International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 5, Issue 1
January 2018

Economic Operation with DC Link Placement Problem by using Self Adaptive Firefly Algorithm

Dr. B.Suresh Babu
Joginpally B.R.Engineering College

ABSTRACT *–Optimal Power Flow is an important operational and planning problem in minimizing the chosen objective functions of the power systems. Economic load dispatch (ELD) is an important operational problem of the power system, aiming to minimize the fuel cost(FC). The recent developments in power electronics have enabled introduction of dc links in the AC power systems with a view of making the operation more flexible, secure and economical .The solution process involves AC/DC power flow and uses a self adaptive technique so as to avoid landing at the suboptimal solutions. The proposed algorithm (PA) is applied to the standard IEEE 14, 30 and 57 bus test systems and the results are presented to demonstrate its effectiveness.*

Keywords: Economic load Dispatch, AC/DC power flow, firefly optimization, valve point effect

1. INTRODUCTION

The optimal power flow (OPF) has been widely used in power system operation and planning since its introduction by Carpenter in 1962 [1]. The OPF determines optimal settings for certain power system control variables by optimizing a few selected objective functions while satisfying a set of equality and inequality constraints for given settings of loads and system parameters. The control variables include generator active powers, generator bus voltages, transformer tap ratios and the reactive power generation of shunt compensators. In general, the total fuel cost (FC) is commonly used as the main objective for OPF problems. However, the other objectives, such as reduction of real power loss (RPL), improvement of the voltage profile (VP) and enhancement of the voltage stability (VS) can also be included, as it has progressively become easy to formulate and solve large-scaled complex problems with the advancement in computing technologies. The equality constraints are the power flow balance equations, while the inequality constraints are the limits on the control variables and the operating limits of the power system dependent variables.

The recent developments in power electronics have introduced DC transmission links in the existing AC transmission systems with a view of achieving the benefits of reduced network loss, lower number of power conductors, increased stability, enhanced security, etc. They are often considered for transmission of bulk power via long distances. The attributes of DC transmission links include low capacitance, low average transmission cost in long distances, ability to prevent cascaded outages in AC systems, rapid adjustments for direct power flow controls, ability to improve the stability of AC systems, mitigation of transmission congestion, enhancement of transmission capacity, rapid frequency control following a loss of generation, ability to damp out regional power oscillations following major contingencies and offering major economic incentives for supplying loads. Flexible and fast DC controls provide efficient and desirable performance for a wide range of AC systems. The existing OPF problem can be modified to handle AC/DC systems [2-3]. The resulting optimization problem, designated as OPF with DC links (OPFDC), is a large scale, non-linear non-convex and multimodal optimization problem with continuous and discrete control variables. The existence of nonlinear power flow constraints and the DC link equations make the problem non-convex even in the absence of discrete control variables [4].

In the recent decades, numerous mathematical programming techniques such as gradient method [1], linear programming [5], nonlinear programming [6], interior point method [7] and quadratic programming [8] with various degrees of near-optimality, efficiency, ability to handle difficult constraints and heuristics, have been widely applied in solving the OPF problems. Although many of these techniques have excellent convergence characteristics, they have severe limitations in handling non-linear and discontinuous objectives and constraints. The gradient method suffer from the difficulty in handling inequality constraints; and the linear programming requires the objective and constraint functions to be linearized during optimization, which may lead to the loss of accuracy. Besides they may converge to local solution instead of global ones, when the initial guess is in the neighborhood of a local solution. Thus there is always a need for simple and efficient solution methods for obtaining global optimal solution for the OPF problems.

Apart from the above methods, another class of numerical techniques called evolutionary search algorithms such as genetic algorithm (GA) [9], evolutionary programming [10], particle swarm optimization (PSO) [11], differential evolution [12], frog leaping [13], harmony search optimization (HSO) [14], gravitational search [15], clonal search [16], artificial bee colony [17] and teaching-learning [18] have been widely applied in solving the OPF problems. Having in common processes of natural evolution, these algorithms share many similarities; each maintains a population of solutions that are evolved through random alterations and selection. The differences between these procedures lie in the techniques they utilize to encode candidates, the type of alterations they use to create new solutions, and the mechanism they employ for selecting the new parents. These algorithms have yielded satisfactory results across a great variety of power system problems. The main difficulty is their sensitivity to the choice of the parameters, such as the crossover and mutation probabilities in GA and the inertia weight, acceleration coefficients and velocity limits in PSO.

