage Stability, Flexible AC Transmission Systems (FACTS), Unified Power Flow Controller (UPFC), Genetic Algorithm (GA), Particle Swarm Optimization (PSO)

INTRODUCTION

The power system stability is considered as one of the most significant concepts of power systems quality. 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.

Voltage stability refer to the ability of power system to maintain steady voltages at all buses in the system after being subjected to a disturbance from a given initial operating condition. Voltage instability is loss of load in an area, or tripping of transmission lines and other elements by their protective systems leading to cascading outages. Loss of synchronism of some generators may result from these outages or from operating conditions that violate field current limit. So that control of load 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 device are introduced.

FACTS can increase controllability and optimize the utilization of the existing power system capacity. FACTS employ high speed thyristors for switching in or out transmission line components such as capacitor, reactor or phase shifting transformer for some desirable performance of the systems. UPFC is the one of the most important device in FACTS controllers. It is in multiple line compensation are integrated into a generalized power flow controller that is able to maintain prescribed, and independently controllable, real and reactive power flow in the line.

A Genetic algorithm (GA) is a search heuristic that mimics the process of natural selection. This heuristic (also sometimes called metaheuristic) is routinely used to generate useful solutions to optimization and search problems.

Particle Swarm Optimization (PSO) is an extremely simple algorithm that seems to be effective for optimizing a wide range of functions. PSO is applied for solving various optimization problems in electrical engineering.

PSO shared many similarities with evolutionary computation techniques such as Genetic Algorithms (GA). The system is initialized with a population of random solutions and searches for optima by updating generations. However, unlike GA, PSO have no evolution operators. In PSO, the potential solutions, called particles, fly through the problem space by following the current optimum particles. PSO is easy to implement and there are few parameters to adjust.

MODELLING OF UPFC

Unified Power Flow Controller is the one of main component of the FACTS devices. It consists of two switching converters that are operated from a common direct current link provided by direct current storage capacitor. Converter 2 provides the main function of UPFC by injecting an alternative current voltage of controllable magnitude and phase angle in series with the transmission line via a series transformer 1. The basic function of converter 1 is to supply or absorb the real power demand by converter 2 at the common direct current link. The active current component of converter 1 is obtained from power balance between the series and the shunt converters and the reactive component can be independently controlled to provide necessary voltage support at the bus.

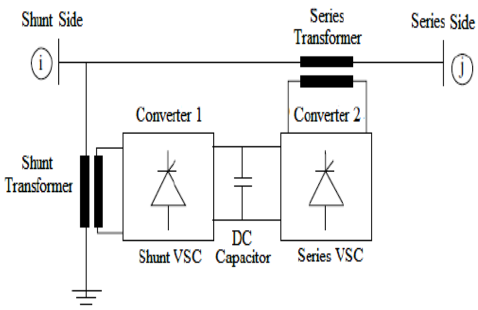

Figure 1: Structure of UPFC

Power flow through the transmission line i-j namely is depend on line reactanceX_{ij}, bus voltage magnitudes V_i, V_j and phase angle between sending and receiving buses $\delta_i - \delta_j$. This is expressed by Eq. 1.

$$P_{ij} = \frac{V_i V_j}{X_{ij}} \sin(\delta_i - \delta_j) \tag{1}$$

Two types of UPFC models are available. One is a coupled model and other is decoupled model. In the first type, UPFC is modelled with series combination of a voltage source and impedance in the transmission line. In decoupled model, UPFC is modelled with between separated buses. First model is more complex compared with the second one because modification of Jacobian matrix in coupled model is evitable. In decoupled model can be easily implemented in conventional power low algorithm without modification of Jacobian matrix elements. Decoupled model has been used for modelling UPFC in power flow study. To obtain UPFC model in load low study, it is represented by four variables (i.e. P_{u1}, Q_{u1}, P_{u2} and Q_{u2}). Assuming UPFC to be lossless and real power flow from bus i to bus j can be expressed as: [8]

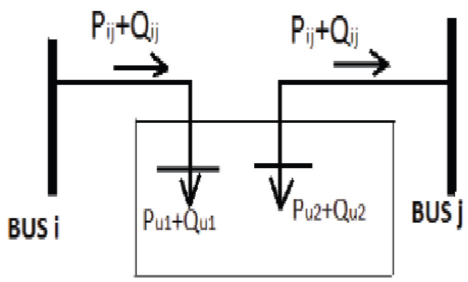

Figure 2: Decoupled Model of UPFC

$P_{ij} = P_{u1}$ (2)

Although UPFC can control the power flow, but cannot generate the real power. So

$P_{u1} + P_{u2} = 0$ (3)

It is assumed that the UPFCs are installed in the middle of lines. Each reactive power output of UPFC $Q_{u1,}$ Q_{u2} can be set to an arbitrary value depends on rating of UPFC to maintain bus voltage.

