

The Optimal Location of Interline Power Flow Controller in the Transmission Lines for Reduction Losses using the Particle Swarm Optimization Algorithm

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ABSTRACT:

Interline power flow controller (IPFC) is a concept of AC flexible control of the transmission system (FACTS), with the ability to series compensation and power flow management in multi lines of a post power. Out of all FACTS devices, interline power flow converter (IPFC) is considered to be most flexible, powerful and versatile. IPFC has the capability of compensating multi-transmission line. The proper placement of interline power flow controller (IPFC) can improve the transmission line congestion problem to a great extent. This paper proposes the optimal location of the IPFC in electrical power systems, using the particle swarm optimization algorithm. Expression of sample figure and analysis of the sample system show that IPFC is effective to minimize the power losses in the power system.

Keywords: Interline Power Flow Controller (IPFC), Particle Swarm Optimization (PSO), Transmission Lines, Power System.

1. INTRODUCTION

Nowadays, due to the increased power and other factors, emission power from transmission lines is beyond the limits of heat capacity lines that it causes load density in the power grid. The FACTS Equipment is preferred in modern power systems based on their overall performance. Among them, combined compensation as IPFC and UPFC are effective tools. The main purpose of using IPFC is active and reactive power flow optimization across multiple lines, this feature causes an active and reactive power balance in a line. Moreover, it compensates the reactive power corresponding to the line and increases the effect of compensation system for disturbance transient and dynamic.

In [1] using PSO technique, the optimal location of FACTS devices such as SVC, TCSC and UPFC is done. The mathematical model for improved economic dispatch is represented in [2]. Cai [3] proposed the optimal choice of FACTS devices using Genetic Algorithm. The effects of FACTS controllers such as STATCOM, TCSC, SSSC and UPFC are studied in [4] which concluded that applying saddle node bifurcation theory has effects on maximum loading point. An optimal location and the parameter settings for UPFC which improved the load ability of the power system are presented in [5]. While in [6] optimal location for SVC and TCSC are proposed. Zuwei [7] studied the

optimal placement of FACTS devices with due consideration to line loss. The optimal power flow that used ABC algorithm [8] was improved in [9]. The solutions of OPF incorporating IPFC in the network are proposed in [10] and [11]. Basu [12] obtained a solution for optimal power flow problem incorporating TCSC, TCPS. Rami Reddy [13] proposed technique for solving the optimization problems using techniques inspired by natural evolution. Optimal location based on trial and error method was proposed by S. Jangjit and P. Kumkratug that is very time consuming for a large power system. Differential evaluation algorithm was proposed by Stron and Price [14, 15]. In this paper, purpose is optimization by using the Particle Swarm optimization algorithm, means that we follow the overall active power loss reduction. The simulation obtained from MATLAB software shows that total active power losses in power systems was reduced by using the IPFC.

2. MATHEMATICAL MODEL

The IPFC contains multiple series voltage source converters that are coupled by a DC link. The power flowed by the line can be controlled by series voltage injections. In this model the converters can generate or absorb the reactive power. While the total active power exchanged between series converters, without loss, is zero.

To obtain the IPFC injection model, electrical series voltage source model is necessary. Figure 1b illustrates the IPFC injection model that as V_i , V_j and V_k are defined as Complex voltages at buses $x = i, j, k$. Vse_{in} is controllable series injected voltage source that is defined as $Vse_{in} = Vse_{in} < \theta se_{in} (n = j, k)$. Series impedance transformer coupled is $Zse_{in} (n = j, k)$. Active and reactive power injection at each bus can be calculated by IPFC as a current source [16]. Finally, following IPFC injection model equations is used in PSO algorithm.