Recently, firefly optimization (FO) has been suggested by Dr. Xin-She Yang for solving optimization problems [19]. It is inspired by the light attenuation over the distance and fireflies' mutual attraction rather than the phenomenon of the fireflies' light flashing. In this approach, each problem solution is represented by a firefly, which tries to move to a greater light source, than its own. It has been applied to a variety of engineering optimization problems and found to yield satisfactory results. However, the choice of FO parameters is important in obtaining good convergence and global optimal solution.

This paper formulates the problem of OPFDC, suggests a solution methodology involving a self adaptive FO (SFO) with a view of obtaining the global best solution and demonstrates its performance through simulation results on the modified IEEE 14, 30 and 57 bus systems.

2. PROBLEM FORMULATION

The exercise is to identify the optimal control parameters such as generator active powers, generator bus voltages, transformer tap ratios and the reactive power generation of shunt compensators, besides determining the DC control parameters. The formation of the problem involves both the AC and DC sets of equations. The AC set of equations are the standard AC power balance equations whereas the DC set equations represent power, current and voltage balance equations at both DC and AC terminal buses of DC links. Moreover the DC link can be operated in different modes such as constant current, constant power, etc [8]. In this formulation, DC links with constant current control are considered. The OPFDC problem is formulated as a constrained nonlinear optimization problem through combining the standard OPF problem and the DC link equations as

$$\text{Minimize} \quad \Phi(x,u) \tag{1}$$

Subject to

$$b(x,u)=0 \tag{2}$$

$$g(x,u)\le 0 \tag{3}$$

Where

$$x=[V_i^L, Q_j^G, P_s^G] \tag{4}$$

$$u=[P_k^G, V_j^G, T_v, Q_q^C, I_p^{dc}] \tag{5}$$

$$b(x,u)=\begin{Bmatrix} P_m^G - P_m^D - V_m \sum_{n\in\{\Omega,\Pi\}} V_n (G_{mn}\cos ¢_{mn} + B_{mn}\sin ¢_{mn}) = 0 \\ Q_m^G - Q_m^D - V_m \sum_{n\in\{\Omega,\Pi\}} V_n (G_{mn}\sin ¢_{mn} - B_{mn}\cos ¢_{mn}) = 0 \\ h(x,u)=0 \end{Bmatrix} \quad (6)$$

$$g(x,u)=\begin{Bmatrix} P_k^{G(\min)} \le P_k^G \le P_k^{G(\max)} \\ Q_j^{G(\min)} \le Q_j^G \le Q_j^{G(\max)} \\ Q_q^{C(\min)} \le Q_q^C \le Q_q^{C(\max)} \\ T_v^{\min} \le T_v \le T_v^{\max} \\ V_j^{G(\min)} \le V_j^G \le V_j^{G(\max)} \\ V_i^{L(\min)} \le V_i^L \le V_i^{L(\max)} \\ I_p^{dc(\min)} \le I_p^{dc} \le I_p^{dc(\max)} \\ |S_{Li}| \le S_{Li}^{\max} \end{Bmatrix} \quad (7)$$

$$h(x,u)=\begin{Bmatrix} V_m^{dc} - s_m c_2 h_m V_w^{ac} \cos\theta_m + s_m c_3 X_m^c I_m^{dc} = 0 \\ V_m^{dc} - 0.995 s_m c_2 h_m V_w^{ac} \cos\varphi_m = 0 \\ Q_w^{ac} - V_w^{ac} c_2 h_m I_m^{dc} \sin\varphi_m = 0 \\ P_w^{ac} - V_w^{ac} c_2 h_m I_m^{dc} \cos\varphi_m = 0 \\ P_m^{dc} - V_m^{dc} I_m^{dc} = 0 \\ I_m^{dc} - (V_m^{dc} - V_n^{dc})/R_{mn}^{dc} = 0 \\ V_m^{dc} - V_n^{dc} - I_m^{dc} R_{mn}^{dc} = 0 \end{Bmatrix} \quad (8)$$

s_m = 1 for rectifier and -1 for inverter

$c_2 = 3\sqrt{2}/®$ $\quad c_3 = 3/®$

$i \in \Omega$ $\quad j \in \Pi$

$k \in \Psi$ $\quad v \in \Re$

$p \in \Im$ $\quad q \in \aleph$

Minimization of Fuel Cost

Minimize $\quad \Phi_1(x,u) = \sum_{j\in\Pi} a_j P_j^{G^2} + b_j P_j^G + c_j + \left| d_j \sin(e_j (P_j^G(\min) - P_j^G)) \right|$ (9)

