ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 6, June 2017

Solution of Optimal Reactive Power Dispatch by Fire Fly algorithm

Dr.A.Subramanian[1], R.Viola[2], S.Vijayaraj[3]

Professor, Dept. of EEE, IFET College of Engineering, Villupuram, Tamilnadu, India[1]

UG Student, Dept. of EEE, IFET College of Engineering, Villupuram, Tamilnadu, India[2]

Assistant Professor, Dept. of EEE, KCET, Cuddalore, Tamilnadu, India[3]

ABSTRACT: This study presents an efficient and reliable evolutionary-based approach, termed as Fire Fly Algorithm (FFA), to solve the optimal reactive power dispatch (ORPD) problem of power system. The performance of the proposed FFA is examined and tested, successfully, on standard IEEE-30 test power systems for the solution of ORPD problem in which control of bus voltages, tap position of transformers and reactive power sources are involved. The objective function considered is either minimisation of active power transmission loss or that of total voltage deviation or enhancement of voltage stability index. The results offered by the proposed FFA are compared with those offered by other evolutionary optimisation techniques surfaced in the recent state-of-the-art literature. Simulation results indicate that the proposed FFA yields superior solution over the other recently surfaced popular techniques in terms of effectiveness and convergence speed.

KEYWORDS: Reactive Power Dispatch, Fire Fly Algorithm, Loss

I. INTRODUCTION

Optimal reactive power dispatch problem is one of the difficult optimization problems in power systems. The sources of the reactive power are the generators, synchronous condensers, capacitors, static compensators and tap changing transformers. The problem that has to be solved in a reactive power optimization is to determine the required reactive generation at various locations so as to optimize the objective function. Here the reactive power dispatch problem involves best utilization of the existing generator bus voltage magnitudes, transformer tap setting and the output of reactive power sources so as to minimize the loss and to enhance the voltage stability of the system. It involves a non linear optimization problem. Various mathematical techniques have been adopted to solve this optimal reactive power dispatch problem. These include the gradient method , Newton method and linear programming .The gradient and Newton methods suffer from the difficulty in handling inequality constraints. To apply linear programming, the input-output function is to be expressed as a set of linear functions which may lead to loss of accuracy. Recently global optimization techniques such as genetic algorithms have been proposed to solve the reactive power flow problem . A genetic algorithm is a stochastic search technique based on the mechanics of natural selection. In this paper, genetic algorithm is used to solve the voltage constrained reactive power dispatch problem. The proposed algorithm identifies the optimal values of generation bus voltage magnitudes, transformer tap setting and the output of the reactive power sources so as to minimize the transmission loss and to improve the voltage stability. The effectiveness of the proposed approach is demonstrated through IEEE-30 bus system. The test results show the proposed algorithm gives better results with less computational burden and is fairly consistent in reaching the near optimal solution .

In this paper, FFA is applied for achieving enhanced computational speed and improved convergence profile of ORPD problem on standard IEEE-30 bus power system. The simulation results yielded by the proposed FFA technique are compared with those offered by the other computational intelligence-based techniques.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 6, June 2017

II. PROBLEM FORMULATION

ORPD problem is, mainly, concerned with either minimisation of PLoss or that of TVD or improvement of VSI, satisfying various equality and inequality constraints.

Minimisation of P_{loss}:

The general formulation of Ploss minimisation problem may be expressed as follows :

$$\text{minimize } J_1(x_1, x_2) = \text{minimize } P_{loss}$$
$$= \sum_{K=1}^{NL} \left[G_k \left(V_p^2 + V_q^2 - 2V_p V_q \cos\delta_{pq} \right) \right] \quad (1)$$

subject to

$$\begin{Bmatrix} g(X_1, X_2 = 0) \\ h(X_1, X_2 \leq 0) \end{Bmatrix} \quad (2)$$

where $J_1(x_1, x_2)$ is the active power transmission loss minimisation function, X_1 is the vector of dependent variables consisting of load voltages $\left(V_{L1}, \dots, V_{LN_{PQ}}\right)$ generators' reactive powers $\left(Q_{G1}, \dots, Q_{GN_{PV}}\right)$ and transmission line loadings $\left(S_{L1}, \dots, V_{LN_L}\right)$ X_2 is the vector of control variables consisting of generators' voltages $\left(V_{G1}, \dots, V_{GN_{PV}}\right)$ transformers' tap settings $\left(T_1, \dots, T_{N_T}\right)$ and reactive power injections $\left(Q_{C1}, \dots, Q_{CN_C}\right)$, G_k is the conductance of branch k, V_p, V_q are voltages of the p_{th} and the q_{th} buses, respectively and δ_{pq} is the voltage angle difference between buses p and q. Therefore X_1 and X_2 may be expressed as