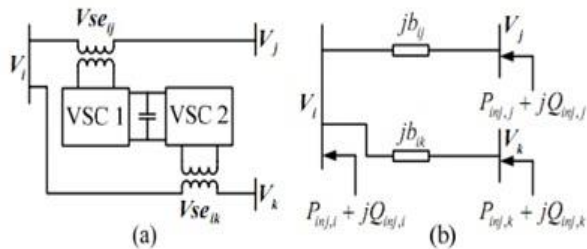


Fig. 1. (a) The model of IPFC converters (b) The model of injected power.

$$P_{inj,i} = \sum_{n=j,k} V_i Vse_{in} b_{in} \sin(\theta_i - \theta se_{in}) \quad (1)$$

$$Q_{inj,i} = -\sum_{n=j,k} V_i Vse_{in} b_{in} \cos(\theta_i - \theta se_{in}) \quad (2)$$

$$P_{inj,n} = -V_n Vse_{in} b_{in} \sin(\theta_n - \theta se_{in}) \quad (3)$$

$$Q_{inj,n} = V_n Vse_{in} b_{in} \cos(\theta_n - \theta se_{in}) \quad (4)$$

$$\text{Re}(Vse_{ij} \bar{I}_{ji} + Vse_{ik} \bar{I}_{ki}) = 0 \quad (5)$$

$$\sum_{m=i,j,k} P_{inj,m} = 0 \quad (6)$$

3. PSO ALGORIHM

PSO starts working with a group of random answers. Every particle as multidimensional are defined with V_{id} and X_{id} . At each stage of population movement, each particle is updated according to the two best values.

The first value is the best solution in terms of competency that has been obtained for each particle separately. This value is the best individual and it is called p_{best} . The other best value obtained by PSO is a best value ever achieved by all particles in the population and it is called g_{best} . After finding p_{best} and g_{best} , each particle velocity is updated and its new location is obtained by the following equation.

$$X_i(t+1) = X_i(t) + V_i(t+1) \quad (7)$$

$$V_{ij}(t+1) = w(V_{ij}(t) + c_1 r_{1,j}(t) [p_{besti,j} - X_{i,j}(t)] + c_2 r_{2,j}(t) [g_{besti}(t) - X_{i,j}(t)]) \quad (8)$$

Where, w is inertia weight, c_2 and c_1 are acceleration coefficients, r_2 and r_1 are random numbers in the range (0, 1). To avoid the divergence of the algorithm, the final value velocity of every particle is limited in the range of $[-V_{MAX}, V_{MAX}]$. c_2, c_1, w are parameters of PSO that the convergence of the algorithm is dependent to value of them. Usually, c_2 and c_1 are between 1.5 to 2 but the best choice is $c_1 = c_2 = 2.05$ and $0 \leq w < 1$. Convergence depends strongly on the value of w and it is better to be defined as dynamically. In the range of 0.2-0.9, linear is reduced during the evolution of a population. For better possibility of finding good solutions at first stage, w should be large and at the final stages, small w , makes a better convergence. PSO updates its population by using Equations 7 and 8 and it is called basic or standard PSO that its flow chart is shown in figure 2. So, $pf_{fitness}$ and $pf_{fitness_{best}}$ is the best fitness among the particles fitness [17].

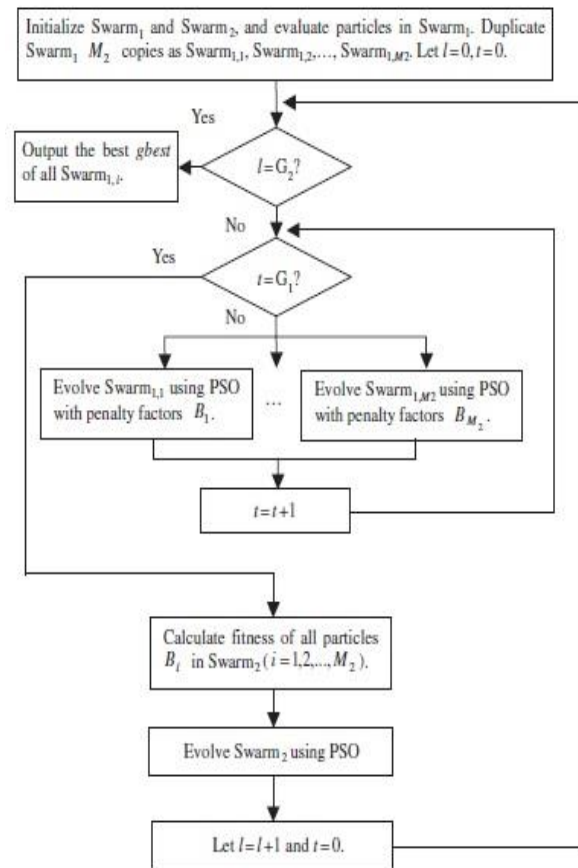


Fig. 2. Flow chart of PSO algorithm.