Minimization of Real Power Loss

Minimize $\quad \Phi_2(x,u) = \sum_{w=1}^{nl} g_{mn} \left(|V_m|^2 + |V_n|^2 - 2|V_m||V_n| \cos ¢_{mn} \right.$ (10)

International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 5, Issue 1
January 2018

Enhancement of Voltage Stability

The VS can be enhanced by minimizing the Largest value of VS index (LVSI) of load buses [20] as

Minimize $$\Phi_3(x,u) = \max\{L_i ; i \in \Omega\} \tag{11}$$

Where $$L_i = \left| 1 - \sum_{j=\Pi} F_{ji} \frac{V_j}{V_i} \right| \tag{12}$$

The multi-objective OPFDC problem is tailored by combining several objectives through weight factors so as to optimize all the objectives simultaneously.

Minimize $$\Phi(x,u) = \sum_{i=1}^{nobj} w_i \ \Phi_i \tag{13}$$

3. EQUATIONS AND UNITS

The FO is a metaheuristic, nature-inspired, optimization algorithm which is based on the social flashing behavior of fireflies. FO initially produces a swarm of fireflies located randomly in the search space. In each iterative step, the positions of the fireflies are updated based on the brightness and the relative attractiveness of each firefly. After a sufficient amount of iterations, all fireflies converge to the best possible position on the search space [19]. The self-adaptive control of the parameters $\sim_i$, $_o$ and ¥ during the search process effectively leads the algorithm to land at the global best solution with minimum computational effort. The proposed method (PM) involves representation of problem variables that include the control variables and self-adaptive parameters $\sim_i$, $_{oi}$ and $¥_i$ and the formation of a light intensity function, LI .

3.1 Representation of decision variables

The decision variables in the PM thus comprises real power generation at PV buses, voltage magnitudes at generator buses, transformer tap settings, DC link currents, ~ , $_o$ and ¥ . Each firefly in the PM is defined to denote these decision variables in vector form as

$$f = [P_k^G, V_j^G, T_v, I_p^{dc}, L_{p,} \sim, \ _o, ¥]; \quad j \in \Pi \quad k \in \Psi \quad v \in \Re \quad p \in \Im \tag{14}$$

3.2 Intensity Function

The SFO searches for optimal solution by maximizing a light intensity function, denoted by LI , which is formulated from the objective function of Eq. (1) and the penalty terms representing the limit violation of the dependant variables such as reactive power generation at generator buses, voltage magnitude at load buses and real power generation at slack bus. The LI can be built as

$$\text{Maximize} \quad LI = \frac{1}{1+\Phi^A} \tag{15}$$

Where

$$\Phi^A = \Phi(x,u) + ª_V \sum_{i\in\Omega} \left(V_i^L - V_i^{\text{limit}}\right)^2 + ª_Q \sum_{i\in\Pi} \left(Q_i^G - Q_i^{\text{limit}}\right)^2 + ª_P \left(P_s^G - P_s^{\text{limit}}\right)^2 + ª_S \sum_{i\in M} \left(S_{Li} - S_{Li}^{max}\right)^2 \tag{16}$$

The power system is altered through setting the control parameters of $\{P_k^G, V_j^G, T \text{ and } I_p^{dc}\}$ for each firefly. The AC/DC power flow is then run with a view of computing the objective function $\Phi(x,u)$ and the light intensity function LI .

3.3 Solution Process

An initial swarm of fireflies is obtained by generating random values within their respective limits to every individual in the swarm. The LI is calculated by considering the values of each firefly and the movements of all fireflies are performed with a view of maximizing the LI till the number of iterations reaches a maximum specified number of iterations $Iter^{\max}$. The pseudo code of the PM is as follows.

