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Bat Search Algorithm Based Hybrid PSO Approaches to Optimize the Location of UPFC in Power System

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Abstract: FACTS devices plays a significant role to control the power flow of power transmission system. In this paper, a hybrid PSO algorithm is proposed to optimize the location of UPFC in power system. The proposed hybrid PSO algorithm has solved the formulated multiobjective optimization problem. This paper, five objective function to be considered in the form of minimization such as the fast voltage stability index (FVSI), fuel cost, power loss, voltage deviation and UPFC cost respectively. To improve the non satisfied solution of PSO algorithm, bat search optimization is used and the performance of PSO algorithm is enhanced. The proposed hybrid technique is implemented in MATLAB working platform which is tested with IEEE 14 bus bench mark system. Here, two load cases are considered to evaluate the proposed method and compared with traditional PSO algorithm. The comparative analysis are conformed the effectiveness hybrid PSO algorithm for solving multiobjective optimal power flow problem.

Keywords: Line flow control, multiobjective algorithm, hybrid PSO, bat search method.

1. Introduction

Current electric power system network experiences astonishing fast changes in terms of demand generation arrays and trading actions that hold back the system operation and security [1]. For the operation of power system, control of active and reactive power flow is very significant [2]. The variables and parameter of the transmission line, which comprise line reactance, voltage magnitude, and phase angle are capable to be controlled by means of FACTS controllers in a rapid and successful way [3-5]. The advantages obtained from FACTS consist of improvement of the stability of power system networks, such as voltage stability, line stability, small signal stability, transient stability, and hence improve system dependability [6] [7]. The Unified Power Flow Controller (UPFC) is one of the most luminous of FACTS controllers which is capable of offering active and reactive power control separately [8-10]. UPFC offers improved voltage control as compared to Static Var Compensator (SVC) and Static Synchronous compensator (STATCOM) [11].

UPFC have gone up amongst researchers in power systems as it presents important multifunctional flexibility necessary to work out different problems in power system and can control voltage magnitude, phase angle and impedance at the same time [12] [13]. The UPFC, the most adaptable of these tools, joins shunt current injection with series voltage injection to make it competent of simultaneously controlling active and reactive power flows in a transmission line, and offer series and shunt compensation as required [14]. As different UPFC placements can cause important variations in the transient behaviour of the system, placements must be selected with care [15]. On the other hand, with the suitable parameter setting, it is extremely significant to find out the optimal location of this tool in the power system to attain such functionality of UPFC [16].

An optimal UPFC placement must integrate not only each feasible system topology (line

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outages, load profiles, etc.) however must also regard as the complete range of possible control settings which may themselves be reliant on system topology [17]. The active power loss reduction, the stability margin improvement, the power transmission capacity increasing, and the power blackout prevention, are some features that can be regarded in selection integrate with UPFC regarding one or all of the above revealed factors [18]. The top location of UPFC to reduced the generation cost function, the investment cost on the UPFC tool, the power loss, and the voltage deviation; in addition, the voltage stability margin better [19] [20].

2. Recent Research Works: A Brief Review

Various associated works are previously presented in literature which is based on optimal placement of Unified Power Flow Controller (UPFC). A few of them reassessed here. A novel strategy based on computational intelligence (CI) methods has been offered by H.I. Shaheen *et al.* [21] to discover the optimal placement and parameter setting of UPFC for improving power system security under single line contingencies (N-1 contingency). Initially, a contingency study and ranking process to find out the most severe line outage contingencies, regarding lines overload and bus voltage limit violations as a performance index, was executed. Secondly, a comparatively novel evolutionary optimization method, namely: differential evolution (DE) method was used to discover the optimal location and parameter setting of UPFC under the decided contingency scenarios.

To work out optimal power flow problem in the presence of multiple UPFC devices, the Gravitational Search Algorithm (GSA) has been suggested by Jayanti Sarker *et al.* [22]. The presentation of GSA was compared for precision and convergence features with heuristic search methods like Biogeography-Based Optimization (BBO), Stud Genetic Algorithm (Stud GA), Genetic Algorithm (GA), Ant Colony Optimization (ACO), Probability-Based Incremental Learning (PBIL), on the diverse cases of standard test systems and actual life power system.

Seyed Abbas Taher *et al.* [23] have offered the application of hybrid immune algorithm (HIA) such as immune genetic algorithm (IGA) and immune particle swarm algorithm (IPSO) to locate optimal location of UPFC to attain optimal power flow (OPF). The overall cost function, the objective function in the OPF, comprises the total active and reactive production cost function of the generators and installation cost of UPFCs and thus, should be reduced. The OPF limitations were generators, transmission lines and UPFCs limits. In power system, it may not all the time be feasible to send out the contracted power transactions entirely due to congestion of the related transmission corridors.

A novel approach based on Differential Evolution (DE) method has been offered by Husam I. Shaheen *et al.* [24] to find out the optimal placement and parameter setting of Unified Power Flow Controller (UPFC) for improving power system security under single line contingencies. Initially, they executed a contingency study and ranking process to find out the most severe line outage contingencies regarding line overloads and bus voltage limit violations as a Performance Index. Secondly, they employed DE method to discover the optimal location and parameter setting of UPFC under the decided contingency scenarios.