$$X_1 = [V_{L1,} \dots \dots V_{LN_{PQ},} Q_{G1,\dots\dots} Q_{GN_{PV},} S_{L1\dots\dots,} S_{LN_L} \quad (3)$$
$$X_{2=} \left[V_{G1,\dots\dots} V_{GN_{PV},} T_{1,\dots\dots} T_{N_T,} Q_{C1\dots\dots\dots} Q_{CN_C} \right] \quad (4)$$

where N_{PV} is the number of generator buses, N_{PQ} is the number of load buses, N_L is the number of transmission lines, N_T is the number of tap setting transformer branches and N_C is the number of capacitor banks.

Minimisation of TVD:

The general formulation of TVD minimisation objective may be stated as in (5)

$$\text{minimize } J_2(x_1, x_2) = \text{minimize TVD} = \sum_{P=1}^{N_{PQ}} \left| V_P - V_P^{ref} \right| \quad (5)$$

where $J_2(x1, x2)$ is the TVD minimisation objective function, V_p is the voltage at bus p and V_P^{ref} is the desired value of the voltage magnitude of the p_{th} bus, taken as 1 pu.

Improvement of VSI:

The general objective of VSI improvement problem may be stated as in (6)

$$\text{Minimise } J_3(X_1, X_2) = \text{Minimise}(L_{max})$$
$$= \min[\max(LK)], \qquad K = 1,2 \qquad N\,P\,Q \quad (6)$$

where Lk is the voltage stability indicator (L-index) of the kth node. The value of Lk may be written as

$$L_k = \left| 1 - \sum_{P=1}^{NPV} m_{qp} \frac{Vp}{Vq} < \{\lambda pq + (\theta_p - \theta_q)\} \right| \quad (7)$$

where Mqp are the (p, q)th components of the sub-matrices obtained from partial inversion of Y_{bus} matrix.

The value of M_{qp} is given by (8)

$$M_{qp} = -[Y_{qq}]^{-1}[Y_{qp}] \quad (8)$$

where λpq is the phase angle of M_{qp}, θ_p, θ_q are phase angles of the pth and the qth bus voltages, respectively, Y_{qq} is the self-admittance term of the qth bus and Y_{qp} is the mutual admittance between the qth and pth buses.

Equality constraints:

constraints representing the load flow equations given by (9)

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 6, June 2017

$$\begin{cases} P_{Gp} - P_{Lp} = \sum_{q=1}^{NB} V_p \| V_q (G_{pq}\cos\delta_{pq} + B_{pq}\sin\delta_{pq}) \\ Q_{Gp} - Q_{Lp} = \sum_{q=1}^{NB} Vp\|Vq(G_{pq}\sin\delta_{pq} - B_{pq}\cos\delta_{pq} \end{cases} \quad (09)$$

where PGp, QGp are injected active and reactive powers, at the pth bus, respectively, PLp , QLp are active and reactive power demands, at the pth bus, respectively, Gpq, Bpq are transfer conductance and susceptance, between the pth and the qth buses, respectively and NB is the number of buses.

Inequality constraints:

i**. Generator constraints:**

For all the generator voltages (including slack bus), real and reactive power outputs (including slack bus) must be restricted within their lower and upper limits as stated in (10)

$$\begin{cases} V_{Gp}^{Min} \le V_{Gp} \le V_{Gp}^{Max}, p = 1,2, \dots \dots . N_{PV} \\ V_{Gp}^{min} \le Q_{Gp} \le Q_{Gp}^{max}, P = 1,2 \dots \dots \dots N_{PV} \end{cases} \quad (10)$$

ii**. Transformer constraints:**

Transformer tap settings must be within their specified lower and upper limits as presented in (11)

$$T_{GP}^{min} \le Q_{GP} \le Q_{GP}^{max} , p = 1,2 \dots \dots . . N_T \quad (11)$$

iii. Shunt VAR compensator constraints:

