International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 5, May - 2014

Optimal Power Flow Analysis by using Hybrid Cuckoo Search Algorithm

M. Balasubba Reddy
Department of EEE
Prakasam Engineering College
Kandukur, India

Dr. Y. P. Obulesh
Deprtment of EEE
LBR College of Engineering
Mylavaram, India

Dr. S. Sivanaga Raju
Deprtment of EEE
UCE Kakinada,
Kakinada

Ch Venkata Suresh
Deprtment of EEE
UCE Kakinada
Kakinada

Abstract*— This paper proposes a novel algorithm for continuous non linear optimal power flow problem. The objective of the proposed method is to find the steady state operating point which minimizes the fuel cost with proper system performance in terms of limits on generator power voltage and line flow. The proposed approach employs hybrid cuckoo search algorithm for optimal setting of OPF control variables. This optimization algorithm is inspired by the life style cuckoo bird. Similar to the other evolutionary algorithms it starts with an initial population to solve the optimization problem. The proposed technique is tested on the standard IEEE 30 bus system various objectives and is compared with a conventional method. The simulation results verify the effectiveness of the proposed method.

Keywords—Optimal power flow, HCSA, Fuel cost, Transmission power loss, L-index,

I. INTRODUCTION

Power flow studies are of great importance for reliable, stable and secure operation of a power system and for proper planning as well as designed for future extension. In the past few decades, optimal power flow (OPF) problem has received greater attention, because it is one of the most powerful tools to analyze static systems of electrical energy. The main aim of OPF problem solution is to optimize a selected objective function such as fuel cost, power loss etc. In solving OPF problem, objective function is optimized by adjusting system control variable while satisfying the various constraints. Constraints are of two types, equality constraints normally power flow equations and inequality constraints which are limits on control variables and limits of power system dependant variables. In the past conventional methods were employed for solving OPF problem. Recently several classical optimization techniques have been employed for the solution of OPF problem.

Santos Jr., G.R.M. da Costa, describes a new approach to the optimal-power-flow problem based on Newton's method which it operates with an augmented original problem [1]. Momoh, et,l., proposed an improved quadratic interior point (IQIP) method is used to solve comprehensive OPF problem with a variety of objective functions, including economic dispatch, VAR planning and loss minimization [2]. M. R. AlRashidi etl., he investigated the applicability of Hybrid particle swarm optimization (HPSO) in solving the OPF problem under different formulations and considering different objectives [3]. Florin Capitanescu etl., he proposed Interior-point based algorithms for the solution of optimal power flow problems for the minimization of overall generation cost, minimization of active power losses, maximization of power system loadability and minimization of the amount of load curtailment [4]. An approach for the multi objective OPF problem using 'differential evolution' is presented by M.Varada Rajan, K.S.Swarup[5]. Xiaoqing Bai etl,. He described new solution using the semi definite programming (SDP) technique to solve the optimal power flow problems (OPF). The proposed method involves reformulating the OPF problems into a SDP model and developing an algorithm of interior point method (IPM) for SDP [6]. Xin-She Yang etl., he intend to formulate a new meta-heuristic algorithm, called Cuckoo Search (CS), for solving optimization problems [7]. T.Niknam, M.R.Narimani etl [8] has proposed 'improved particle swarm optimization for multi objective OPF considering cost, loss, emission voltage stability index. Ramin Rajabioun proposed a novel evolutionary algorithm Cuckoo Optimization Algorithm, suitable for continuous nonlinear optimization problems [9].

Xin-She yang,Suash Deb uses cuckoo search algorithm for Multi objective design optimisation [10].Multi objective harmonic search algorithm for OPF has been formulated by S.Sivasubramani, K.S.Swarup [11] to give well distributed pareto optimal solution. A technique was developed from the inspiration of swarm behaviors in nature namely 'gravitational search algorithm' by A Bhaltacharya for solving multi-objective OPF problem [12]. Modified ABC algorithm used by A Khorsandi etl [13] based on fuzzy multi-objective technique for optimal power flow problem to minimize total fuel cost of thermal units, total emission, and total power loss and voltage deviation.

Careful study of the former literature reveals that there is a multiple objective optimal power flow in which number of objectives can be optimized by a various evolutionary algorithms. But in this chapter we proposed a comprehensive optimization technique known as hybrid cuckoo search algorithm to solve OPF problem in power system. In this algorithm cross over technique is used with levy flights to modify the existing nests. Hence there are more chances to get best nest leads to optimal solution.