Read *the Power System Data*

Choose *the parameters,* nf *and* $Iter^{\max}$.

Generate *the initial population of fireflies*

Set *the iteration counter* $t = 0$

while *(termination requirements are not met) do*

for $i = 1 : nf$

- *Set the control parameters according to* i *-th firefly values*
- *Obtain the values for* $\sim_i$, $_o$ and ¥ *from the firefly*
- *Run AC/DC power flow*
- *Evaluate the augmented objective function* Φ^A *and light intensity function* LI_i *using Eqs. 16 and 15 respectively*

for $j = 1 : nf$

- *Set the control parameters according to* j*-th firefly values*
- *Obtain the values for* $\sim_i$, $_o$ and ¥ *from the firefly*
- *Run AC/DC power flow*
- *Evaluate the augmented objective function* Φ^A *and light intensity function* LI_j *using Eqs. 16 and 15 respectively*

if $LI_i < LI_j$

Compute $r_{i,j} = \left\| f_i - f_j \right\| = \sqrt{\sum_{k=1}^{nd} \left(f_i^k - f_j^k \right)^2}$

Evaluate $_{i,j} = \ _{o,i} \exp\left(-¥_i \, r_{i,j}^2 \right)$

Move i*-th firefly towards* j*-th firefly through*

$$f_i(t) = f_i(t-1) + \ _{i,j}\left(f_j(t-1) - f_i(t-1) \right) + \sim\left(rand - 0.5 \right)$$

end*-(if)*

end*-(*j*)*

end*-(*i*)*

Rank the fireflies and find the current best.

end*-(while)*

Choose *the best firefly possessing the largest* LI_i *in the population as the optimal solution*

International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 5, Issue 1
January 2018

4. SIMULATIONS

The PM is tested on IEEE 14, 30 and 57 bus test systems. The fuel cost coefficients, lower and upper generation limits for these two test systems are taken from Ref. [21-23]. The sequential AC/DC power flow involving NR technique is used during the optimization process [4]. Programs are developed in Matlab 7.5 and executed on a 2.67 GHz Intel core-i5 personal computer. The OPFDC problem is also solved using the PSO and HSO with a view of demonstrating the efficacy of the PM. The performances in terms of FC of PM and are compared with those of the PSO and HSO based algorithms Table 2 for IEEE 14, 30 and 57 bus system respectively. The parameters chosen for the PA are given in Table 1.

Table 1 FA Parameter

Parameter	Value
nf	30
$Iter^{max}$	300

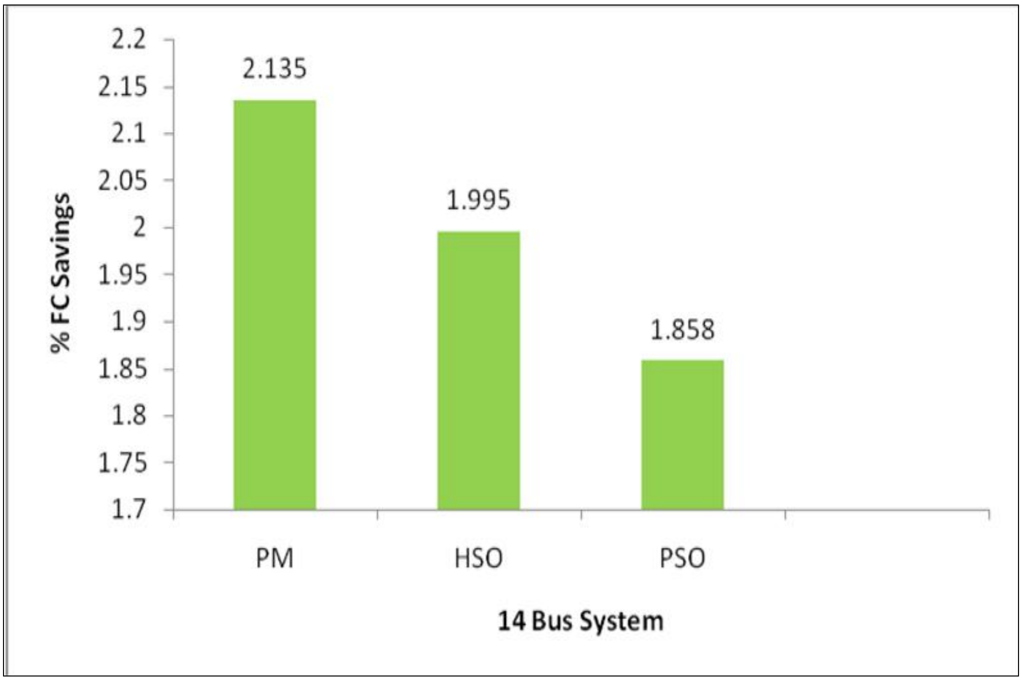
Table 2 Comparison of Performances for FC

