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Research Article

Application of PSO and GA in Optimal Placement of FACTS devices in Transmission line

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Abstract

With the help of FACTS controllers, it is possible to reduce real and reactive power losses in the power system. Location and type chosen should be proper and rating must be optimal for economical operation of the power system. In Order find suitable FACTS location more easily and with more flexibility, this paper presents a graphical user interface (GUI) based on a genetic algorithm(GA) and particle swarm optimization(PSO) which is able to find the optimal locations an sizing parameters of FACTS devices. Among various FACTS controllers Thyristor Controlled series capacitor(TCSC), Static Var Compensator(SVC), Unified Power Flow Controller(UPFC) are considered in this paper. To verify the effectiveness of proposed algorithm, studies are carried out on IEEE 30 bus systems, with single and double type FACTS controllers. It is clear from the results that loss minimization is highly sensitive to range of compensation. MATLAB coding is developed for the simulation.

Keywords: *FACTS devices, Genetic Algorithm, Particle Swarm Algorithm, Optimal location*

1. Introduction

With the ongoing expansion and growth of the electric utility industry, including deregulation in many countries, numerous changes are continuously being introduced to a once predictable business. Although electricity is a highly engineered product, it is increasingly being considered and handled as a commodity. Thus, transmission system are being pushed closer to their stability and thermal limits while the focus on the quality of power delivered is greater than ever.

In the evolving utility environment, financial and market forces are, and will continue to, demand a more optimal and profitable operation of the power system with respect to generation, transmission and distribution. Now, more than ever, advanced technologies and paramount foe the reliable and secure operation of the power system. To achieve both operational reliability and financial profitability, it has become clear that more efficient utilization and control of the existing transmission system infrastructure is required.

Improved utilization of the existing power system is provided through the application of advanced control technologies. Power electronics based equipment, or Flexible AC Transmission Systems(FACTS), provide proven technical solutions to address these new operating challenges being presented today. FACTS technologies allow foe improved transmission system operation with minimal infrastructure investment, environmental impact, and implementation time compared to the construction of new transmission lines.

Traditional solutions to upgrading the electrical transmission system infrastructure have been primarily in the form of new transmission lines, substations, and associated equipment. However, as experiences have been proven over the past decade or more, the process to permit, site, and construct new transmission lines has become extremely difficult, expensive, time-consuming, and controversial. FACTS technologies provide advanced solution to cost-effective alternatives to new transmission line construction (John J. Paserba,2004). Different types of devices have been developed and there is various way to class them:

1) Technology of the used semiconductor
2) The possible benefits of the controllers
3) The type of compensation

According to the last classification, can be divided into 4 categories of FACTS controllers:

- Series controllers
- Shunt controllers
- Combined Series-Shunt controllers
- Combined Series-Series controllers

Several FACTS devices exist and each one has its own properties and may be used in specific contexts.(Lijun Cai and Istvan Erlich, Yicheng Luo).

2. Benefits of utilizing FACTS Devices

The benefits utilizing FACTS devices in electrical transmission systems can be summarized as follows,

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- Better utilization of existing transmission system.
- Increased transmission system reliability and availability.
- Increased quality of supply for sensitive industries.

In many countries, increasing the energy transfer capacity and controlling the load flow of transmission lines are of vital importance, especially in de-regulated markets, where the locations of generation and the bulk load centres can change rapidly. Frequently, adding new transmission lines to meet increasing electricity demand is limited by economical and environmental constraints. FACTS devices help to meet these requirements with the existing transmission systems(Sajid Ali,2012).

