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Multi-objective Optimization using Non-dominated Sorting Improved Particle Swarm Optimization

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Abstract: **This paper mainly concentrates in finding enhanced optimal solution for Multi-Objective Problem (MOP) formulated using generation fuel cost, emission, and loss objectives. Improved Particle swarm optimization (IPSO) is proposed to select best value as compared with existing evaluation algorithms. Optimizing multiple objectives simultaneously and selecting a best compromised solution as per the requirements of decision maker needs an application of MOP along with fuzzy decision making tool. The proposed Non-dominated Sorting Improved Particle swarm optimization (NSIPSO) is tested on IEEE 30 bus test system and corresponding results are analyzed.**

Key words: Multi object, fuel cost, emission, total power loss, non-dominated sorting, IPSO.

I. INTRODUCTION

The aim of optimal power flow is to determine the optimal combination of real power generation, voltage magnitudes, compensator capacitors and transformer tap position to minimize the specific objective function like total generation cost in power systems. The mentioned conditions make the OPF problem a large scale non-linear constrained optimization problem [1].

The literature on OPF is vast and [5] presented the major contributions in this area, where a review of literature is done on Optimal Power Flow up to 1993. Dommel and Tinney [6] has given a practical method for solving the power flow program with control variables such as real and reactive power and transformer ratios automatically adjusted to minimize instantaneous costs or losses.

There are several techniques that have been considered in the literature to solve multi-objective problems. One of these methods is reducing the multi-objective problem into a single objective problem by considering one objective as a target and others as a constraint. Another strategy is combining all objective functions into one objective function. The above strategies have some weak points such as the limitation of the available choices and their priori selection need of weights for each objective function. Besides the above drawbacks, finding just one solution for the multi-objective problem is known as the most important weak point of these strategies. Over the past few years, the studies on evolutionary algorithms have revealed that these methods can be efficiently used for solving the multi-objective optimization problem, some of these algorithms are multi-objective evolutionary algorithm [7], strength Pareto evolutionary algorithm (SPEA) [8], non-dominating sorting genetic algorithm (NSGA) [9] and multi-objective PSO algorithm [10]. Since these algorithms are population based techniques, multiple Pareto-optimal solutions can be found in one program run.

In this paper the proposed NSIPSO algorithm is used for solving multi objective optimization problems and tested with standard IEEE test systems compared with existing methods. The result shows proposed method gives the best compared with existing literature.

II. GENERAL OPF PROBLEM FORMULATION

The standard OPF problem can be written in the following form

Single objective optimization

$$Min.\,F(x,u) \tag{1}$$

Subject to: $h(x,u) = 0$

and $g(x,u) \leq 0$

Where,

$x = [V_l^T \;\; \delta^T \;\; P_{sg} \;\; Q_g^T]$

$u = [Q_c^T \;\; Tc^T \;\; V_g^T \;\; P_g^T]$

x is vector of state variables, u is vector of control variables, Q_c = Reactive power supplied by all shunt reactors, Tc = Transformer load tap changer magnitudes, $V_g =$ Voltage magnitude at PV buses, P_g = Active power generated at the PV buses, $V_l =$ Voltage magnitude at PQ buses, δ = Voltage angles of all buses, except the slack bus, P_{sg} = Active generating power of the slack bus, Q_g = Reactive power of all generator units, and $'u'$ is the vector of control variables, the control variable can be generated active and reactive power, generation bus voltage magnitudes, transformer taps etc.

Multi objective Problem formulation

Let $f_i(x), i = 1,2 \ldots, m$ be m objective functions defined over n dimensional search space. A multi objective optimization problem can then be formulated as [18]:

$$minimize \quad f_i(x) = \{f_1(x), f_2(x), \ldots, f_m(x)\} \qquad (2)$$

Subjected to the constraints, this will give a set of Pareto-optimal solutions. A decision vector, x (a set of control parameters) is said to be Pareto optimal, if there is no other decision vector, y dominating x with respect to the set of objective functions. The decision vector x is said to strictly dominate the another vector y (denoted by $x \prec y$) if;

$$f_i(x) \leq f_i(y); \qquad \forall_i = 1,2 \ldots, m$$

$f_i(x) < f_i(y)$; for at least one i.