R.K. Pandey *et al.* [25] have offered UPFC control parameter identification for successful power oscillation damping (POD). A relative study with minimum singular value (MSV), Hankel singular value (HSV), direct component of torque (DCT) and residue has been suggested for finding the most suitable control input parameters of unified power flow controller (UPFC) for damping power system oscillations. The fundamental purpose was to recognize the control parameters of UPFC so as to offer enough damping in power network with changing system conditions.

J. Belwin Edward *et al*. [26] have suggested an improved bacterial foraging algorithm to find out the appropriate kind of FACTS tools, its optimal size and location. The conventional optimal power flow problem was reframed to integrate FACTS tools. To assess the system performance, the generation cost of power plants and the investment cost of FACTS tools were furthermore comprised in the objective function. The lately framed objective function was worked out by means of three evolutionary algorithms namely Genetic Algorithm (GA), Bacterial Foraging Algorithm (BFA) and suggested Enhanced Bacterial Foraging Algorithm (EBFA). The algorithms were experimented for IEEE 30 bus system under dissimilar loading conditions. The effectiveness of the algorithm was assessed based on computation time, convergence features and precision of the solution. From the relative results, it was found that the suggested algorithm is vigorous and appropriate for sizing and location of FACTS tools. The suggested algorithm could be broadened for higher bus system.

Ghahremani, E *et al*. [27] have offered a graphical user interface (GUI) based on a genetic algorithm (GA) which was demonstrated able to find the optimal locations and sizing parameters of multi-type FACTS tools in large power systems. This user-friendly device, called the FACTS Placement Toolbox, permits the user to select a power system network, find out the GA settings and choose the number and kinds of FACTS tools to be assigned in the network. The GA-based optimization process was applied to attain optimal locations and ratings of the chosen FACTS to maximize the system static load ability. Five dissimilar FACTS tools were executed: SVC, TCSC, TCVR, TCPST and UPFC.

The above reassess illustrates that, one of the multi objective optimization problems which covenant by the exploitation of FACTS tools in power networks is competent of managing opposing intentions in different operational modes. Therefore, to optimize the distribution of these tools, different optimization algorithms are applied in power systems. These methods are classified into the following classes such as analytical, numerical programming, heuristic, and artificial intelligence based methods. Mainly, the heuristic based methods have been commonly applying for working out the optimal placement examination problem.

Different techniques and approaches to finding out the optimal location of FACTS in the power system have been statement, and different methods, such as the genetic algorithm (GA), simulated annealing (SA), artificial immune system (AIS), and particle swarm optimization (PSO), have been employed. The results of these algorithms are applied to find out the location, types, and sizes of tools, with their settings at dissimilar operating conditions. Alternatively, the precision of solution may change due to the reason of multimodality search of the objective function. As a result, the hybrid approach is explored to develop the optimization performance in multiobjective optimization problems. In this document, a hybrid approaches to optimize the location of UPFC in power system. Hybrid approach is the mixture of PSO and bat search optimization algorithm which employed to develop the multiobjective problem working out performance of PSO algorithm. The main function formulation is specified in section 3. In section 4, suggested hybrid PSO algorithm is made clear. Section 5, the effects and discussion are offered and section 6 finishes the document.

3. Formulation of Objective function

In this paper multi objective function is used to control the power flow of UPFC using hybrid approach. The objective function is formulated by minimization of the fast voltage stability index (FVSI), fuel cost, power loss, voltage deviation and UPFC cost respectively. The formulation of each objective function depends on the real and reactive powers of the system, voltage magnitude and angle, line conductance and installation cost of UPFC. The mathematical model of objective function are described as follow,

$$Minimize = \sum \left(F_1 + F_2 + F_3 + F_4 + F_5\right) \tag{1}$$

Where, F_1 is the fast voltage stability index, F_2 is the fuel cost, F_3 is the power loss, F_4 is the fast voltage deviation, and F_5 is the cost of FACTS device. These objective functions are expressed as mathematically by follow,

Fast voltage stability index $$(FVSI)_{ij} = \frac{4z_{ij}^2 Q_j}{V_i^2 X_{ij}} \tag{2}$$

$$\text{Fuel cost } F = \sum_{i=1}^{n} \left(a_i P_{G_i}^2 + b_i P_{G_i} + c_i \right) \$ / hr \tag{3}$$

$$\text{Power loss } P_{loss} = \sum_{i=1}^{N_L} G_{ij} \left(V_i^2 + V_j^2 - 2 V_i V_j \cos(\delta_i - \delta_j) \right) \tag{4}$$

$$\text{Voltage deviation } V_D = \sum_{i=1}^{n} \left| V_i - 1 \right|^2 \tag{5}$$

$$\text{Cost of UPFC } C_F = \left(0.0003 S^2 - 0.2691 S + 188.22 \right) \$ / KVar \tag{6}$$

In equations (2) to (6), where, z_{ij} is the impedance value of line i and j, Q_j is the reactive power of j^{th} line, V_i is the voltage magnitude of i^{th} bus, X_{ij} is the reactance value of line i and j. P_{G_i} is the real power of i^{th} generator, a_i, b_i and c_i are the fuel cost coefficient, N_L is the number of transmission line, δ_i and δ_j are voltage angles, S is the operating limits of UPFC in MVAR i.e. $S = Q_j - Q_i$, Q_j and Q_i are the MVAR flow of i^{th} and j^{th} buses. Then, the objective function depending equality and inequality constraints are expressed as follow,