Benefits with the Application of FACTS controllers

The benefits due to FACTS controllers are listed below,

1) They contribute to optimal system operation by reducing power losses and improving voltage profile.
2) The transient stability limit is increased thereby improving dynamic security of the system and reducing the incidents of blockouts caused by cascading outages.
3) The steady state or small signal stability region can be increased by proving auxillary stabilizing controllers to damp low frequency oscillations.
4) The problem of voltage fluctuations and in particular, dynamic over- voltages can be overcome by FACTS controllers

3. Choice of FACTS Devices

In an interconnected electrical network, power flows obey Kirchhoff's laws. Usually, the value of the transverse conductance is close to zero and for most transmission lines, the resistance is small compared to the reactance. By neglecting the transverse capacitance, active and reactive power transmitted by a line between two buses 1 and 2 may be approximated by the following relationships:

$P_{12}=(V_1V_2 / X_{12})\sin\Theta_{12}$ (1)

$Q_{12}=(1/X_{12})(V_1^2-V_1V_2\cos\Theta_{12})$ (2)

Where,

V_1 and V_2 voltage at bus 1 &2

X_{12} is the reactance of the line

Θ_{12} is the angle between V_1 and V_2

Three different types of devices have been chosen to be optimally located in order to control power flows. Each of them is able to change only one of the above three mentioned parameters. The first one is the TCSC (Thyristor Controlled Series Capacitor), which permits to decrease or increase the reactance of the line. The second one is the SVC (Static Var Compensator) is used to absorb or inject reactive power at the midpoint of the line. Finally, the UPFC(Unified Power Flow Controller), which control voltage magnitude and the phase angle of the sending end buses of the lines where major active power flow takes place(Lijun Cai and Istvan Erlich, Yicheng Luo).

4. Mathematical Model of FACTS devices

In this paper steady state model of FACTS devices are developed for power flow studies. So TCSC is modelled simply to just modify the reactance of transmission line. SVC and UPFC are modelled using the power injection models. Models integrated into transmission line for TCSC and UPFC and SVC is modelled and incorporated into the bus as shunt element of transmission line. Mathematical models for FACTS devices are implemented by MATLAB programming language.

TCSC:- TCSC acts as the capacitive or inductive compensator by modifying reactance of transmission line. This changes line flow due to change in series reactance. In this paper TCSC is modelled by changing transmission line reactance as below:

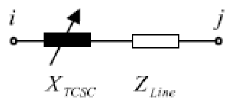

Fig 1: TCSC structure

$$X_{ij} = X_{Line} + X_{TCSC} = rtcsc.\, X_{Line} \qquad (3)$$

Where X_{line} is the reactance of the line and r_{tcsc} is the coefficient which represent the degree of compensation by TCSC. The TCSC reactance is chosen between -0.105 X_{line} to 0.105 $X_{line.}$

SVC:- SVC can be used for both inductive and capacitive compensation.

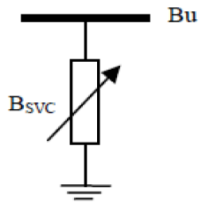

Fig 2: SVC structure

In this paper SVC is modelled as an ideal reactive power injection at bus i:

$$\Delta Q_{is} = Q_{SVC} \qquad (4)$$

UPFC:- UPFC can be represented by two voltage sources representing fundamental components of output voltage waveforms of the two converters and impedances being leakage reactance's of the coupling transformers.

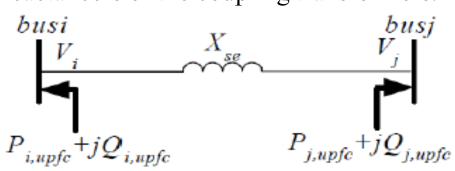

Fig 3 UPFC structure

The elements of the equivalent power injections in fig 3. are,

$P_{i,upfc} = 0.02rb_{se}V_i^2 \sin\gamma - 1.02\, rb_{se} V_iV_j \sin(\gamma + \Theta_i - \Theta_j)$ (5)

$P_{j,upfc} = rb_{se}V_iVj \sin(\gamma + \Theta_i - \Theta_j)$ (6)

$Q_{i,upfc} = -rb_{se}V_i^2$ (7)

$Q_{j,upfc} = rb_{se}V_iV_j\cos(\gamma + \Theta_i - \Theta_j)$ (8)

Where, $b_{se} = 1/X_{se}$.

5. Optimization Process

A. Genetic Algorithm

The Genetic Algorithm(GA) was developed by the evolutionary theory of Darwin. GA was initially used by Holland in 1975, for solving the optimization problem(Rengin Idil CABADAG,2013).