III. OBJECTIVES FORMULATION

The three considered objective functions are described as follows

Objective1: Generation cost

The generation cost function can be mathematically stated as follows [3].

$$F_1(X) = \sum_{i=1}^{N_{gen}} \left(a_i P_{gi}^2 + b_i P_{gi} + c_i\right) \quad \$/h \qquad (3)$$

where $F_1(X)$ is the total fuel cost $(\$/h)$, a_i, b_i, c_i are fuel cost coefficients of the i^{th} unit, P_{gi} is the real power generation of the i^{th} unit, V_{gi} is the voltage magnitude of the i^{th} generator, TAP_i is the tap of the i^{th} transformer, Q_{ci} is the reactive power of the i^{th} compensator capacitor, N_{gen} is the total number of generation units, N_{tran} is the number of tap transformer and N_{cap} is the number of the compensation capacitor.

Objective 2: Emission

The emission function can be presented as the sum of all types of emissions considered, such as NO_X, SO_X, thermal emission, etc. In the present study, two important types of emission gases are taken into account. The amount of NO_X and SO_X emission is given as a function of generator output that is the sum of a quadratic and exponential function as follows.

$$F_2(X) = \sum_{i=1}^{N_{gen}} \left(\alpha_i + \beta_i P_{gi} + \gamma_i P_{gi}^2 + \xi_i \exp\left(\lambda_i P_{gi}\right)\right) \ (ton/h) \qquad (4)$$

Where $F_2(X)$ is the total emission (ton/h), $\alpha_i, \beta_i, \gamma_i, \xi_i, \lambda_i$ are the emission coefficients of the i^{th} unit.

Objective 3: Transmission loss

The power flow solution gives all bus voltage magnitudes and angles. Then, the active power loss in transmission line can be computed as follows.

$$F_3(X) = \sum_{i=1}^{N_{line}} g_k \left[V_i^2 + V_j^2 - 2V_i V_j \cos\left(\delta_i - \delta_j\right)\right] MW \qquad (5)$$

Where $F_3(X)$ is the total transmission loss (MW), N_{line} is the number of transmission lines, δ_i and δ_j are the bus voltage angles at the two ends of the k^{th} line, V_i and V_j are bus voltage amplitudes at the two ends of the k^{th} line and g_k is the conductance of the k^{th} line.

IV. CONSTRAINTS

(a) Equality constraints:

The OPF equality constraints reflect the physics of the power systems. Equality constraints are expressed in the following equations

$$P_i = P_{gi} - P_{di}$$

$$Q_i = Q_{gi} - Q_{di}$$

Where $i = 1,2, \ldots, N_{bus}$.

(b) Inequality constraints:

The inequality constraints of the OPF reflect the limits on physical devices in the power system as well as the limits created to ensure system security. They are presented in the following.

$$P_{gi\,min} \leq P_{gi} \leq P_{gi\,max}; \qquad i = 1,2, \ldots, N_{gen}$$

$$Q_{gi\,min} \leq Q_{gi} \leq Q_{gi\,max}; \qquad i = 1,2, \ldots, N_{gen}$$

$$|P_{ij}| \leq P_{ijmax};$$

$$V_{i\,min} \leq V_i \leq V_{i\,max}; \qquad i = 1,2, \ldots, N_l$$

$$Q_{ci\,min} \leq Q_{ci} \leq Q_{ci\,max}; \qquad i = 1,2, \ldots, N_{cap}$$

$$TAP_{i\,min} \leq TAP_i \leq TAP_{i\,max}; \qquad i = 1,2, \ldots, N_{tran}$$

Where N_l is the number of load bus and P_{ij} is the power that flows between bus i and bus j. $V_{i\,max}$ and $V_{i\,min}$ are the maximum and minimum valid voltages for i^{th} bus. P_{ijmax} is the maximum power flow through the branch. $P_{gi\,max}$ and $P_{gi\,min}$ are the maximum and minimum active power values of the i^{th} bus, respectively. $Q_{gi\,max}$ and $Q_{gi\,min}$ are the maximum and minimum reactive power values of the i^{th} bus.