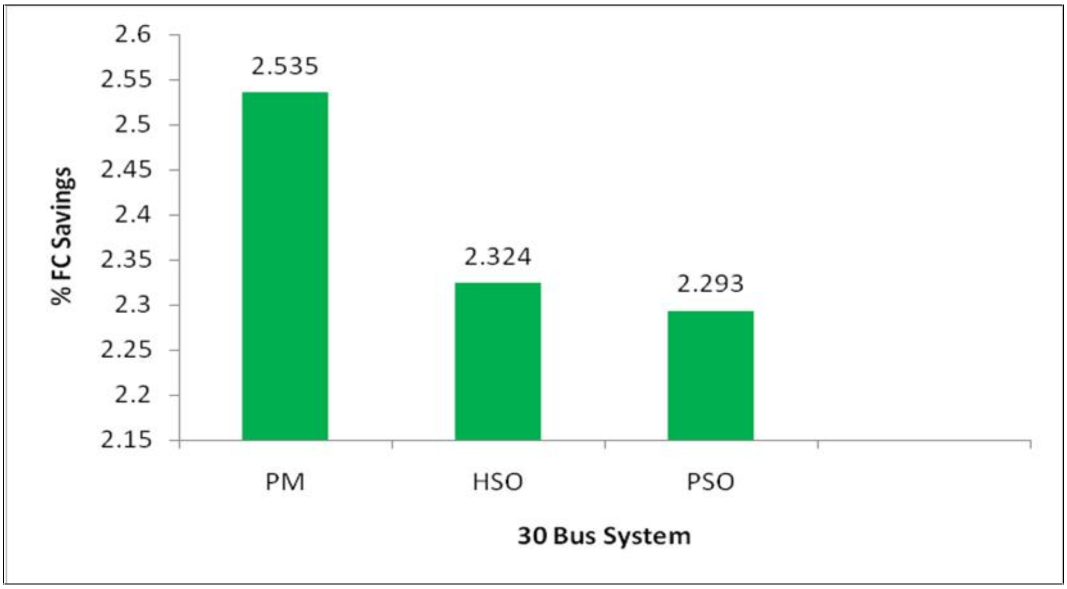
		Before Placement	FC		
			PM	**PSO**	**HSO**
14	FC	834.6716	816.8550	819.1639	818.0184
	RPL	8.9737	6.8716	7.3627	7.1733
	NVSI	0.3724	0.3730	0.3906	0.3732
	LVSI	0.0750	0.0763	0.0797	0.0772
30	FC	813.6941	793.0635	795.0379	794.7864
	RPL	7.0990	6.7575	7.3043	6.9238
	NVSI	1.6705	1.7003	1.6962	1.7332
	LVSI	0.1336	0.1368	0.1231	0.1422
57	FC	4556.5930	3804.9280	3806.4773	3806.2054
	RPL	28.8037	29.2642	29.3098	29.3097
	NVSI	5.7914	5.4953	5.6427	5.6452
	LVSI	0.2887	0.2468	0.2418	0.2421