The operational constraints are used to control the system variables such as active and reactive power flows and bus voltages respectively. The constraints are the power balance condition, apparent power flow, bus voltage limits, active and reactive power limits, phase angle, line flow limits, and the UPFC control parameters. These constrains are described as following them,

Power flow balance equations: It is used to balance the active and reactive power flow of each node. The power balance model is derived by the generators, load and transmission loss of the systems. The balance model is described as follow,

$$P_{G_i} = \sum_{\substack{i \neq j, \\ j=1}}^{N_b} V_i V_j \left(G_{ij} \cos \delta_{ij} + B_{ij} \sin \delta_{ij} \right) \tag{7}$$

$$Q_{G_i} = \sum_{\substack{i \neq j, \\ j=1}}^{N_b} V_i V_j \left(G_{ij} \sin \delta_{ij} - B_{ij} \cos \delta_{ij} \right) \tag{8}$$

Where, P_{G_i} and Q_{G_i} are the active and reactive power of i^{th} generator, P_{L_i} and Q_{L_i} are the active and reactive power of i^{th} load bus. G_{ij} and B_{ij} are the conductance and susceptance of line between i^{th} and j^{th} buses.

Apparent power flow limit: The apparent power flow through the line l is not exceeding the limits $S_{l\max}$. The limit is considered by the inequality function as follows:

$$S_l \leq S_{l\max} \tag{9}$$

Bus voltage magnitude and phase angle limits: The magnitude of bus voltage is varied in the bounded with the limits of $V_{i\min}$ and $V_{i\max}$. From the limits, the voltage stability of the system is to be defined. Similarly, the phase angle of voltage is to be defined. The inequality constraints are expressed as follows:

$$V_{i\min} \le V_i \le V_i \max \tag{10}$$

$$\delta_{i\min} \le \delta_i \le \delta_i \max \tag{11}$$

Active power of generators: The active power limits of the generator is varied from the $P_{G_i \min}$ and $P_{G_i \max}$ limits. The inequality constrain of the generator is given as follows:

$$P_{G_i \min} \le P_{G_i \min} \le P_{G_i \max} \tag{12}$$

Active power flow limits: The active power flow through the line l is not exceeding the active power flow limits $P_{l\max}$. The limit is considered by the inequality function as follow:

$$P_l^{\max} \le P_l \tag{13}$$

UPFC control parameter limits: The control parameters of UPFC used to control the sending and receiving end power flows. The inequality constraints of phase angle and voltage magnitude ϕ_{sl} are described as follows:

$$0 \le \phi_{sl} \le 2\pi \tag{14}$$

$$0.5 \ge V_{sl\max} \ge 0 \tag{15}$$

$$0 \le V_{sl} \le V_{sl\max} \tag{16}$$

These are the equality and inequality constraints used for optimal location of UPFC for optimal power flow. The UPFC is optimally located by hybrid PSO technique. The detailed description of hybrid PSO technique is explained as follows:

4. Hybrid PSO for Optimal Location of UPFC

In this paper, the introduced multi objective function is solved by hybrid PSO technique. Using this hybrid technique the optimal location of UPFC is determined. In PSO algorithm, PSO is one of the swarm intelligence algorithms which are used for solving the optimization problems [28]. The searching of PSO algorithm depends on populations and the population is referred as particles. The particles are defined in the search space which flies in the search spaces with different velocity. Each particle velocity are updated randomly which depends on its individual flying experience and other particles flying experience. According to the position of the particles, the best fitness solution is determined. The personal best solution is known as *pbest* and the global best solution is called as *gbest.*

When the velocity is distributed randomly, the solution is uncertainty. For that reason, the solution may deviate from the objective function and the best solution is affected. Hence, it is needed to confirm the new updated candidate solution. In this paper, a bat search algorithm is hybridized with PSO algorithm to conform the new particle i.e. solution. Therefore, the new update particle is selected by bat search algorithm. Here, the multiobjective problem is solved by the proposed hybrid approach. The detailed description of the proposed approach for optimal location of UPFC is described as follows:

Steps of Hybrid PSO Algorithm

Initialization

The first step of hybrid PSO algorithm is initialization. In this step, N numbers of particles are initialized. Here, the parameters of the multi objective function are considered as particles and each particles have their own initial velocity. Also, the solution searching dimension is specified. The search space for the optimized parameter y_i is represented as $[y_i^{\min}, y_i^{\max}]$. The velocity of the i^{th} dimension is represented as $[-v_i^{\max}, v_i^{\max}]$. In this paper, the optimized parameters of the objective functions are represented as F_1, F_2, F_3, F_4, and F_5 respectively.

Fitness Evaluation

Calculate the fitness function of the selected objective functions with the initial position, the velocity and weights. Set the best particle from the initially evaluated solution. Then, the solution is updated by the time t, weight $w(t)$, velocity $v_i(t)$, position x_i, *pbest*, and *gbest*.

Time and Inertia Weight Updating

Update the time t as $t+1$ and the inertia weight $w(t-1)$ as $w(t)$.