V. SINGLE OBJECTIVE IPSO BASED OPF

An algorithm for single objective IPSO based OPF is given bellow.

Algorithm

Step 1: Initialize the population and PSO parameters.
Step 2: Read the input system data and select the PSO control variables.
Step 3: Randomly generate the velocities and populations.
Step4: Update the bus and line data's of given system according to the population generation and run the NR load flow.
Step 5: After load flow calculation check the equality and inequality constraints; if any violets add the penalty terms to the objective function.
Step 6: Compute the objective function and fitness values.
Step 7: Do the same process of step4 and step5 for all populations and select the best fitness value as globalfit value and corresponding particles are Gbest values
Step 8: Initialize the iteration counter Iter, and start the iteration process
Step 9: Update the velocities and position values, check the updated velocities and positions within limit or not. Fix those values min or max according to their violation.
Step 10: Repeat the step4 to step6 for all populations.
Step 11: Update the localbest and globalbest values.
Step 12: Repeat the step9 to step11 until Iter < IterMax.
Step 13: Stop the process and print the Gbest values.

VI. MULTI OBJECTIVE NSIPSO BASED OPF

An algorithm and flow chart for multi objective NSIPSO based OPF is given bellow.

Algorithm

Step 1: Initialize the random population and velocities.
Step 2: Update the system data according to the population generation.
Step 3: Run the load flow solution for updated system.
Step 4: Check the equality and inequality constraints and calculate penalty terms.
Step 5: Select the optimized objectives and calculate their objective function values and fitness value. Save these values in a repository.
Step 6: Initialize the Pbest values and found the Gbest value.
Step 7: Start the iteration process and update the velocities and positions, check their limits and fix the values, Repeat the process step3 to step5 generate new population.
Step 8: The new populations add with old repository and there by apply non-dominate sorting technique.
Step 9: After sorting, save the non dominated pareto fronts and apply the crowding distance and crowding sort techniques.
Step 10: After non dominated set re arrangement select top 10% values are Gbest values and update Pbest values.
Step 11: Repeat the process step7 to step10 until maximum iteration value. And stop the iteration process
Step 12: Finally we get the non dominated repository; it is apply to fuzzy decision maker tool and calculated the best feasible compromised multi objective solution according to their weighting factors.

VII. RESULT AND ANALYSIS

In this paper, the multi objective OPF solution using Non Dominated Sorting IPSO (NSIPSO) is given. The proposed method is tested on IEEE 30 bus test systems with bus voltages, real and reactive power and line flow constraints. On all optimization runs, the IPSO population size and the maximum number of iterations which are set on 100 each considered.

The IEEE-30 bus system is used throughout this work to test the proposed algorithm (IPSO based OPF for single objective and NSIPSO based OPF for multi objective). This system consists of 6 generator units as well as 41 transmission lines. The detailed bus and line parameters are presented in [22].

In this section we describe the single and multi objective analysis.

7.1 Single objective minimization

Case Study 1: Fuel cost minimization

In this case, developed algorithm is applied to minimize the fuel cost objective. The obtained results are compared with Ant Colony Algorithm (ACA) are tabulated in table 1. The convergence pattern is shown in Fig 1.