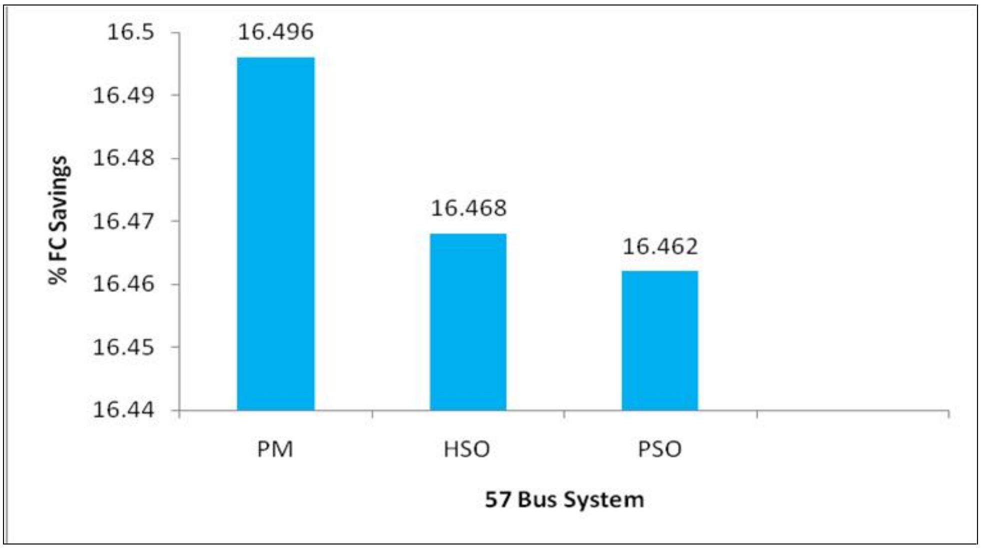
The objective in this case is the minimization of the FC. It is observed from Table 2 In case of 14 bus system the initial FC of 834.6716 $/h is reduced to 816.8550, 819.1639 and 818.0184 $/h by the PM, PSO and

HSO respectively.In case of 30 bus system the initial FC of 813.6941 \$/h is reduced to793.0635 \$/h , 795.0379\$/h and 794.7864\$/h by the PM , PSO ,HSO respectively.In case of 57 bus system the initial FC of 4556.5930 \$/h is reduced to 3804.9280, 3806.4773 and 3806.2054 \$/h by the PM, PSO and HSO respectively. It is very clear from the results that the PM offers best possible control settings with optimal dc link parameters, which minimize the FC to the lowest possible value, when compared with those of PSO and HSO. It is to be noted that PM offers better control settings with optimal dc link parameters, resulting in lower FC than those of PSO and HSO. The % FC savings of PM is graphically compared with those of PSO and HSO in Figure 1 for all the test systems. It is seen from the figures that the %FC savings of PM is greater than those of PSO and HSO.

Figure 1 Comparison of % FC Savings







5. CONCLUSION

The study of OPF is an important analysis in power system operational planning. A self adaptive FO strategy for multi-objective OPF problem for AC/DC systems is suggested with a with a view to prevent sub-optimal solutions. The FO is a meta heuristic, nature-inspired, optimization algorithm which is based on the social flashing behavior of fireflies. The algorithm uses sequential AC/DC load flow involving NR technique for computing the objective function during search and is able to offer the global best solution. The objective in this case is the minimization of FC and tested on IEEE 14,30 and 57 bus test systems.

ACKNOWLEDGEMENT

The author gratefully acknowledge the authorities of Joginpally B.R. Engineering College for their continued support, encouragement and the facilities provided to carry out this work.

REFERENCES

[1] Carpentier, J, “Contribution a l’Etude du Dispatching Economique,” Bulletin de la Societe Francaise des Electriciens, vol. 3, pp.431-474, 1962.
[2] Cong Ji, Zhi-nong Wei, Guo-qiang Sun, Yong-hui Sun, “AC-DC Decoupling Algorithm of Optimal Power Flow with HVDC System,” Applied Mechanics and Materials, vol.457, pp.1107-1112, 2014.
[3] Wang Feng , Le Anh Tuan, Lina Bertling Tjernberg, Anders Mannikoff and Anders Bergman, “A New Approach for Benefit Evaluation of Multiterminal VSC–HVDC Using a Proposed Mixed AC/DC Optimal Power Flow,” IEEE Trans. on Power Delivery, vol.29, no.1, 432-443, 2014.
[4] J.Arrillaga, C.RArnold and B.J.Harker, “Computer Modeling of Electrical power systems,” John Wiley & sons Ltd, pp.168-185, 1983.
[5] K. Mangoli, and K.Y. Lee, “Optimal real and reactive power control using linear programming, Electrical Power System Research,” vol.26, no.1, pp.1-10, 1993.
[6] O.Alsac,and B. Scott, “Optimal load flow with steady state security, IEEE Transactions on power Apparatus and systems,” vol.PAS, pp.745-751, 1974.
[7] Momoh JA and Zhu JZ, “Improved interior point method for OPF problems,” IEEE Trans Power Syst., vol.14, no.3, pp.1114–20, 1999.
[8] Burchett RC, Happ HH and Vierath DR, “Quadratically convergent optimal power flow,” IEEE Trans Power Apparatus Syst., vol.103, pp.3267–76, 1984.
[9] Abdel-Fattah Attia, Yusuf A.Al-Turki and Abdullah M.Abusorrah, “Optimal power flow using adapted genetic algorithm with adjusting population size,” Electric Power Components and Systems, vol.40, pp.1285-99, 2012.