Velocity Updating

In this stage, the velocities of the particles are updated as per the values of *pbest*, and *gbest*. The n^{th} particle velocity is updated in the i^{th} dimension, which is given as follows:

$$v_{i,n}(t) = w(t)\, v_{i,n}(t-1) + c_1 rand_1\left(x^{*}_{i,n}(t-1) - x_{i,n}(t-1)\right) + c_2 rand_2\left(x^{**}_{i,n}(t-1) - x_{i,n}(t-1)\right) \tag{17}$$

Where, c_1 and c_2 are the positive constants and $rand_1$ and $rand_2$ are random numbers which is uniformly distributed between (0, 1). $x^{*}_{i,n}(t-1)$ the personal best position and $x^{**}_{i,n}(t-1)$ is the global best position n^{th} dimension. Suppose, the particle violates the velocity limits, then, set its velocity equal to the limit.

Position Updating

Depending on the updated velocities of each particle changes its position according to the following expression,

$$x_j(t) = x_j(t-1) + v_j(t) \tag{18}$$

If a particle violates its position limits in any dimension, then set its position at the proper limit.

Personal and Global Best Updating

Each particle position is updated according to the position. If the $x^{*}_{i,n}(t-1)$ is best when compared to $x^{*}_{i,n}(t)$, then select $x^{*}_{i,n}(t)$ as the personal best position of the particle. In the same way, if the $x^{**}_{i,n}(t-1)$ is best when compared to $x^{**}_{i,n}(t)$, and then select $x^{**}_{i,n}(t)$ as the global best position of the particle. Then, check the solution. If the solution minimize the objective functions F_1, F_2, F_3, F_4, and F_5, then select the best solution. Otherwise generate the new solution by bat search.

Stopping Criteria

At the end, check the solution. If the solution minimize the objective functions F_1, F_2, F_3, F_4, and F_5, then select the best solution. Otherwise, generate the new solution by bat search algorithm and continue the procedure from step (2).

Bat Inspired Search Algorithm

The bat search algorithm is derived from the echolocation characteristics of microbats [29]. It is followed on idealized rules to improve the solution. In the paper, bat algorithm is used to generate the best solution from the non satisfied solution of PSO algorithm. Therefore, the performance of PSO algorithm is improved. Bats fly randomly with the velocity $v_i(t)$, position $x_i(t)$, fixed frequency $f_{\min}$, wave length λ, and loudness A_0. They adjust the wavelength automatically by the emitted pulse and varying the pulse rate between 0 and 1 which depends on the proximity effect. The loudness can vary in positive values A_0 to minimum constant value $A_{\min}$. The solution of bat search algorithm mainly depends on the moment of virtual bats and the loudness and pulse emission.

Initialization

Initialize the bat population x_i which is obtained from the non satisfied solution of PSO algorithm. Set the searching dimension n and fix the frequency $[f_{\min}, f_{\max}]$ and the wave length $[\lambda_{\min}, \lambda_{\max}]$. The minimum frequency is selected as zero.

Moment of Virtual Bat

The initial position of n^{th} dimension solution is selected as $x_{i,n}(t)$. The frequency f_i, velocity $v_i(t)$ and the position $x_i(t)$ of new i^{th} solution is updated as following expression,

$$f_i = f_{\min} + rand(0,1)\left(f_{\max} - f_{\min}\right) \tag{19}$$

$$v_i(t) = v_i(t-1) + f_i\left(x_i(t) - x_*(t)\right) \tag{20}$$

$$x_i(t) = x_i(t-1) + v_i(t) \tag{21}$$

where, $rand(0,1)$ is the uniformly distributed random number between 0 and 1.During local search, once a solution is obtained from the midst of the present best solutions, then generate local solution for every bat by means of random walk which is described as follow,

$$x_{i,new}(t) = x_{i,old}(t-1) + rand(-1,1)A_i(t) \tag{22}$$

Where, $x_{i,old}(t-1)$ is the old position. $rand(-1,1)$ is the random number uniformly generated between -1 and 1. $A_i(t)$ is the average number loudness of all bats at step time t.

Loudness and pulse emission

In addition, the loudness $A_i(t)$ and the rate $r_i(t)$ of pulse emission have to be rationalized consequently at every iteration progressed. Generally, the loudness reduces once a bat has originated its victim, at the same time the rate of pulse emission is amplified; the loudness can be selected as some value of expediency. The expression of loudness and pulse emission are given as follows:

$$A_i(t+1) = \alpha A_i(t) \tag{23}$$

$$r_i(t+1) = r_i(t)\left[1 - \exp(-\gamma t)\right] \tag{24}$$

where, α and γ are the constants. For simplicity, the same value of α and γ can be selected.