II. OPF PROBLEM FORMULATION

Optimal power flow solution aim is to optimize a selective objective function through optimal adjustment of control variables by satisfying equality and inequality constraints. The OPF problem can be mathematically formulated as follows:

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

$$\text{Subjected to constrain } g(x,u)=0 \quad (2)$$

$$h_{\min} \le h(x,u) \le h_{\max} \quad (3)$$

Where,

$C(x,u)$ is the objective function, x is the vector of dependent variables, u is the vector of independent or control variables, $g(x,u)$ represents equality constraints, $h(x,u)$ represents inequality constraints. Optimal power flow solution gives a set of optimal variables to achieve the main objective function as minimum generation cost, power loss etc. subjected to all the equality and inequality constraints. Here x is the vector of dependent variables consists of Active power output of generator at slack bus (P_{G1}), Load bus voltage (V_L), Reactive power output of generator (Q_G), Line flow limits (S_l)

Thus x can be written as,

$$x^T = [P_{G1},\ V_{L1},\ \ldots\ V_{LNL},\ Q_{G1},\ \ldots\ Q_{GNG},\ S_{l1}\ \ldots\ S_{lnl}] \quad (4)$$

Where NL =Number of load buses, NG =Number of generator buses, nl =Number of lines

u is the vector of independent variables such as continuous and discreet variables consists of Generator active power output P_G at all generators except at slake bus, Generator voltages V_G, Transformer tap settings T, Shunt VAr compensation(or) reactive power injections Q_c.

Here P_G, V_G are continuous variables and T and Q_c are the discrete variables. Hence u can be expressed as

$$u^T = [P_{G2}\ \ldots\ P_{GNG},\ V_{G1}\ \ldots\ V_{GNG},\ Q_{c1}\ \ldots\ Q_{cNC},\ T_1\ \ldots\ T_{NT}] \quad (5)$$

NT & NC are number of regulating transformers and VAr compensators

A. *Objective functions*

The main objective of OPF problem is to minimize the total fuel cost, real power loss of a transmission line in a system and L-Index.

1) Fuel cost (or) Generation cost

The fuel cost curves of thermal generators are modeled as a quadratic cost curve which can be represented as,

$$C = \sum_{i=1}^{NG} C_i(P_{Gi}) \quad (6)$$

$$C_i(P_{Gi}) = a_i P_{Gi}^2 + b_i P_{Gi} + d_i \ \$/hr \quad (7)$$

Where a_i, b_i and d_i are i^{th} generating unit cost coefficients, P_{Gi} is real power generation of i^{th} generating unit, NG is total number of generating units

2) Active power loss

Second objective function is to minimize the real power transmission line loss in the system which can be expressed as,

$$C = \sum_{i=1}^{nl} Loss_i \quad (8)$$

Power loss through a line is a function of power flow through it, which can be obtained from power flow solution.

3) L-index (or) Voltage stability index

The significance of L-index of load buses in a power system is to monitor the voltage stability. It uses information from the normal load flow. It is in the range of 0 to 1. Voltage collapse can be controlled by minimizing the sum of squares of L-indices for a given operating condition.

$$C = \sum_{j=NG+1}^{NB} L_j^2 \quad (9)$$

Where,

NB is the total number of buses in the system.

$$L_j = \left| 1 - \sum_{i=1}^{NG} C_{ji} \frac{V_i}{V_j} \right| \quad (10)$$

Where,

$$j = NG+1, \ldots, NB$$

C_{ji} is obtained from Y_{bus} matrices

B. *Constraints*

Constraints made on OPF problem are usually two types. They are equality constraints and inequality constraints

1) Equality constraints: These constraints mentioned in equation (2) are usually load flow equations described as

$$P_{Gi} - P_{Di} - \sum_{j=1}^{NB} |V_i||V_j||Y_{ij}| \cos(\theta_{ij} - \delta_i + \delta_j) = 0 \quad (11)$$

$$Q_{Gi} - Q_{Di} + \sum_{j=1}^{NB} |V_i||V_j||Y_{ij}| \cos(\theta_{ij} - \delta_i + \delta_j) = 0 \quad (12)$$

Where,

δ_i, δ_j are phase angles of voltages at i^{th} and j^{th} bus

$|Y_{ij}|$, θ_{ij} are the bus admittance magnitude and angle between i^{th} and j^{th} bus

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 5, May - 2014

2) Inequality Constraints

These are the constraints represents the system operational and security limits which are continuous and discrete constraints.