Table 1: Fuel cost minimization

Control variable	Existing ACA method [3]	Proposed method
PG1, MW	181.945	176.6491
PG2, MW	47.001	48.83991
PG3, MW	20.553	21.52671
PG4, MW	21.146	21.73635
PG5, MW	10.433	12.16658
PG6, MW	12.173	12
Fuel Cost ($/h)	802.578	802.4029

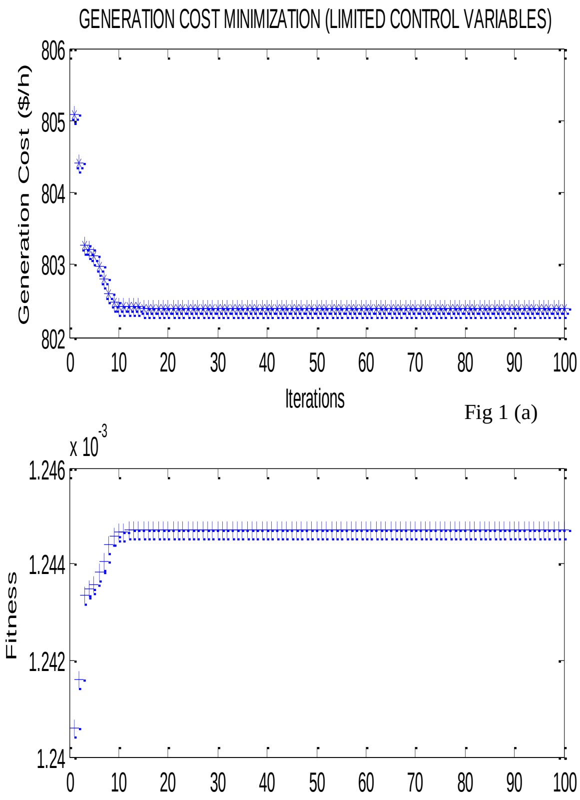

Fig 1 (a)

Fig 1 (b)

Fig 1 Fuel cost convergence pattern

It can be easily seen from the Table 1, the fuel cost with existing ACA [3] method is 802.578 $/h and with the proposed method is 802.4029 $/h. It is clear that the proposed method can achieve better result when compared to ACA method. In Fig 1, (a) and (b) shows the fuel cost variation and the fitness variation with respect to number of iterations respectively. The final solution of the proposed method is converged with in 15 iterations.

Case Study 2: Emission minimization

In this case, developed algorithm is applied to minimize the emission objective. The obtained results are compared with Genetic Algorithm (GA) are tabulated in Table 2. The convergence pattern is shown in Fig 2.

Table 2: Emission minimization

Control variable	Existing GA method [3]	Proposed method
PG1, MW	69.73	64.32621
PG2, MW	67.84	67.76814
PG3, MW	49.73	50
PG4, MW	34.42	35
PG5, MW	29.15	30
PG6, MW	39.29	40
Emission (ton/h)	0.2072	0.204838

It can be easily seen from the Table 2, the emission with existing GA [3] method is 0.2072 ton/h and with the proposed method is 0.204838 ton/h. It is clear that the proposed method can achieve better result when compared to GA method. In Fig 2, (a) and (b) shows the emission variation and the fitness variation with respect to number of iterations respectively. The final solution of the proposed method is converged with in 15 iterations.

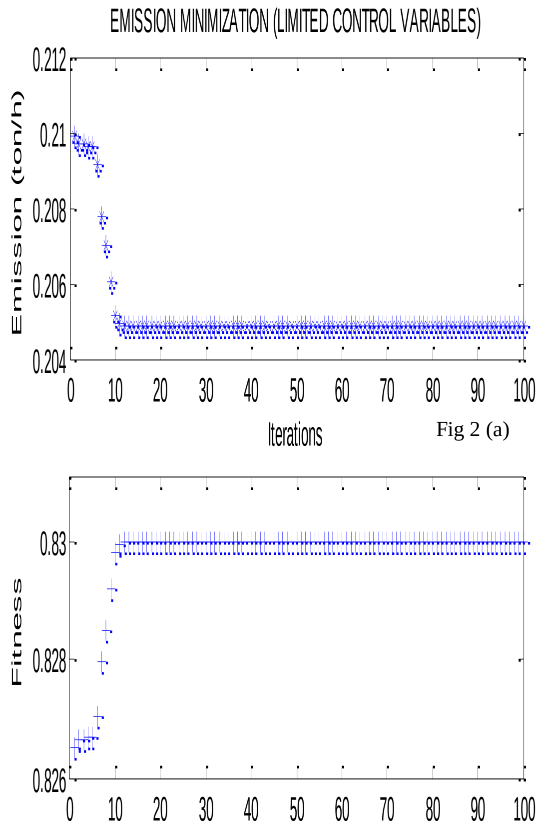

Fig 2 (a)