At the end of each update, the fitness values are evaluated. If the fitness values are satisfied, select the best value, otherwise iterate the solution with new set of non satisfied solution of PSO algorithm. The flow chart of hybrid PSO is illustrated as follows:

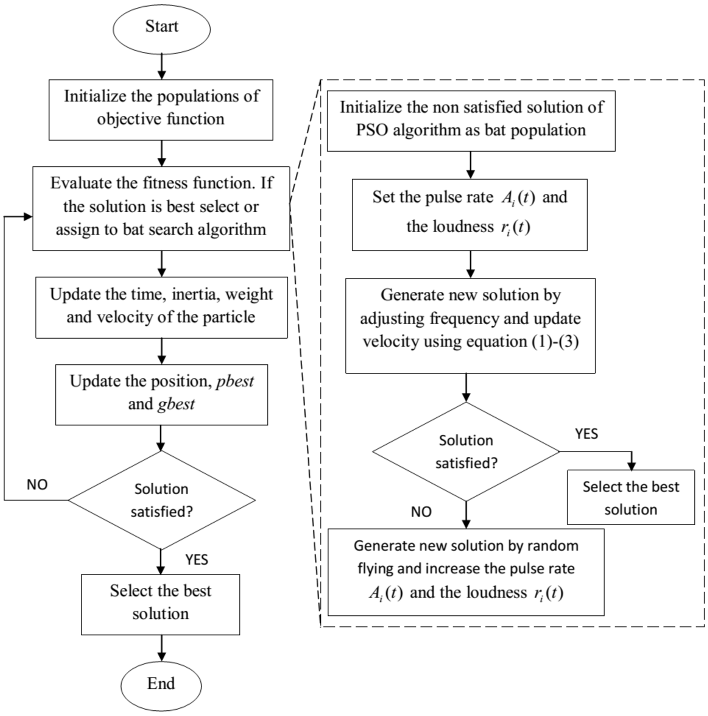


Figure 1. Flow chart of proposed hybrid PSO algorithm.

5. Results and Discussion

The proposed hybrid PSO algorithm was implemented in MATLAB working platform and the performance evaluated. The proposed algorithm tested by IEEE 14 bus bench mark transmission system by locating UPFC. The line data and the bus data are used from the reference [30]. The single line diagram of IEEE 14 is illustrated in figure 2. The performance of proposed method is examined by two cases. Then, the power loss, fuel cost, UPFC cost, and voltage stability are analyzed. The result of proposed hybrid PSO method is compared with traditional PSO algorithm. The testing system consists of two generators buses 1, 2 and three synchronous condensers 3, 6, and 8 respectively. In the generators, the minimum power generation limit is 20 MW and the maximum power generation limits is 270 MW. The active power of generation limits of generators and the fuel cost coefficients of IEEE 14 bus system is referred from [23] which are tabulated in Table I.

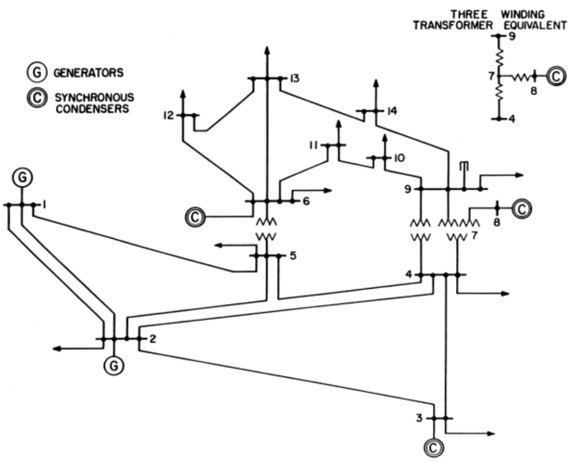


Figure 2. Single line diagram of IEEE 14 bus system.

Table 1. Fuel cost coefficients and generator data.

Buses		a_i	b_i	c_i	$P_{g,min}$ in MW	$P_{g,max}$ in MW
Generator	1	100	15	0.02	30	200
	2	100	10	0.01	20	270
Synchronous Condenser	3	100	30	0.05	20	200
	6	100	20	0.03	40	200
	8	100	30	0.05	20	250

Case I: New Loading In One Load Bus

In case I, different loading condition is applied in a particular load buses and the power flow is evaluated. Under this loading condition, three load buses are selected for testing as 13, 6 and 14 respectively. In the selected load buses, the load values are changed arbitrary from the actual load values. Consequently, the power flow of the system is varied; the voltage stability and power loss are affected. Using the proposed hybrid technique, the system parameters are maintained to stable level. Initially, the system parameters are assigned to the multi-objective function which is mentioned in equation (1). Then, the optimal location of UPFC is determined and the power flow of the system is evaluated.

For the considered case, the optimal location and capacity of UPFC, the system demand and the generator values are given in table II. In table II, the optimal location of UPFC is varied by PSO and hybrid PSO algorithm. Then, the UPFC cost and the fuel cost are compared in tabulation which are given in table III with load changing at buses 13, 6, and 14. The total cost ($/hr) of the system depends on the total generation. The optimal power generation is obtained by hybrid PSO algorithm. Therefore, the fuel cost of the system is reduced. The UPFC cost, the fuel cost and the total cost of the system is given in table III for case I. In addition, the case I power loss is presented in table IV and the performance of voltage stability and fuel cost are given in figure 3 when new loading is done in one bus.

The power loss comparison shows that, the proposed method gives as the minimum power loss 7.0311 MW. It is less when compared to the power loss obtained from PSO algorithm as 9.0966 MW. In figure 3, the voltage stability is compared with base case, after load change, PSO, and hybrid algorithm. The case I fuel cost iteration curve shows that the hybrid PSO algorithm converge to solution is better than PSO algorithm.