The GA is initialized with a population of individuals (solution-optimal location) and a binary representation of the decision variables to perform the search by using genetic operators i.e. selection, crossover, mutation and elitism. The quality of an individual is assessed by its fitness, which is based on fitness function. In case of FACTS placement, this fitness is evaluated based on minimizing real and reactive power losses, to reduce investments and operational costs, and providing optimal size.

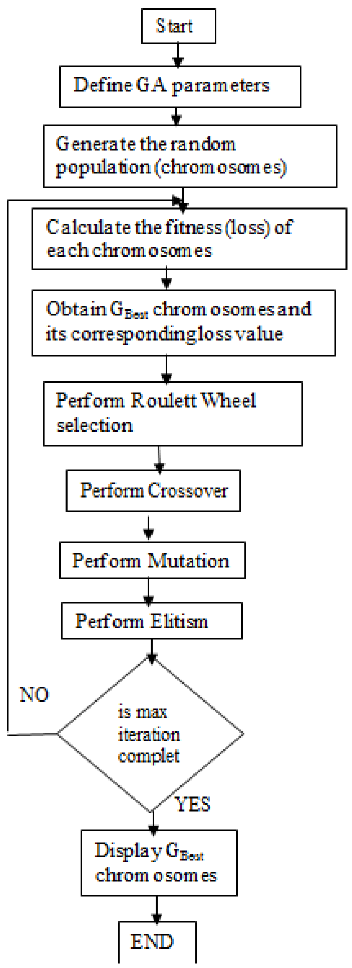

Fig 4 Flowchart of GA

The population is randomly created at the beginning of each search step. The fitness assessment is used to select the best solutions (individuals) from the current generation to upgrade into the next generation. The GA operators are applied for the next generation for having new and better individuals. This process is continued until the best solution (FACTS optimal location) in the population is found .The flowchart of GA is shown in fig.4.

B. Particle Swarm Optimization

Particle Swarm Optimization (PSO) is a population based search algorithm and searches in parallel using a group of particles proposed by Kennedy and Eberhart in 1995.

PSO is initialized with a group of random particles and then searches for optima by updating generations. Each particles in PSO changes its position with time and moves to optimum position. Another characteristics in the PSO method is called swarm. A swarm includes a set of particles, neighbouring the particle and its history experience. Each particle in PSO makes its decision using its own experience and its neighbour's experiences for evolution. That is, particles approach to the optimum through its present velocity, previous experience, and the best experience of its neighbours(M.N. Suharto, M.P. AbdhulaH,2012).

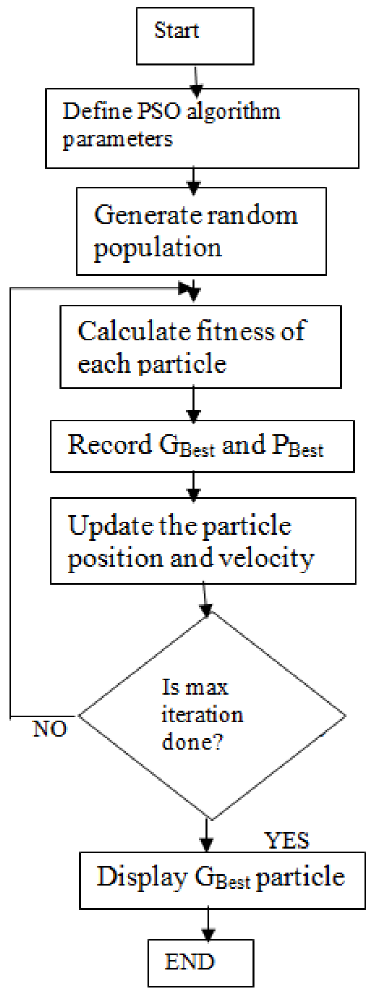

Fig 5 Flow chart of PSO

The main advantages of PSO compared to other optimization are as follows

- Coding implementation in PSO is easy.
- PSO has stable convergence characteristics.
- PSO has very fewer parameters to adjust.
- PSO is less sensitive to the nature of objective function.
- PSO is very efficient in performing a global search.
- PSO can obtain high quality solutions within shorter calculation time.