Generator Constraints:

These are the generator real and reactive power constraints

$$P_{Gi\min} \le P_{Gi} \le P_{Gi\max}; \qquad i = 1, 2, ..., NG \qquad (13)$$

$$Q_{Gi\min} \le Q_{Gi} \le Q_{Gi\max}; \qquad i = 1, 2, ..., NG \qquad (14)$$

Voltage Constraints:

Generation bus voltages are restricted by their upper and lower limits

$$V_{i\min} \le V_i \le V_{i\max}; \qquad i = 1, 2, ..., NB \qquad (15)$$

Transformer Tap Setting Constraints:

Tap setting of transformers are restricted by their upper and lower limits

$$T_{i\min} \le T_i \le T_{i\max}; \qquad i = 1, 2, ..., NT \qquad (16)$$

Shunt VAr Compensator Constraints:

Shunt VAr compensator constraints are given by,

$$Q_{Ci\min} \le Q_{Ci} \le Q_{Ci\max}; \qquad i = 1, 2, ..., NC \qquad (17)$$

Security constraints:

These are the constraints includes voltages at buses and transmission line loading

$$V_{i\min} \le V_i \le V_{i\max}; \qquad i = 1, 2, ..., NB \qquad (18)$$

$$S_{Li} \le S_{Li\max}; \qquad i = 1, 2, ..., NL \qquad (19)$$

III. Overview of Cuckoo Search Algorithm

The cuckoo search algorithm is a recently developed optimization algorithm, which is suitable for solving continuous non linear optimization problems. This algorithm was developed from the lifestyle of Cuckoo bird family. The basic incentive for developing algorithm is special life style of cuckoo birds, characteristics in egg laying as well as breeding. Usually cuckoo algorithm starts with initial number of cuckoos which have to lay eggs in some host bird's nests. Since cuckoo eggs are almost similar to host bird's eggs. When cuckoo laid eggs in the host birds nest's some of those eggs have the opportunity to grow up and became mature Cuckoo. Some other eggs are detected by hosts bird's and are killed. The nests in which more eggs survive reveal the suitability of nests in that area. The more eggs survival rate in an area shows more profit in that area.

Cuckoo searches for the nest where there is more chance to grow eggs and turn into a mature Cuckoo. These matured Cuckoos will form societies. Each society has its habitat region to live in. The habitat in which more number of eggs grown to mature Cuckoos will be the destination for the Cuckoos in other societies. Thus all the Cuckoos immigrate towards this best habitat. By knowing the probable number of eggs each cuckoo has and cuckoo's distance to the best habituate egg laying radii is calculated. Now cuckoo starts to lay egg within the egg laying radius. Thus best habitat with maximum profit value is obtained where maximum cuckoo population is gathered. In an optimization problem, the value of problem variables must be formed as an array. In cuckoo optimization algorithm such an array is called habitat.

$$Habitat = [x_1,\ x_2,\ ....\ x_n] \qquad (20)$$

Where, habitat is an array of n-variables representing current living position of cuckoos. The profit of habitat is estimated by evaluating profit function as,

$$profit = F[habitat] = F[x_1, x_2, ...\ x_n] \qquad (21)$$

IV. Proposed Hybrid Cuckoo Search Algorithm

Cuckoo search algorithm is population based evolutionary computation technique. CSA has been applied to many optimization problems and observed that it yields to better performance. Main steps of hybrid cuckoo search optimization can be described as follows.

A. Initialization:

Randomly generate a population of specified size for each control variable is given by

$$x_{pq} = x_q^{\min} + rand(0,1) \times (x_q^{\max} - x_q^{\min}) \qquad (22)$$

Where,

$p = 1, 2, ..., n$; $q = 1, 2, ..., m$; $n =$ Number of host nests; $m =$ Number of control variables

$x_q^{\min}$ *and* $x_q^{\max}$ are minimum and maximum limits of q^{th} control variable

$rand(0,1)$ is uniformly distributed random number between 0 and 1

Population vector or target vector is of size $(n \times m)$ generated and it is used for evolutionary operations.