Table 2. Different loading condition for case I and the total generation.

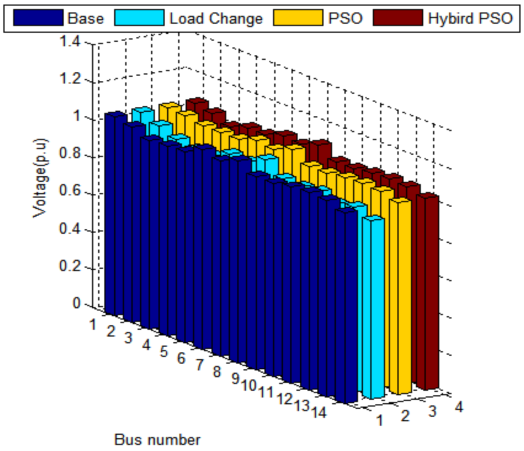
Cases	Bus number	Normal loading in MW	New loading in MW	PSO algorithm			Hybrid PSO algorithm		
				UPFC location	Total demand in MW	Total generation in MW	UPFC location	Total demand in MW	Total generation in MW
I	13	70.5	98.5	2&5	287	296.2518	6&13	287	294.3394
	6	39.2	67.2	2&3	315	324.7453	1&5	315	322.5558
	14	34.9	54.9	2&3	306	316.6747	2&4	306	313.6581
II	5&12	31.6&34.1	55.6&62.1	2&5	358	368.1418	9&14	358	365.9259
	13&8	70.5&24	99.5&48	2&4	368	378.4288	6&13	368	376.024

Table 3. Comparison of UPFC and fuel cost of case I.

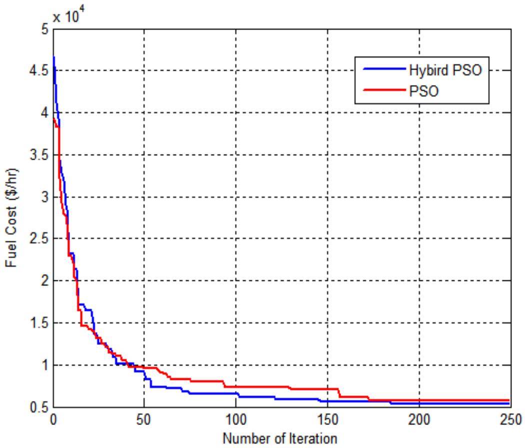
Cases	Bus number	PSO algorithm			Hybrid PSO algorithm		
		UPFC cost in $/KVAR	Fuel cost in $/hr	Total cost in $/hr	UPFC cost in $/KVAR	Fuel cost in $/hr	Total cost in $/hr
I	13	181.5319	6016.74	6198.2719	181.22	5033.4368	5214.6568
	6	181.1085	6039.22	6220.3285	182.4451	5665.3377	5847.7828
	14	180.0235	5640.2605	5998.6332	180.0032	5818.63	5820.284
II	5&12	177.5759	5811.1453	6138.582	172.652	5965.93	5988.7212
	13&8	182.6520	6538.09	6720.742	181.8731	5918.2248	6100.0979

Table 4. Total system loss comparison of case I and case II.

Cases	New loading buses	Power loss at new loading in MW	Total system losses in MW	
			PSO algorithm	Hybrid PSO algorithm
I	13	17.8298	9.1489	7.2571
	6	21.7605	9.0966	7.0311
	14	20.399	9.7207	7.2018
II	13&8	33.2902	9.5146	7.0454
	5&12	30.0093	9.3339	7.2307



(a)



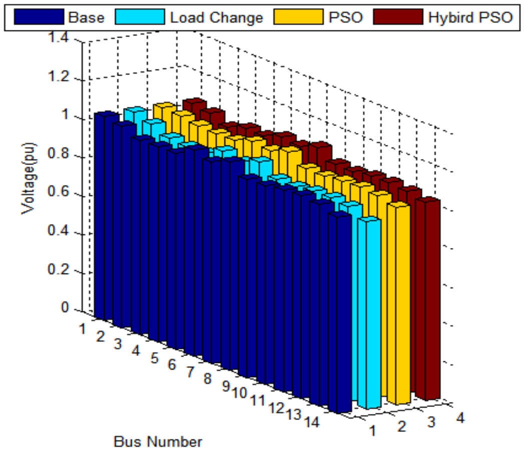
(b)

Figure 3. Performance of (a) voltage stability and (b) fuel cost when new loading in one bus.

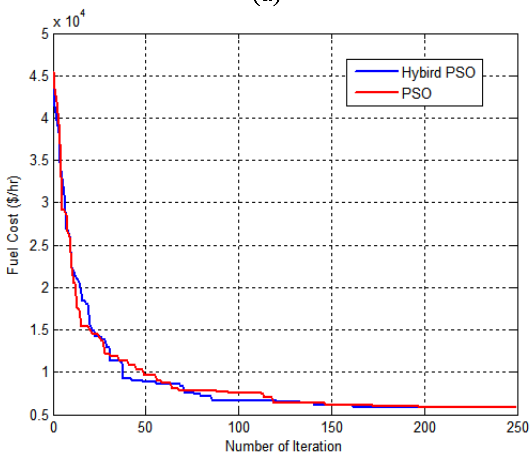
Case II: New Loading In Two Load Bus

When considering case II, various loading condition is applied in two load buses and the power flow is evaluated. In this loading condition, three load buses are selected for testing as 13&8 and 5&12 respectively. In the selected load buses, the load values are changed randomly from the actual load values. Therefore, the power flow of the system is changed; the voltage stability and power loss are affected. Subsequently, the optimal location of UPFC is determined and the power flow of the system is calculated and the system parameters are continued to stable level. In this case, the optimal location of UPFC, the system demand and the generator active powers are given in table 2. From that, the optimal location of UPFC is varied by PSO and hybrid PSO algorithm.