Fig 2 (b)

Fig 2 Emission convergence pattern

Case Study 3: Transmission loss minimization

In this case, developed algorithm is applied to minimize the transmission loss objective. The obtained results are compared with Genetic Algorithm (GA) are tabulated in Table 3. The convergence pattern is shown in Fig 3.

Table 3: Transmission loss minimization

Control variable	Existing GA method [3]	Proposed method
VG1, p.u.	1.03	1.1
VG2, p.u.	1.00	1.07135
VG3, p.u.	1.00	1.06827
VG4, p.u.	1.02	1.0735
VG5, p.u.	1.04	0.95708
VG6, p.u.	1.00	1.03229
T6-9, p.u.	1.00	1
T6-10, p.u.	1.01	1.08182
T4-12, p.u.	1.00	1.1
T27-28, p.u.	1.04	1.03477
Transmission Loss, MW	5.3513	4.97153

It can be easily seen from the Table 3, the transmission loss with existing GA [3] method is 5.3513 MW and with the proposed method is 4.97153 MW. It is clear that the proposed method can achieve better result when compared to GA method. In Fig 3, (a) and (b) shows the transmission loss variation and the fitness variation with respect to number of iterations respectively. The final solution of the proposed method is converged with in 15 iterations.

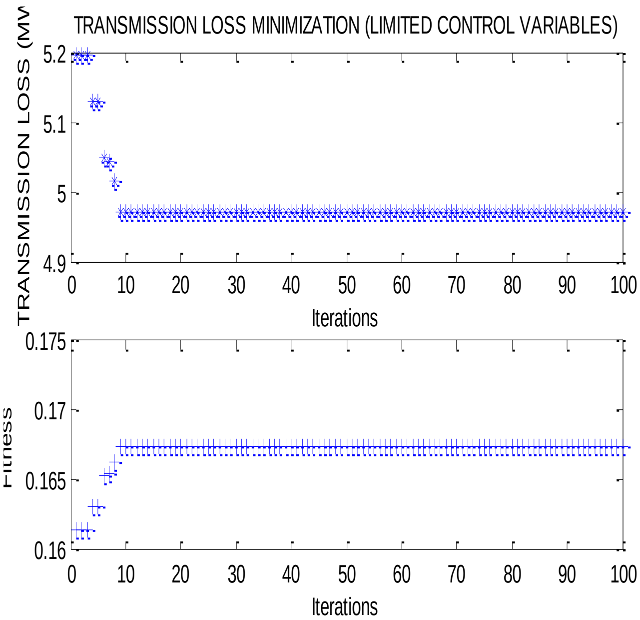

Fig 3 Transmission loss convergence pattern

The obtained results for single objective OPF problem based on PSO algorithm is given in Table 4.

Table 4: PSO based OPF Solutions for five different objectives individually

Control variables	Fuel cost minimization	Emission minimization	Loss minimization
PG1, MW	177.22929	64.00868	51.39099
PG2, MW	48.550303	67.59438	80
PG3, MW	21.462934	50	50
PG4, MW	21.211045	35	35
PG5, MW	11.881975	30	30
PG6, MW	12.000032	40	40
VG1, p.u.	1.1	1.092719	1.1
VG2, p.u.	1.0370108	1.082577	1.041686
VG3, p.u.	1.0646606	1.057189	1.083148
VG4, p.u.	1.0544999	1.068489	1.087906
VG5, p.u.	0.9634969	0.944209	1.099556
VG6, p.u.	1.1	1.093477	1.1
T6-9, p.u.	0.9514214	1.015055	1.017291
T6-10, p.u.	0.9910521	0.9562	0.968865
T4-12,pu	0.9919611	0.994948	0.983142
T27-28, p.u.	0.9679805	0.966505	0.970435
Qc10,MVA	15.974439	17.78494	21.07306
Qc24,MVA	10.460198	17.53809	11.67689
Fuel cost ($/h)	800.17747	944.3457	967.4024
Emission (ton/h)	0.3664768	0.204683	0.207122
Power Loss (MW)	8.9355744	3.203066	2.99099

From table 4 it is observed that cost is 800.17746 $/h, emission is 0.0204683 ton/h and total power loss is 2.99099MW.