B. Levy flights

Levy flight operation is used in CSA compared to other evolutionary algorithms. A randomly distributed initial population of host nests is generated and then the population of solution is subjected to repeated cycles of search process of cuckoo bird. The cuckoo randomly chooses the nest position to lay egg is given in equations (23) and (25). For i^{th} cuckoo, while generating new solutions levy flight is performed

$$x_i(t+1) = x_i(t) + Spq \times \alpha \oplus Levy(\lambda) \qquad (23)$$

Where

α is generated randomly between -1 and 1; $\oplus$ Gives entry wise multiplication

$s_{pq} > 0$, it is the step size if it is too large the new solution is generated will be far away from the old, and too small search is not efficient. Hence step size is calculated as

$$s_{pq} = x_{pq}^t - x_{fq}^t \quad (24)$$

Where $p, f = 1, 2, ..., n$; $q = 1, 2, ..., m$;

levy flights in which the step lengths are distributed according to heavy tailed probability distribution mathematically

$$Levy(\lambda) = \left| \frac{\Gamma(1+\lambda) \times \sin\left(\frac{\pi \times \lambda}{2}\right)}{\Gamma\left(\frac{1+\lambda}{2}\right) \times \lambda \times 2^{\left(\frac{\lambda-1}{2}\right)}} \right|^{1/\lambda} \quad ; \quad 1 < \lambda \leq 3 \quad (25)$$

Some of the new solutions should be generated by levy walk around the best solution obtained so far, which will speed up the local search. Above levy flight equation gives modified variables in the population vector x_{pq}^{t+1} i.e, belongs to p^{th} nest and q^{th} control variable. Here old x_{pq} variable is modified with respect to f^{th} neighborhood's nest, using eqn (20) cuckoo chooses the nest and the egg laid by cuckoo is evaluated.

C. Cross over

Once population of random set of points is created, a reproduction operator can be used to select good population. Recently new efficient crossover operators have been designed for searching process.

$$x_{pq}^{new} = (1-\lambda) \times x_{1q}^{ref} + \lambda \times x_{pq}^{old} \quad (26)$$

Where, λ is random number between 0 and 1.

Modified value of x_{pq} is obtained by the crossover of old value and its reference value. After getting new values of control variables for total number of nests, whose limits has to check if control variable obtained is beyond its maximum limit equate it to maximum and below its minimum limit equate it to minimum otherwise keep the value same as obtained.

D. Selection

For this work sorting and ranking process is used. By comparing fitness vectors obtained randomly and after performing crossover process. Now fitness vector is obtained for new population, the fitness vector with minimum fitness value will be memorized. Now, the fitness vectors in which fitness values are ranked from lower to higher value. Then lowest fitness value and its corresponding population value are treated as best, and best population vector is considered for the next generation until the stopping criteria is reached.

E. Stopping criteria

The stopping criteria is the number of generations equals to the specified maximum number of generations.

V. RESULTS AND ANALYSIS

In order to demonstrate the effectiveness and robustness of the proposed method, the example namely IEEE 30 bus system have been considered. Implemented on a personal computer with i3-370M processor 2.40 GHz and 3 GB RAM. The input parameter of the proposed method for the example is given in Table 1. Table 2 gives the comparison of OPF solutions for existing GA and proposed method. The solution for optimal power flow problem has been obtained using proposed method and is tabulated in Table 3. The convergence characteristics for the test system such as cost, loss and L-index with number of iterations are shown in Fig.1, Fig.2, and Fig.3 respectively. From Table 2, it can be observed that the OPF solution obtained using proposed method is close to the existing method. But, the total real power generation, and cost is less in the proposed method than existing GA method. From Table 3 it is observed that total cost of generation is minimum in case-1, power loss is minimum in case-2, voltage stability index in case-3 compared to other cases.

From Fig 1 it is observed that generation cost decreases as the number of iterations increases initially graph starts at higher value and slowly decreases with respect to iterations reaches to optimal value and maintained as constant. From Fig 2 it is observed that power loss decreases with increase in number of iterations. Fig 3 gives variation of L-index with iteration count in which voltage stability improved with increase in number of iterations.