6. Case study and results

A. Considerations

In this paper studies are carried out on IEEE 30 bus system for optimal placement of three types of FACTS devices and several scenarios has been considered. This problem has been solved by the Genetic Algorithm(GA) and Particle Swarm Optimization(PSO). In this study below cases have been considered.

- Single type FACTS allocation
- Double type FACTS allocation.

B. Network Data

The 30 bus IEEE power system has been selected for this study that is shown in Fig 6.

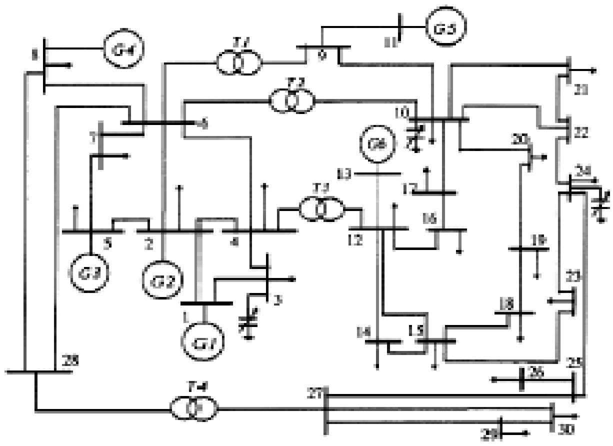

Fig 6 IEEE 30 bus system

Case 1: One- type FACTS allocation using GA and PSO

In this case, allocation of one-type FACTS devices has ben performed using GA and PSO. Three different kinds of FACTS devices (SVC, TCSC, UPFC) have been used to be placed in optimal location solely to reduce real and reactive power losses. Results for one-type FACTS allocation using GA and PSO have been compared and presented in tables 1-3

Table 1 Optimal location and related parameters for SVC

Algorithm	SVC		
	Location (Bus no)	Susceptance (B)	Losses in p.u
GA	1	0.05	0.197
PSO	1	0.0006	0.197

Table 2 Optimal location and related parameters for TCSC

Algorithm	TCSC		
	Location (Bus no)	Reactance(X)	Losses in p.u
GA	32	-0.0727	0.206
PSO	24	-0.0106	0.206

Table 3 Optimal location and related parameters for UPFC

Algorithm	UPFC			
	Location (Bus no)	Voltage (V)	Reactance (X)	Losses in p.u
GA	26	0.0664	0.9754	0.0482
PSO	26	0.1492	0.9608	0.0428

Case 2: Two- type FACTS allocation using GA and PSO

In this case, allocation of two-type FACTS devices has been performed using GA and PSO. Two FACTS devices among SVC, TCSC, UPFC have been selected and are located in optimal location to reduce losses. Results for two-type FACTS allocation using GA and PSO have been compared and presented in tables 4-6.

Table 4 Optimal location and related parameters for 2 SVC

SVC using GA		SVC using PSO	
Location (Bus no)	Losses in p.u	Location (Bus no)	Losses in p.u
1	0.186	25	0.168

Table 5 Optimal location and related parameters for 2 TCSC

TCSC using GA		TCSC using PSO	
Location (Bus no)	Losses in p.u	Location (Bus no)	Losses in p.u
24	0.1694	10	0.1633

Table 6 Optimal location and related parameters for 2 UPFC

UPFC using GA		UPFC using PSO	
Location (Bus no)	Losses in p.u	Location (Bus no)	Losses in p.u
2	0.0386	7	0.0365

Conclusion

In this paper, a method for placement of FACTS devices based on Genetic Algorithm(GA) and Particle Swarm Optimization(PSO) has been presented. Three types of FACTS devices (SVC, TCSC, UPFC) have been modelled. The criteria for optimization were considered as the minimization of losses. For investigation of the purposes, different scenarios have been considered. The results of execution of these scenarios on a typical 30-bus test system were clarified robustness of this method in optimal and fast placement of FACTS devices. From these 2 scenarios it has been concluded that more loss reduction occurs for two-type FACTS devices than one-type FACTS devices.

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