Optimal Location for UPFC

In order to find the optimal location or the UPFC to be placed the bus which is mostly affected during faults has to be identified. With the increased loading of transmission and distribution lines, voltage instability problem has become a concern and serious issue for power system planners and operators. The main challenge of this problem is to narrow down the locations where voltage instability could be initiated and to understand the origin of the problem. One effective way to narrow down the workspace is to identify weak buses in the systems, which are most likely to face voltage collapse and transmission line losses.

VOLTAGE STABILITY INDEX (VSI)

Consider the power network where n is the total number of buses with 1, 2…g generator buses, and g+1…n remaining (n-g) buses. For a given system operating condition, using the load flow results, the voltage stability index ‘L’ can be calculated as [7]

$$L_j = \left|1 - \sum_{i=1}^{g} F_{IJ} \frac{|V_i|}{|V_j|}\right| \quad (4)$$

Where j=g+1….n and all the terms inside the sigma on the right hand side complex quantities. The complex values of F_{ij} are obtained from Y_{bus} matrix of power system. For a given operating condition.

$$\begin{bmatrix} I_G \\ I_L \end{bmatrix} = \begin{bmatrix} Y_{GG} & Y_{GL} \\ Y_{LG} & Y_{LL} \end{bmatrix} \begin{bmatrix} V_G \\ V_L \end{bmatrix}$$

Where I_G, I_L and V_G, V_L represent complex current and voltage vectors at the generator nodes and load nodes$[Y_{GG}]$,$[Y_{GL}]$, $[Y_{LG}] and [Y_{LL}]$ are corresponding partitioned portions of the Y_{BUS} matrix.

This analysis will be carried out only for the load buses; hence the index obtained is for load buses only. For stability the index L must not be more than 1 for any of the nodes j. the global index for stability of the given power system is defined to be L= maximum of Lj for all j (load buses). The index far away from 1 and close 0 indicates voltage stability. The L index will give the scalar number to each load bus. Among the various indices for voltage stability and voltage collapse prediction (i.e. far away from 1 and close to 1 or >1 respectively), the L index will give more accurate results. The L indices for given load conditions are calculated for all load buses and the maximum of the L indices gives the proximity of the system to voltage collapse.

EVOLUTION OF OPTIMIZATION TECHNIQUES

Genetic Algorithm

GAs, as powerful and broadly applicable stochastic search and optimization techniques, are perhaps the most widely known types of evolutionary computation methods today. GA of evolutionary computation is inspired by Darwin's theory of evolution. A GA generates a population of possible solutions encoded as chromosomes, evaluates their fitness and creates a new population by applying genetic operators which are selection, crossover and mutation.

- **Selection**

In proposed GA, method of tournament selection is used for selection. This method chooses each parent by choosing n_t (tournament size) players randomly and choosing the best individual out of that set to be a parent. In this paper $n_t$is chosen $n_t = 4$.

- **Cross Over**

Cross over allows the genes from different parents to be combined in children by exchanging materials between two parents. Cross over function randomly selects a gene at the same coordinate from one of two parents and assign it to child. For each chromosome, a random number is selected. If this number is between 0.01 and 0.3, two parents are combined; else chromosome is transferred with no cross over.

- **Mutation**

GA creates mutation children by randomly changing the genes of individual parents. In this paper, GA adds a random vector from a Gaussian distribution to the parents. For each chromosome, random number is selected. If this number is between 0.01 and 0.1, mutation process is applied; else chromosome is transferred with no mutation.

Particle Swarm Optimization

Inspired by social behaviour of bird flocking or fish schooling, Eberhartand Kennedy first developed the particle swarm optimization(PSO) algorithm in 1995. PSO, as a branch of evolutionary computation, has been successfully applied in many research and application areas in the past several years. The PSO as an optimization tool provides a population-based search procedure in which individuals called particles change their position (state) with time. In a PSO system, particles fly around in a multidimensional search space. During flight, each particle adjust its position according to its own experience (This value is called Pbest), and according to the experience of a neighbouring particle (This value is called Gbest), made use of the best position encountered by itself and its neighbour. [5] Each particle is treated as a point in a D dimensional space.