TABLE I. INPUT PARAMETERS FOR TEST EXAMPLE

Parameters	Quantity
Number of host nest	50
Recombination constant	rand(0,1)
Number of Iteration	100
Levy flight constant (λ)	$1 \leq \lambda \leq 3$
Levy flight constant (α)	rand(-1,1)

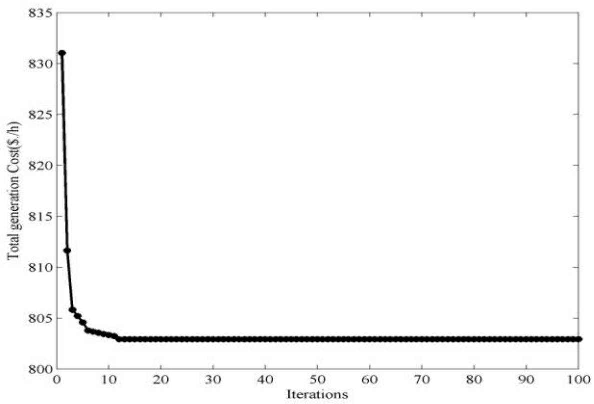

Fig. 1. Variation of total real power generation with number of iterations

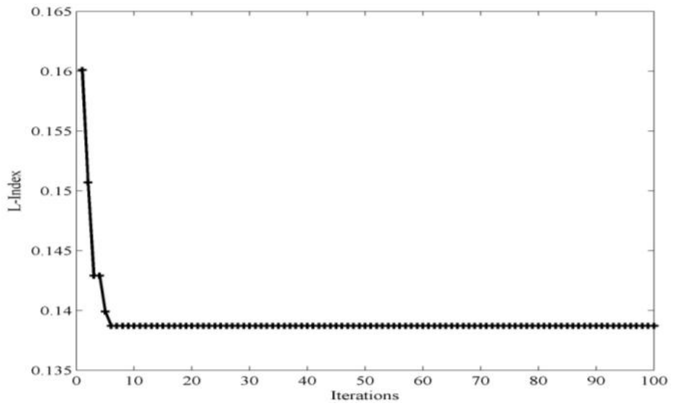

Fig. 2. Variation of total power loss with number of iterations

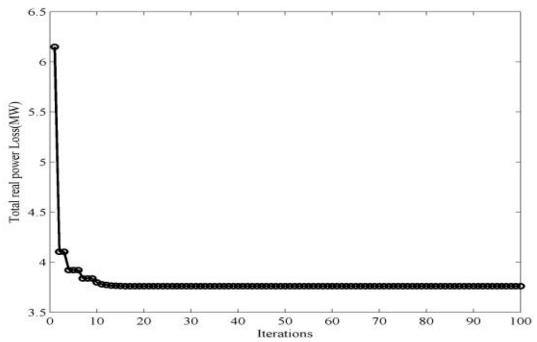

Fig. 3. L-Index value with Iteration

TABLE II. COMPARISON OF OPF FOR IEEE 30 BUS SYSTEM

Parameter		Existing GA method[14]	Proposed Method
Real power generation (MW)	P_{G1}	174.833	173.1757
	P_{G2}	48.885	48.9576
	P_{G5}	23.784	21.0722
	P_{G8}	20.196	21.1542
	P_{G11}	13.137	12.8771
	P_{G13}	12.220	15.4747
Total real power generation (MW)		293.055	292.711
Total cost ($./h)		803.916	802.9293