Then, the UPFC cost and the fuel cost are compared in tabulation, which are given in table III with load changing at buses 13&8 and 5&12. The total cost ($/hr) of the system is depends on the total generation cost ($/hr) and the UPFC cost ($/KVAR). From the table, the optimal power generation is obtained by hybrid PSO algorithm which gives less cost. For case II, the UPFC cost, the fuel cost and the total cost of the system is given in table III. Moreover, the case II power loss is presented in table IV and the performance of voltage stability and fuel cost are given in figure 4 at the time of new loading in one bus. The power loss comparison shows that, the hybrid method gives the minimum power loss 7.0454 MW. It is less when compared to the power loss obtained from PSO algorithm as 9.5146 MW. For case II, the voltage stability is compared with base case, after load change, PSO, and hybrid algorithm which are given in figure 4. The comparative analyses shows that, the proposed method solved the multi-objective optimal power flow problem effectively.



(a)



(b)

Figure 4. Performance of (a) voltage stability and (b) fuel cost when new loading in two buses.

6. Conclusion

In this paper, the hybrid approach was proposed for solving multiobjective problem in power transmission system. FACTS devices plays a significant role to control the power flow of power transmission system. A hybrid PSO algorithm is proposed here is to optimize the location of UPFC in power system. The proposed hybrid PSO algorithm has solved the formulated multiobjective optimization problem. In this paper, five objective function to be considered in the form of minimization such as the fast voltage stability index (FVSI), fuel cost, power loss, voltage deviation and UPFC cost respectively. To improve the non satisfied solution of PSO algorithm, bat search optimization is used and the performance of PSO algorithm is enhanced. The proposed hybrid technique is implemented in MATLAB working platform which is tested with IEEE 14 bus bench mark system. Here, two loading cases are considered to evaluate the proposed method and the total system cost, power loss, voltage are compared with traditional PSO algorithm. The comparative analysis conformed the effectiveness hybrid PSO algorithm for solving multiobjective optimization.

7. References

[1]. Arup Ratan Bhowmik, Ajoy Kumar Chakraborty and P.N.Das, "Placement of UPFC for Minimizing Active Power Loss and Total Cost Function by PSO Algorithm", *In the proceedings of Advance Electronic Systems*, pp.217-220, 2013

[2]. Anju Gupta and P R Sharma, "Static and Transient Stability Enhancement of Power System by Optimally Placing UPFC (Unified Power Flow Controller)", *In the proceedings of Advanced Computing & Communication Technologies*, pp.121-125, 2013

[3]. I Made Wartana, Jai Govind Singh, Weerakorn Ongsakul, Kittavit Buayai and Sasidharan Sreedharan, "Optimal Placement of UPFC for Maximizing System Load ability and Minimize Active Power Losses by NSGA-II", *In the proceedings of Electrical Engineering and Informatics*, pp.1-6, 2011

[4]. Ahmad Rezaee Jordehi, and Mahmood Joorabian, "Optimal Placement of Multi-Type FACTS Devices in Power Systems Using Evolution Strategies", *In the proceedings of Power Engineering and Optimization*, pp.352-357, 2011

[5]. Jafar Jafarzadeh, Dr. Mehrdad Trafdar Haq, Seyyed Mehdi Mahaei and Payam Farhadi, "Optimal Placement of FACTS devices based on Network Security", *In the proceedings of Computer Research and Development*, Vol.3, pp.345-349, 2011

[6]. Made Wartana and Ni Putu Agustini, "Optimal Placement of UPFC for Maximizing System Load ability and Minimizing Active Power Losses in System Stability Margins by NSGA-II", pp.1-8, 2011

[7]. S. Harish Kiran, C. Subramani, S. S. Dash, M.Arunbhaskar and M. Jagadeeshkumar, "Particle Swarm Optimization Algorithm to find the Location of Facts Controllers for a Transmission Line", *In the proceedings of Process Automation, Control and Computing*, pp.1-5, 2011

[8]. A. Lashkar Ara, A. Kazemi, and S. A. Nabavi Niaki, "Multiobjective Optimal Location of FACTS Shunt-Series Controllers for Power System Operation Planning", *IEEE Transactions On Power Delivery*, Vol.27, No.2, pp. 481-490, 2012

[9]. Bo Hu, Kaigui Xie and Rajesh Karki, "Reliability Evaluation of Bulk Power Systems Incorporating UPFC", *In the proceedings of Probabilistic Methods Applied to Power Systems*, pp.259 - 264, 2010

[10]. Anju Gupta and P.R.Sharma, "Optimal Placement of FACTS Devices for Voltage Stability Using Line Indicators", *In the proceedings of Power India*, pp.1-5, 2012