The ith particle is represented as

$$X_i = (X_{i1}, X_{i2}, \dots .. X_{id})$$

The best previous position of the ith particle is recorded and represented as

$$P_{besti} = (P_{besti1,} P_{besti2}, \dots \dots \dots P_{bestid})$$

The index of the best particle among the entire particle in the population is represented by the symbol g_{bestid}. The rate of the position change (velocity) for the particle is represented as

$$V_i = (V_{i1}, V_{i2}, \dots \dots V_{id})$$

After the search procedure for the Pbest id and gbest id the modified velocity and position of each particle can be calculated using the current velocity and the distance from P_{bestid} to g_{bestid} as shown in the following equation.

$$V_{\boldsymbol{id}}(t+1) = W * V_{id}(t) + C_1 * rand_1\left(P_{bestid} - X_{id}(t)\right) + C_2 * rand_2\left(g_{bestid} - X_{id}(t)\right) \quad (5)$$

Where

i = 1, 2, 3…n

d = 1,2,3….m

n: number of particles

m: solution's dimensions i.e., the number of control variables

$V_{id}(t)$: Current velocity of the i at iteration t

$V_{id}(t+1)$: modified velocity of particle i

Rand: random number between 0 and 1

$X_{id}(t)$: Current position of particle i at iteration t

P_{bestid}: P_{best} of particle i

g_{bestid}: g_{best} of particle i

W: weight function for velocity of particle i

C_i: weight coefficient of each term

The first term on the RHS of the equation is the previous velocity of the particle. Without the second and third term, the agent will keep on flying in the same direction until it hits in the boundary. In the end the particles will try to converge to the P_{best} or g_{best}.

V_{max}: So from the convergence V_{max} is obtained V_{max} that is the maximum change in one particle can take during the iteration, which if too high the particle must fly past good solutions, similarly if it is too small particles may not explore sufficiently beyond the local solution.

C: the constant C_1 and C_2 represent acceleration constants or learning factors, usually considered equal and ranges from [0,4] when C1=C2=2

W: To control the impact of previous history of velocities on the current velocity the inertia weight W is employed which influences the trade-off between global and local exploration abilities of the flying point. Thus suitable selection of inertia weight W can provide a balance between global and local exploration abilities and will require less iteration on average to find the optimum. W can be calculated according to the following equation,

$$W = W_{max} - \frac{W_{max} - W_{min}}{iter_{max}} \times iter \tag{6}$$

$Iter_{max} is the maximum number of iteratios$

Iter-is the number of iterations until the current stage

Where W_{max}= 0.9 and W_{min}= 0.4

Using the above equation, a certain velocity that gradually gets close to P_{best} and g_{best} can be calculated, which can be further used to calculate the current position with the following equation

$$X_{id}(t+1) = X_{id}(t) + V_{id}(t+1) \tag{7}$$

$X_{id}(t)$: Current position of particle I at iteration t

$X_{id}(t+1)$: Current position of particle I at iteration t+1

$V_{id}(t+1)$: Modified velocity of particle i

Algorithm

The following PSO algorithm is used to obtain the optimal location of UPFC for loss minimization.

Step 1: Initial searching points and velocities are randomly generated within their limits.

Step 2: P_{best} is set to each initial searching points. The best evaluated values among the P_{best} are set to g_{best}.

Step 3: new velocities are calculated using equation (5)

Step 4: If $V_{id}(t+1) < V_{dmin}$

Then $V_{id}(t+1) = V_{dmin}$ and if $V_{id}(t+1) > V_{dmax}$

Then $V_{id}(t+1) = V_{dmax}$

Step 5: New searching points are calculated using equation (7)

Step 6: Check the capacity limits constraints

If $P_{id}(t+1) > P_{dmax}$

Then $P_{id}(t+1) = P_{dmax}$ and if $P_{id}(t+1) < P_{dmin}$

Then $P_{id}(t+1) = P_{dmin}$

Step 7: Evaluate the fitness value for new searching point. If evaluated value of each agent is better than previous P_{best} then set to P_{best}.if the best P_{best} is better than g_{best} then set to g_{best}

Step 8: If the maximum iteration is reached stop the process otherwise go to step 3.

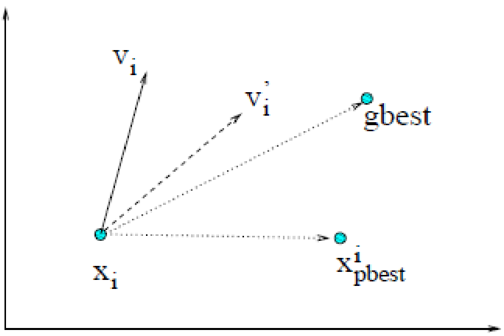

Figure 3: Concept of Modification Searching Points in PSO

RESULTS

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

Scenario 1: Power system normal operation (without FACTS devices installation).

Scenario 2: UPFC-GA operation

Scenario 3: UPFC-PSO operation

The first scenario is normal operation of network without installation any device. In second UPFC-GA was installed. And finally UPFC-PSO was installed. By comparing Scenario 2 & 3, 3rd one UPFC-PSO was given best improvement and reduces the losses comparing UPFC-GA.