4. PROCESS PSO ALGORITHM WITH IPFC

In this section, best installation location, value and performance rate of IPFC in the buses of power network will be determined by following proposed method.

- 1) Determining the primary particles and enter the basic network parameters.
- 2) Placement IPFC in network according to the characteristics of each particle.
- 3) Determining the fitness function for each particle according to the network with IPFC.
- 4) Finding the values P_{best} and G_{best} .
- 5) If the fitness function is calculated for all the particles then goes to the next step, otherwise, it backs to the second step.
- 6) Creating a new population according to equations of particle swarm algorithm.
- 7) If number of iterations is maximized then goes to the next step. Otherwise, it backs to the second step and one adds to Counters of iteration.
- 8) At the end of performance for all iterations, value of G_{best} determines optimal point that here it is most optimal point for installation location of IPFC.

4.1. Objective Function to Reduce Network Losses

The objective function is a function to check the compatibility of the particles that are defined according to the proposed optimization. it is the most important part of PSO algorithm and basic of the optimization program. In this paper, objective function includes reducing transmission system losses. Therefore, it has to be weighted appropriately.

$$F = \alpha \cdot P_{loss} \quad (9)$$

Where,

P_{loss} : total active losses in power system.

α : Weight associated with the purpose that minimizes the total active losses in power system.

4.2. State Variables

X state vector can be presented by vector control variables as following [18].

$$X = [V, \theta, V_{se}, \theta_{se}, P_g, Q_g]^T \quad (10)$$

V, θ : complex voltages of buses.

V_{se}, θ_{se} : complex voltages of IPFC converters.

P_g, Q_g : active and reactive power sources.

5. TEST SYSTEM AND OPTIMAL LOCATION PROCESS

The optimal location of IPFC in power transmission system used IEEE 30-bus standard system and is shown in figure 3. This system includes 5 Generator and 41 transmission lines. To obtain optimal location by PSO algorithm for installing IPFC to find the most appropriate lines for maximum, first the losses of the transmission system using the parameters in the Data Base file are calculated without IPFC with Newton-Raphson method Then by particle swarm algorithm for

each of the lines that are connected to a common bus, IPFC injection model is applied.

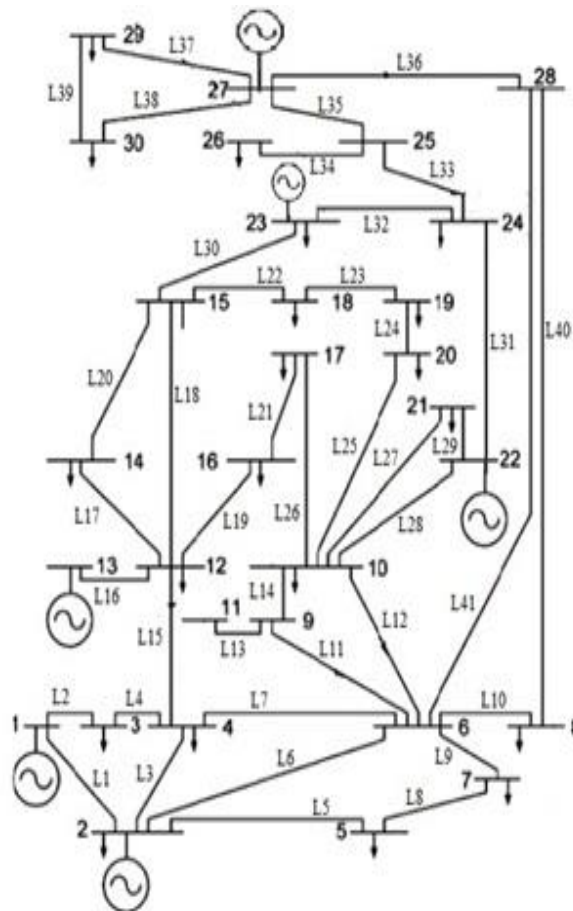


Fig. 3. Single-line diagram of the IEEE 30 buses standard system.