[10] Sood YR, “Evolutionary programming based optimal power flow and its validation for deregulated power system analysis,” Int J Electr Power Energy Syst, vol.29, no. 1, pp.65-75, 2007.

[11] Mahmood Joorabian and Ehsan Afzalan, “Optimal power flow under both normal and contingent operation conditions using the hybrid fuzzy particle swarm optimisation and Nelder–Mead algorithm (HFPSO–NM),” Applied Soft Computing, vol.14, pp.623–633, 2014.

[12] A.V.Naresh babu, T. Ramana and S.Sivanagaraju, “Analysis of optimal power flow problem based on two stage initialization algorithm,” Int J Electr Power Energy Syst., vol.55, pp.91-99, 2014.

[13] Niknam T, Narimani MR, Jabbari M and Malekpour AR, “A modified shuffle frog leaping algorithm for multi-objective optimal power flow,” Energy, vol.36, pp.6420-32, 2011.

[14] Sivasubramani.S and Swarup.KS, “Multi-objective harmony search algorithm for optimal power flow problem,“ Int J Electr Power Energy Syst., vol.33, no.3, pp.745–52, 2011.

[15] Duman S, Güvenç U, Sönmez Y and Yörükeren N, “Optimal power flow using gravitational search algorithm,” Energy Convers Manage, vol.59, pp.86-95, 2012.

[16] B.Srinivasa Rao and K. Vaisakh, “Multi-objective adaptive clonal selection algorithm for solving environmental/economic diaptch and OPF problems with load uncertainty,” Electrical Power and Energy Systems, vol.53, pp.390-408, 2013.

[17] M. Rezaei Adaryani and A. Karami, “Artificial bee colony algorithm for solving multi-objective optimal power flow problem, Electrical Power and Energy Systems,” vol.53, pp. 219-230, 2013.

[18] Mojtaba Ghasemi, Sahand Ghavidel, Mohsen Gitizadeh and Ebrahim Akbari, “An improved teaching-learning-based optimization algorithm using Levy mutation strategy for non-smooth optimal power flow,” Electrical Power and Energy Systems, vol.65, pp.375-384, 2015.

[19] X. S. Yang, “Firefly algorithms for multimodal optimization,” in Proceedings of the Stochastic Algorithms: Foundations and Applications of Lecture Notes in Computing Sciences, Springer, Sapporo, Japan, vol.5792, pp. 178-178, 2009.

[20] P. Kessel and H. Glavitsch, “Estimating the voltage stability of a power system,” IEEE Trans. Power Deliver, vol.1, no.3, pp.346-54, 2000.

[21] Tahir Nadeem Malika, Azzam ul Asarb, Mudasser F. Wynec and Shakil Akhtar, “A new hybrid approach for the solution of nonconvex economic dispatch problem with valve-point effects,” Electric Power Systems Research, vol.80, pp.1128-1136, 2010.

[22] Jason Yuryevich and Kit Po Wong, “Evolutionary programming based optimal power flow,” IEEE Trans. on Power Systems, vol.14, no.4, pp.1245-1257, 1999.

[23] S. Prabhakar Karthikeyan, K. Palanisamy, C. Rani, I. Jacob Raglend and DP. Kothari, “Security constrained unit commitment problem with operational, power flow and environmental constraints,” WSEAS Trans. on Power Systems, vol.4, no.2, pp.53-56, 2009.