Table 1: Power losses with and without UPFC

SCENARIOS	Total Power Losses
WithoutUPFC	29.392
UPFC GA	23.0900
UPFC PSO	22.8591

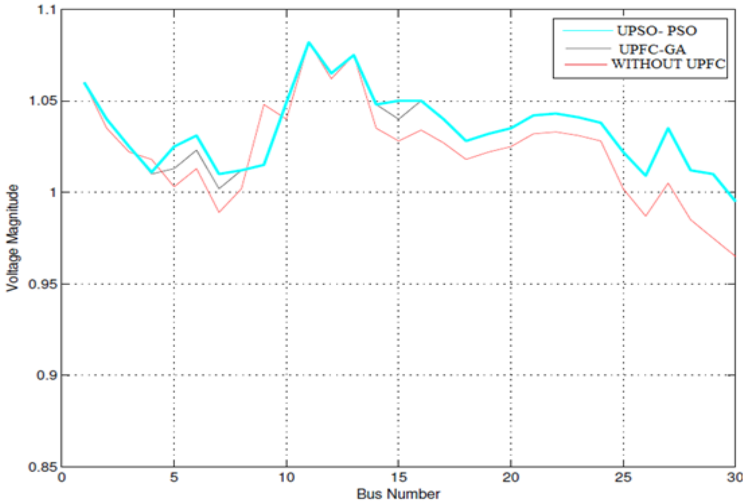

Figure 4: Voltage Profile with and without Placement UPFC

CONCLUSIONS

In this paper, performance of transmission system with UPFC device is studied using Particle Swarm Optimization (PSO) and Genetic Algorithm (GA). It is concluded that with PSO the performance studies in terms of voltage profile and power loss are more accurate compared with GA. Using PSO accurate results can be obtained. Case Study was conducted on IEEE-30 bus system.

REFERENCES

1. K.R. Padiyar, "FACTS Controllers in Power Transmission And Distribution"Copyright © 2007, New Age International (P) Ltd., Publishers
2. N.G. Hingorani, and L. Gyugyi, "Understand FACTS: Concepts and Technology of Flexible AC Transmission Systems", IEEE Press, New-York, 2000.
3. D P Kothari, and I J Nagrath, "Modern Power System Analysis" 4th edition, TATA McGraw Hill Education Private Limited, New Delhi.
4. M. Kowsalya, and D. P. Kothari, "Loss Optimization for Voltage Stability Enhancement Incorporating UPFC Using Particle Swarm Optimization" Journal of Electrical Engineering & Technology Vol. 4, No. 4, pp.492 ~ 498, 2009
5. Jigar S. Sarda, Lalit K.Patel, " Genetic Algorithm Approach for Optimal location of FACTS devices to improve system loadability and minimization o losses" International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering. Vol. 1, Issue 3, September 2012.
6. H.R. Baghaee, B.Vahidi, "Improvement of Voltage Stability and Reduce Power System Losses by Optimal GA-based Allocation of Multi-type FACTS Devices" Optimization of Electrical and Electronic Equipment, 2008. OPTIM 2008. 11th International Conference on 22-24 May 2008.

7. S.Sutha, N.Kamaraj, "Optimal Location of Multi Type Facts Devices for Multiple Contingencies Using Particle Swarm Optimization" World Academy of Science, Engineering and Technology 22 2008.

8. J.Vivekananthan1,R.Karthick2, " Voltage Stability Improvement And Reduce Power System Losses By Bacterial Foraging Optimization Based Location Of Facts Devices,"International Electrical Engineering Journal (IEEJ) Vol. 4 (2013) No. 1, pp. 1034-1040 ISSN 2078-2365

9. Samina Elyas Mubeen, and Gayatri Agnihotri, "Power Flow Control with UPFC in Power Transmission System" World Academy of Science, Engineering and Technology 23 2008.

10. Kalaivani, R. and V. Kamaraj, "Enhancement of Voltage Stability by Optimal Location of Static Var Compensator Using Genetic Algorithm and Particle Swarm Optimization"American J. of Engineering and Applied Sciences 5 (1): 70-77, 2012.

11. Seekanth Reddy Donapati and M.K.Verma, "An Approach for Optimal Placement of UPFC to Enhance Voltage Stability Margin under Contingencies"Fifteenth National Power Systems Conference (NPSC), IIT Bombay, December 2008

12. J.G.Singh, S.C. Srivastava, "Placement of FACTS controller to enhance for Enhancing Power System Loadability" in proc. of the IEEE Power India Conferences, 2006, pp.10-17.

13. Biplab Bhattacharyya, Vikash Kumar Gupta, "Particle Swarm Intelligence based allocation of FACTS controller for the increased load ability of Power system," International Journal on Electrical Engineering and Informatics - Volume 4, Number 4, December 2012.