

# OPTIMAL PLACEMENT AND PARAMETER SETTING OF FACTS DEVICE USING PARTICLE SWARM TECHNIQUE FOR POWER SYSTEM STABILITY PROBLEMS

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**Abstract:** The efficient contribution of an optimization technique for the parameter estimation and suitable location of FACTS Controller for voltage stability enhancement and active power loss reduction in power system network has been presented in this paper. Unified Power Flow Controller (UPFC) is the most promising FACTS devices for power flow control. The Particle Swarm Optimization (PSO) technique is effectively used in this research for identifying the optimal placement and control parameter of FACTS device. Finally the voltage profile enhancement and real power loss reduction has resulted with the help of suitable placement and control parameter of UPFC.

**Key words:** real power loss, voltage stability, control parameter, FACTS, PSO

## 1. Introduction

The placement of FACTS devices is very significant in the system. The optimal placement of FACTS devices is identified with help of different types of optimization techniques [1]. UPFC is controlling the real power and reactive power autonomously or concurrently a versatile FACTS's device which can control the active power, the reactive power. Also the UPFC controls the system voltage for avoiding the voltage fluctuations and improve the stability in the system. It is important that to determine the optimal parameter setting of these devices in the system. The researchers developed and incorporated new algorithms for determining the suitable location of UPFC [2-5]. The Power flow control and bus voltage regulations on the power system network have been effectively achieved by FACTS devices. The power transfer capability improvement, reducing the system loss and stability enhancement in the system can be achieved with the influence of FACTS devices. The Performance of these FACTS devices is highly depending on placement and parameter setting. In general, for power flow control in the network, the UPFC and STATCOMS are preferable according to their operations. Shunt connected FACTS are playing an important role in reactive power flow control in the power system network to avoid the voltage fluctuation and stability improvement. Hence the reactive power compensation is a major issue in power system network [6]. Several

blackouts in the power network due to the voltage collapse problems. The maximum loadability point is generally identified as voltage collapse point. If the load increase the beyond the maximum loadability in the power system network, the system experiencing the voltage collapse. The FACTS device or reactive compensators are helpful to control the power flow and steady state limit in the power system [7-8]. Hence the contribution of these devices is very important in power system for avoiding the voltage collapse. The PSO technique has performed well for the power system stability problem in this paper. The simulations are run on the IEEE 14 bus system to validate the proposed technique. The results shows that the optimal placement and parameter setting of FACTS device.

## 2. Particle Swarm Optimization

PSO technique is a search technique based on the growing association of a group of birds searching food. The number of particles constitutes a Swarm. The global optimum search is looking by each particle. Multidimensional search space is used by particles for flying in this optimization technique. During this search, each particle try to adjust their position according to their own experience. The best position caught by the particles with their own experience and its neighbor's experience. The particles history experience will decide the swarm direction of the particles.  $P_{best}$  is recorded by the previous best particle position and  $G_{best}$  is noted by best particle among all the particles in the group. The following steps are involved in this technique.

Step 1: Input system parameters and variables setting including with limits and constraint

Step 2: Initialization of random particles of the population

Step 3: Initial searching points and velocities generation within the limit.

Step 4: Each initial searching point  $P_{best}$  is to be set. The best values from the  $P_{best}$  are set to  $G_{best}$ .

Step 5: Calculate the new velocities ( $V_i^{k+1}$ )

$$V_i^{k+1} = wV_i^k + c_1 \text{rand}_1 \times (P_{best} - X_i^k) + c_2 \text{rand}_2 \times (G_{best} - X_i^k)$$

Step 6: Update the value of  $P_{best}$  and  $G_{best}$  of each particle

Step 7:  $P_{best}$  value of each particle updated in iteration  $k+1$

$$X_i^{k+1} = X_i^k + V_i^{k+1}$$

Step 8: Stop the iteration in the constraints are satisfied, if not satisfied, again start from Step 5.