7.2 Multi Objective minimization

The results are obtained from the developed algorithm for multi-objective OPF based on NSIPSO method which has been discussed in the above sections. The multi-objective OPF problem has been formulated with different combinations of objectives namely fuel cost- emission, fuel cost-losses and emission-loss combinations are considered.

In this, the proposed methodology handles two different objectives together as multi-objective optimization problem. There are ten possible combinations with the five objectives. The obtained results are compared with existing weighted sum method which is given in Table 5.

Table 5: Multi-objective obtained best compromised results for two different objectives

Optimized Two Objectives	Weighting factors		Proposed method	
Cost-Emission	W1	W2	Cost ($/h)	Emission (ton/h)
	0.8 0.5 0.2	0.2 0.5 0.8	805.9989 830.0619 880.9416	0.311993 0.251936 0.217372
Cost-Loss	W1	W2	Cost ($/h)	Loss (MW)
	0.8 0.5 0.2	0.2 0.5 0.8	809.8782 824.0478 860.88	6.951288 5.695692 4.573103
Emission-Loss	W1	W2	Emission (ton/h)	Loss (MW)
	0.8 0.5 0.2	0.2 0.5 0.8	0.204742 0.205361 0.206237	3.120038 3.073873 3.039198

From the table 5 it is observed that more waited objective will minimize more. It is also observed that cost is 805.9989 $/h and emission is 0.217372 ton/h for the weight is 0.8 in cost-emission combination, cost is 809.8782 $/h and loss is 4.573103 MW for the weight is 0.8 in cost-loss combination and emission is 0.204742 ton/h and loss is 3.039198MW for the weight is 0.8 in emission-loss combination,

The alignments of the generated two dimensional Pareto solutions are shown Fig 4.