[11]. Arup Ratan Bhowmik, Ajoy Kumar Chakraborty and Priyanath Das, "Optimal Location of UPFC Based on PSO Algorithm Considering Active Power Loss Minimization", *In the proceedings of Power India*, pp.1-5, 2012

[12]. M.T. Ameli and S. Hashemi, "Optimal Location of UPFC for Enhancing Voltage Security and Relieving Congestion Using Particle Swarm Optimization", *In the proceedings of Circuits, Communications and System*, Vol.1, pp.429-433, 2010

[13]. T.Nireekshana, Dr.G.Kesava Rao and Dr.S.Siva Naga Raju, "Incorporation of Unified Power Flow Controller Model for Optimal Placement using Particle Swam Optimization

Technique", *In the proceedings of Electronics Computer Technology*, Vol.1, pp.209-214, 2011
[14]. R. W. Chang, T. Kuo and T. K. Saha, "Mixed-Integer Method for Optimal UPFC Placement based on Line Flow-Based Equations", *In the proceedings of Universities Power Engineering Conference*, pp.1-6, 2010
[15]. Mahyar Zarghami and Mariesa L. Crow, "Optimal Placement and Signal Selection for Wide-Area Controlled UPFCs for Damping Power System Oscillations", *In the proceedings of Power Systems Conference and Exposition*, pp.1-6, 2009
[16]. Ghamgeen Izat Rashed, Yuanzhang Sun, Khalid A. Rashed, and H. I. Shaheen, "Optimal Location of Unified Power Flow Controller by Differential Evolution Algorithm Considering Transmission Loss Reduction", *In the proceedings of Power System Technology*, pp.1-6, 2012
[17]. Abdelaziz Laifa and Mohamed Boudour, "Optimal Placement and Parameter Settings of Unified Power Flow Controller Device using a Perturbed Particle Swarm Optimization", *in the proceedings of Energy Conference and Exhibition*, pp.205-210, 2010
[18]. T.Nireekshana, G.Kesava Rao and S.Siva Naga Raju, "Incorporation of Unified Power Flow Controller Model for Optimal Placement using Particle Swam Optimization Technique", *in the proceedings of Electronics Computer Technology*, Vol.1, pp.209-214, 2011
[19]. M.Behshad, A.Lashkarara and A. H.Rahmani, "Optimal Location of UPFC Device Considering System Load ability, Total Fuel cost, Power losses and Cost of Installation", *in the proceedings of Power Electronics and Intelligent Transportation System*, Vol.2, pp.231-237, 2009
[20]. D.Jananisri, M.Kalyanasundaram and B.Gopinath, "Damping of Power System Oscillations Using Unified Power Flow Controller", *in the proceedings of Advances In Engineering, Science And Management*, pp.129-140, 2012
[21]. H.I. Shaheen, G.I. Rashed and S.J. Cheng, "Application and comparison of computational intelligence techniques for optimal location and parameter setting of UPFC", *Engineering Applications of Artificial Intelligence*, Vol.23, No.2, ppp.203-216, 2010
[22]. Jayanti Sarker and S.K. Goswami, "Solution of multiple UPFC placement problems using Gravitational Search Algorithm", *International Journal of Electrical Power & Energy Systems*, Vol.55, pp.531-541, 2014
[23]. Seyed Abbas Taher and Muhammad Karim Amooshahi, "New approach for optimal UPFC placement using hybrid immune algorithm in electric power systems", *International Journal of Electrical Power & Energy Systems*, Vol.43, No.1, pp.899-909, 2012
[24]. Husam I. Shaheen, Ghamgeen I. Rashed and S.J. Cheng, "Optimal location and parameter setting of UPFC for enhancing power system security based on Differential Evolution algorithm", *International Journal of Electrical Power & Energy Systems*, Vol.33, No.1, pp.94-105, January 2011
[25]. R.K. Pandey and N.K. Singh, "UPFC control parameter identification for effective power oscillation damping", *International Journal of Electrical Power & Energy Systems*, Vol.31, No.6, pp.269-276, July 2009
[26]. J. Belwin Edward, N. Rajasekar, K. Sathiyasekar, N. Senthilnathan, and R. Sarjila, "An enhanced bacterial foraging algorithm approach for optimal power flow problem including FACTS devices considering system loadability", *ISA Transactions*, Vol.52, pp.622–628, 2013
[27]. Ghahremani, E., and Kamwa, I., "Optimal placement of multiple-type FACTS devices to maximize power system loadability using a generic graphical user interface", *IEEE Transactions on Power Systems*, Vol.28, No.2, pp,764-778, 2013
[28]. Zwe-Lee Gaing, "A Particle Swarm Optimization Approach for Optimum Design of PID Controller in AVR System", *IEEE Transactions on Energy Conversion*, Vol.19, No.2, pp.384-391, June 2004

[29]. Xin-She Yang, "A New Metaheuristic Bat-Inspired Algorithm", Nature Inspired Cooperative Strategies for Optimization Studies in Computational Intelligence, Vol.284, pp.65-74, 2010
[30]. IEEE 14 bus system data referred from the web link: http://www.ee.washington.edu/research/pstca/pf14/pg_tca14bus.htm

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