### 3. UPFC Modeling

The FACTS devices are positioned to develop the loadability of the system with satisfying the voltage and thermal limit. The main objective of optimization is to achieve the better utilization of the accessible power network. The power system should be in a protected state in terms of improving loadability, reducing the power loss and maintain the system voltage. The objective function is developed as increase the maximum loadability and minimizing the voltage variations. The effect of FACTS device should be helpful for increasing as much as possible the power transmitted to the consumers by the power system network. The basic model of UPFC is shown in Fig. 1. The UPFC model consists of two voltage-source converters). The UPFC is modeled by the simultaneous presence of series and shunt FACTS devices in the one transmission line. A UPFC is the combinations of TCSC and SVC, A TCSC in series in the line and SVC at a bus. With the help decreasing or increasing the reactance of the branch, the operating mode of TCSC changed as inductive or capacitive. The value of reactance is the function of reactance of the line where the TCSC is placed [9]. The impedance of the transmission line

$Z_{ij} = Z_L + j X_{TCSC}$  and  $X_{TCSC} = r_{TCSC} X_L$   
where  $Z_L$  = Transmission line Impedance

$X_{TCSC}$  = reactance of the line where TCSC is located  
 $r_{TCSC}$  = compensation degree of TCSC

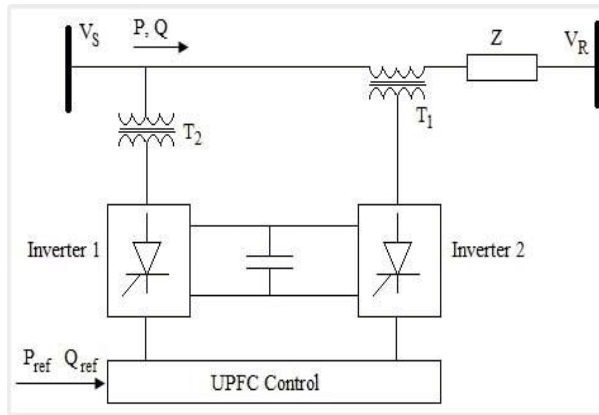


Fig. 1 Basic structure of UPFC controller

The FACTS device SVC is operated as both inductive

and capacitive mode and control bus voltage by absorbing or injecting reactive power. A shunt variable susceptance added at both ends of the line for model the SVC.

The injected reactive power at bus  $i$  is  $\Delta Q_{is} = Q_{svc}$

$Q_{svc}$  = reactive power injected by SVC in MVAR and  
 $Q_{svc} = Q_{min} \sim Q_{max}$

### 4. Problem Formulation

Locations of FACTS devices in the power system are obtained by the PSO technique performance. The placement of the UPFC in the power system network to be determined and the control parameters of UPFC is to be optimized. The UPFC devices are placed in the weakest bus in the system.

*Objective Function:*

- Minimize The  $P_{Loss}$  ( $F(x, u)$ )

This function is depends on depended variable vector ( $x$ ) and control variable vector ( $u$ )

*Constraints:*

- Power flow - equality constraints
- Bus voltage, transformer MVA limit, line MVA limit) (inequality constraints)
- The series voltage source  $V_s$  is controllable in magnitude and phase.  $V_s$  is the function of control parameters  $r$  and  $\gamma$ .  $r$  values are between 0 and  $r_{max}$ ,  $\gamma$  value is 0 to  $2\pi$ . UPFC can control the power flow and reduce the real power loss in the system by selecting the control parameters  $r$  and  $\gamma$  in a proper manner.
- The constrain limit of the UPFC is [8],  $X_{TCSC} = -0.8X_L$  to  $0.2X_L$  and  $Q_{svc} = -200$  MVAR to 200 MVAR

### 5. Results and Discussion

The placement of UPFC and its control parameters are optimized with help of PSO technique. The performance of the PSO algorithm is verified with IEEE 14 bus test power system. The single line diagram of the IEEE 14 bus is shown in Fig. 2. In this analysis, different loading conditions are considered and the algorithm is implemented in MATLAB for finding the optimal location and settings of UPFC to achieve minimum real power loss. Optimal parameter settings and total real and reactive power loss for IEEE 14 bus test system with PSO is represented in Table 1. The weak buses also identified based on maximum loadability. The maximum loadability of all the load buses of the IEEE 14 bus system is shown in table 1 for

different three cases.

*Case 1:* Only changes in Q; *Case 2:* Only changes in P; *Case 3:* Both Q and P changes

The maximum loadability has been identified on all the load buses and identified the weakest bus. From this analysis, the buses 4 and 13 are determined as healthy buses. The bus 14 is identified as weakest bus in the case 1 and 2. The bus 12 is identified as weakest bus in the case 3.