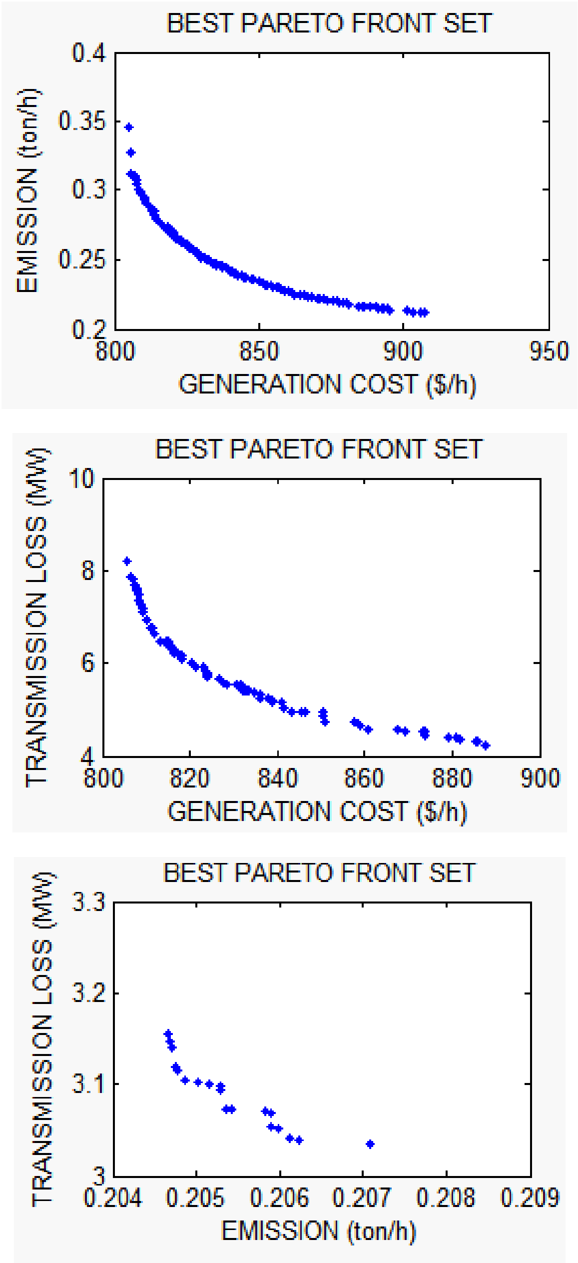

Fig 4: Two-dimensional Pareto-optimal fronts for two different objectives

VIII. CONCLUSION

In this paper proposes an optimal power flow technique with three competitive objectives, cost of generation, emission and loss of thermal plants. A multi-objective Non Dominating sorting improved particle swarm optimization technique has been proposed to solve this optimization problem. To maintain diversity among Pareto-optimal solutions a Non Dominating sorting technique has been proposed. The goal of the proposed multi-objective OPF problem is to compute advised set points for power system controls that satisfy the security, the environment and the economical conditions simultaneously. The most important privilege of the proposed approach for the multi-objective formulation is obtaining several non-dominated solutions allowing the system operator to use his personal preference in selecting one solution for implementation. Furthermore the proposed fuzzy decision method helps the power system operator to apply his decisions very easily. Also in single objective cases, the proposed approach can obtain better results with respect to other algorithm in the literature. In multi-objective cases, the proposed method proves its ability to obtain well-distributed Pareto fronts. The IEEE 30 bus systems are considered for experimentation.

REFERENCES

[1] Niknam, T., Narimani, M.R., Jabbari, M., Malekpour, A.R.: 'A modified shuffle frog leaping algorithm for multi-objective optimal power flow', Energy, 2011, 36, pp. 6420–6432.

[2] Momoh J. A., M. E. El-Hawary and Adapa R., "A review of selected optimal power flow literature to 1993," IEEE Transactions on Power System, Part I and II, Vol. 14, pp. 96–111, 1999.

[3] Dommel H. W. and Tinney W. F., "Optimal power flow solutions," IEEE Transactions on Power Apparatus and Systems, Vol. PAS-87, pp. 1866–1876,1968.

[4] Andrew, K., Haiyang, Z.: 'Optimization of wind turbine energy and power factor with an evolutionary computation algorithm', Energy, 2010, 35, (3), pp. 1324–1332.

[5] Abido, M.A.: 'A novel multi objective evolutionary algorithm for environmental /economic power dispatch', Electr. Power Syst. Res., 2003, 65, (1), pp. 71–81.

[6] Elbeltagi, E., Hegazy, T., Grierson, D.: 'Comparison among five evolutionary-based optimization algorithms', Adv. Eng. Inf., 2005, 19, (1), pp. 43–53.

[7] Niknam, T., ZeinoddiniMeymand, H., DoagouMojarrad, H.: 'A practical multi- objective PSO algorithm for optimal operation management of distribution network with regard to fuel cell power plants', Renew.Energy, 2011, 36, (5), pp. 1529–1544.

[8] J. Hazra, A. K. Sinha," A multi-objective optimal power flow using particle swarm optimization", Euro. Trans. Electr. Power(2010).

[9] T. Niknam, M.R. Narimani, J. Aghaei R. Azizipanah-Abarghooee," Improved particle swarm optimisation for multi-objective optimal power flow considering the cost, loss, emission and voltage stability index", IET Gener. Transm. Distrib., 2012, Vol. 6, Iss. 6, pp. 515 – 527.

[10] Alsac, O., Stott, B.: 'Optimal load flow with steady-state security',IEEE Trans. Power Appar. Syst., 1974, 93, (3), pp. 745–751.