Again, for each state of installing IPFC on the lines, Newton- Raphson power flow was implemented and the total losses for all states were calculated. At each stage, according to the objective function, the lines that have lowest losses were saved. Finally, the appropriate lines for IPFC installation were reported in terms of losses reduction. Fitness of objective function recorded 150 iterations that convergence occurred after 5 iterations and it was reported 1.3744. Weight factor of the purpose function was obtained by trial and error method equal to 0.55. The simulation results are shown in Table 1. It can be seen that with IPFC installing in system in the optimal state, it decreased active losses transmission lines to 366 MW and Reactive losses to 1.41 MVAR.

Also the voltage profile for 30-bus power system with IPFC and without is plotted in figure 4. It is clear that IPFC installing between the lines 6 and 10 (bus 6) has caused improvement in voltage stability in some buses.

Table 1. Simulation results of simulation for IEEE 30-bus system by using PSO algorithm.

Active power losses without IPFC(MW)	Active power losses with IPFC(MW)	Reactive power losses without IPFC(MVAR)	Reactive power losses with IPFC(MVAR)	Active Losses reduction (MW)	Reactive Losses reduction (MVAR)	IPFC installation location
2.865	2.499	13.69	12.28	0.366	1.41	lines 6,10

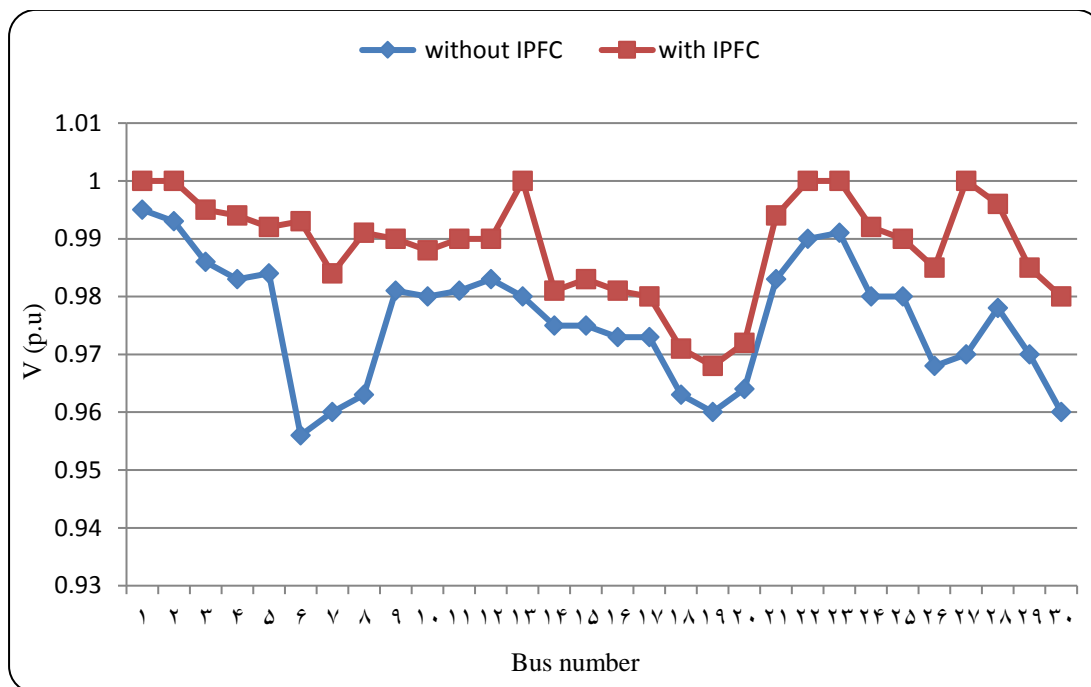


Fig. 4. Voltage profile of 30-bus power system with and without IPFC.

6. CONCLUSION

Nowadays, demand for power and good quality of power supply in the distribution networks have increased. On the other hand, the cost of energy production to provide increasing low demand for power is not economical. Therefore, use of the FACTS equipment will be effective and profitable in order to stability, reducing losses, increasing transmitted power and power quality in power systems.

Since the IPFC has an ability to compensate multi-transmission lines in a certain post, we studied effect of IPFC location in the power system and reducing losses of active and reactive power transmission lines. IPFC Injection model, Newton-Raphson power flow method and optimal location for installation were presented by PSO algorithm. The results of simulation show that use of the IPFC in power system reduces transmission losses and improves voltage stability.

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