TABLE III. OPF SOLUTION FOR IEEE 30 BUS SYSTEM FOR DIFFERENT CASES

	Control parameters	Case-1	Case-2	Case-3
Real power generation (MW)	P_{G1}	173.1757	64.5787	133.7418
	P_{G2}	48.9576	73.1716	37.5136
	P_{G5}	21.0722	49.1044	46.7400
	P_{G8}	21.1542	34.6496	23.7323
	P_{G11}	12.8771	29.3441	26.5676
	P_{G13}	15.4747	36.3133	21.3126
Generator voltages (p.u.)	V_{G1}	1.0412	1.0350	1.0351
	V_{G2}	1.0219	1.0295	1.0214
	V_{G5}	0.9662	1.0297	1.0369
	V_{G8}	0.9960	1.0217	1.0093
	V_{G11}	0.9877	1.0249	1.0227
	V_{G13}	1.0340	1.0293	1.0870
Transformer tap setting (p.u.)	T_{6-9}	1.0171	1.0648	0.9832
	T_{6-10}	0.9594	0.9786	0.9629
	T_{4-12}	1.0580	0.9810	1.0300
	T_{28-27}	0.9722	0.9597	0.9428
Shunt Compensator (MVAr)	Q_{C10}	1.2700	4.1213	0.4928
	Q_{C12}	1.5371	2.4140	2.6806
	Q_{C15}	1.4055	2.7293	4.5697
	Q_{C17}	0.7954	3.0256	3.7292
	Q_{C20}	1.8001	3.3708	3.2782
Shunt Compensator (MVAr)	Q_{C21}	3.4375	1.7614	4.8780
	Q_{C23}	3.4257	2.3555	4.6410
	Q_{C24}	2.5635	3.4874	4.2743
	Q_{C29}	2.6118	2.9807	4.4005
Total real power generation (MW)		292.7115	287.1618	289.6080
Cost (Rs./h)		**802.9293**	940.4399	862.5843
Total real power loss (MW)		9.3115	**3.7618**	6.2080
L-index		0.1815	0.1562	**0.1387**

VI. CONCLUSION

In this paper the proposed hybrid cuckoo search method has been presented.The proposed method employes levy flights and cross over operations. The proposed method proceed in optimal way with the above two operations to modify the worst nests position towards the best. The effectiveness of the proposed method has demonstrated through IEEE 30 bus system. The results obtained for test system using proposed method is compared with existing method. The observations reveal that the results obtained using proposed method is close to the existing method. Also, it is clear that the generation cost, total real power loss obtained is minimum. Voltage stability index also improved with the proposed method.

REFERENCES

[1] A. Santos Jr, G.R.M. da Costa, "Optimal-power-flow solution by Newton's method applied to an augmented Lagrangian function," IEE Proc-Gener, Transm. Distrib. Vol.142, No. 1, Jan. 1995, PP. 33–36.

[2] J. A. Momoh, J.Z. Zhu, "Improved Interior Point Method for OPF Problems," IEEE Trans. On Power Systems, Vol.14, No. 3, Aug. 1999, PP. 1114–1120.

[3] M. R. AIRashidi, M.E. EI-Hawary, "Hybrid Particle Swarm Optimization Approach for Solving the Discrete OPF Problem Considering the Valve Loading Effects," IEEE Trans. On Power Systems, Vol.22, No. 4, Nov. 2007, PP. 2030–2038.

[4] Florin Capitanescu, Mevludin Glavic, Damien Ernst, Louis Wehenkel, "Interior-point based algorithms for the solution of optimal power flow problems," Electric Power Syst. Research, Vol.77, 2007, PP. 508-517.

[5] M.Varadarajan, K.S. Swarup, "Solving multi-object optimal power flow using differential evolution," IET Gener. Transm. Distrib., Vol. 2, 2008, PP. 720-730.

[6] Xiaoqing Bai, Hua Wei, Katsuki Fujisawa, Yong Wang, "Semi definite programming for optimal power flow problems," Electrical Power and Energy Syst., Vol. 30, 2008, PP. 383-392.

[7] Xin-She Yang, Suash Deb, "Cuckoo Search via Levy Flights," IEEE Publications, USA, 2009, PP. 210-214.

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

[9] Ramin Rajabioun, "Cuckoo Optimization Algorithm," Applied soft computing, Vol.11, 2011, PP. 550821-5518.

[10] Xin-She Yang, Suash Deb, "Multiobject cuckoo search for design optimization," Computers and operations research, 2011.

[11] S. Sivasubramani, K.S. Swarup, "Multi-objective harmony search algorithm for optimal power flow problem," Electrical power and Energy Systems, Vol.33, 2011, PP. 745-752.

[12] A. Bhattacharya, P.K. Roy, "Solution of multi-objective optimal power flow using gravitational search algorithm," IET Gener. Transm. Distrib., Vol.6, Iss. 8, 2012, PP. 751–763.

[13] A.Khorsandi, S.H. Hosseinian, A. Ghazanfari, "Modified artificial bee colony algorithm based on fuzzy multi-objective technique for optimal power flow problem," Electric power systems research, Vol.95, 2013, PP. 206–213.

[14] Yog Raj Sood, "Evolutionary programming based optimal power flow and its validation for deregulated power system analysis," Electrical power and energy systems, Vol.29, 2007, PP. 65-75