Table.1 Maximum loadability estimation for IEEE 14 bus system

Bus No.	Case 1	Case 2	Case 3	
	$Q_{\max}$ (MVA R)	$P_{\max}$ (MW)	$Q_{\max}$ (MVAR)	$P_{\max}$ (MW)
4	385.0	541.0	106.0	484.0
<b>12</b>	99.84	180.0	<b>40.50</b>	<b>148.0</b>
13	181.0	269.0	169.0	220.0
<b>14</b>	<b>85.90</b>	<b>145.0</b>	443.0	113.0
Critical Line	13-14	13-14	6-12	
Critical Voltage (p.u)	0.7400	0.6310	0.7100	

The different five loading conditions are considered and identified the location of UPFC and corresponding control parameters using PSO. The loading conditions are

1: Base load; 2: 150 % load; 3: 200 % load ; 4:  $Q_{\max}$  at Bus 14; 5:  $P_{\max}$  at Bus 14; 6:  $Q_{\max}$  and  $P_{\max}$  at Bus 12

The location of UPFC is determined as line 5-6 at the base case loading and the loading is 200% of base load. The line 3-4 is identified as the optimal location during the loading condition is 150% of base load. The real power loss also reduced by the effect of UPFC with optimum control parameters.

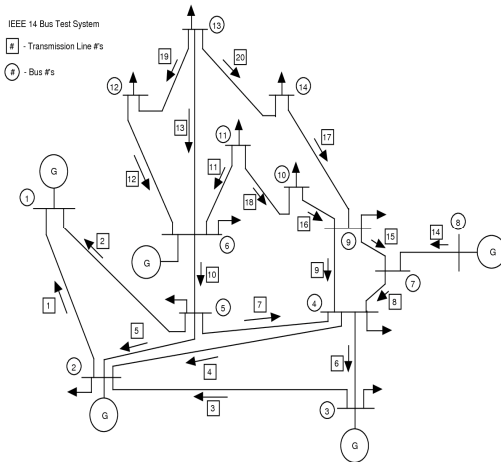


Fig. 2 Single line diagram of IEEE 14 bus system

Then in the special cases, the load increase only in weak bus identified at different three loading cases and the location of UPFC has determined. The real power loss is effectively reduced by the suitable location of UPFC, which shown in table 2. The optimized control parameters are noted in table 3. The voltage profile improvement with UPFC on IEEE 14 bus system with 150% base load condition is shown in Fig. 3.

Table.2 Results of PSO

Loading Conditions	WITHOUT UPFC	WITH UPFC	
	$P_{\text{Loss}}$ (MW)	$P_{\text{Loss}}$ (MW)	Location
1	17.220	16.902	5-6
2	64.990	63.987	3-4
3	87.550	86.991	5-6
4	30.199	30.056	13-14
5	35.400	35.200	13-14
6	28.109	27.975	12-13

Table.3 Optimized Control Parameters of UPFC

Loading Condition		1	2	3	4	5	6
Control parameters	$r$	0.058	0.042	0.037	0.041	0.058	0.032
	$\gamma$ (°)	161	211	248	228	209	159

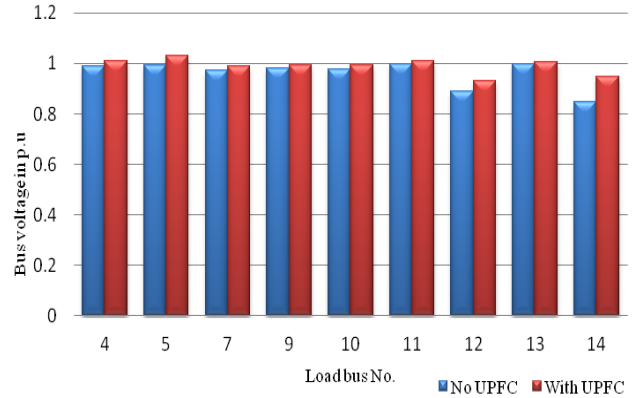


Fig. 3 Voltage Profile of IEEE 14 bus system

## 6. Conclusion

The determination of optimal location and optimized parameters for the UPFC device to minimize total real power loss using PSO techniques has been attempted in this paper. The solution of placement and control parameter estimation of UPFC has been performed by effective implementation of PSO algorithm. The results show that the real power loss is minimized and voltage profile has improved as better level. With this technique, it is possible to locate the UPFC in the transmission line to proper planning and operation of the power system with minimum transmission losses.

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