Reactive power outputs of shunt VAR compensators must be restricted within their lower and upper limits as written in (12)

$$Q_{CP}^{min} \le Q_{CP} \le Q_{CP}^{max} \; p = 1,2 \dots \dots N_C \quad (12)$$

iv. **Security constraints:**

These include the constraints on voltages at load buses and transmission line loadings. Each of these constraints must be within their lower and upper operating limits, as expressed in (13) and (14), respectively

$$V_{LP}^{min} \le V_{Lp} \le V_{LP}^{max} , p = 1,2 \dots \dots . . , N_{PQ} \quad (13)$$

$$S_{LP} \le S_{LP}^{max}, p = 1,2 \dots \dots . . N_L \quad (14)$$

III. FIREFLY ALGORITHM FIREFLY IN NATURE

Fireflies or glowworms are the creatures that can generate light inside of it. Light production in fireflies is due to a type of chemical reaction. This process occurs in specialized light-emitting organs, usually on a firefly's lower abdomen. It is thought that light in adult fireflies was originally used for similar warning purposes, but evolved for use in mate or sexual selection via a variety of ways to communicate with mates in courtships. Although they have many mechanisms, the interesting issues are what they do for any communication to find food and to protect themselves from enemy hunters including their successful reproduction. The pattern of flashes is often unique for a particular species of fireflies. The flashing light is generated by a chemical process of bio luminescence. However, two fundamental functions of such flashes are to attract mating partners or communication, and to attract potential victim. Additionally, flashing may also serve as a protective warning mechanism. Both sexes of fireflies are brought together via the rhythmic flash, the rate of flashing and the amount of time form part of the signal system. Females respond to a male's unique pattern of flashing in the same species, while in some species, female fireflies can mimic the mating flashing pattern of other species so as to lure and eat the male fireflies who may mistake the flashes as a potential suitable mate. The light intensity at a particular distance from the light source follows the inverse square law. That is as the distance increases the light intensity decreases. Furthermore, the air absorbs light which becomes weaker and weaker as there is an increase in the distance. There are two combined factors that make most fireflies visible only to a limited distance that is usually good enough for fireflies to communicate each other. The flashing light can be formulated in such a way that it is associated with the objective function to be optimized. This makes it possible to formulate new meta-heuristic algorithms.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 6, June 2017

The firefly algorithm (FFA) is a meta-heuristic algorithm, inspired by the flashing behaviour of fireflies. The primary purpose for a firefly's flash is to act as a signal system to attract other fireflies. Now this can idealize some of the flashing characteristics of fireflies so as to consequently develop firefly inspired algorithms. For simplicity in describing our new Firefly Algorithm (FFA) , there are the following three idealized rules. On the first rule, each firefly attracts all the other fireflies with weaker flashes. All fireflies are unisex so that one firefly will be attracted to other fireflies regardless of their sex. Secondly, attractiveness is proportional to their brightness which is inversely proportional to their distances. For any two flashing fireflies, the less bright one will move towards the brighter one. The attractiveness is proportional to the brightness and they both decrease as their distance increases. If there is no brighter one than a particular firefly, it will move randomly. Finally, no firefly can attract the brightest firefly and it moves randomly. The brightness of a firefly is affected or determined by the landscape of the objective function. For a maximization problem, the brightness can simply be proportional to the value of the objective function. Other forms of brightness can be defined in a similar way to the fitness function in genetic algorithms. Based on these three rules, the basic steps of the firefly algorithm (FFA) can be summarized as the pseudo code shown below.

PSEUDO CODE OF THE FFA:

Begin FFA Procedure;
Initialize algorithm parameters:
MaxGen: the maximal number of generations
γ: the light absorption coefficient
r: the particular distance from the light source
d: the domain space
Define the objective function of f(x), where $x = (x_1, \ldots\ldots, x_d)^T$
Generate the initial population of fireflies or x_i (i=1, 2... n)
Determine the light intensity of I_i at x_i via f (x_i)
  While (t<MaxGen)
    For i = 1 to n (all n fireflies);
      For j=1 to n (n fireflies)
 If $(I_j > I_i)$, move firefly i towards j; **End if**
 Attractiveness varies with distance r via exp [-γ r2];
 Evaluate new solutions and update light intensity;
      End for j;
    End for i;
    Rank the fireflies and find the current best;
  End while;
Print the results;
End procedure;

In the firefly algorithm there are two important issues of the variation of light intensity and the formulation of the attractiveness. For simplicity, it is assumed that the attractiveness of a firefly is determined by its brightness which in turn is associated with the encoded objective function of the optimization problems. On the attractiveness of the FFA the main form of attractiveness function or $\beta(r)$ can be any monotonically decreasing functions such as the following generalized form of

$$\beta(r) = \beta_0 e^{-\gamma . r^m} (11)$$

where r or r_{ij} is the distance between the i^{th} and j^{th} of two fireflies.
β_0 is the attractiveness at r = 0 and γ is a fixed light absorption coefficient. The distance between any two fireflies 'i' and 'j' at x_i and x_j is the Cartesian distance as follows:

$$r_{ij} = ||x_i - x_j|| = \sqrt{\sum_{k=1}^{d} (x_{ik} - x_{jk})^2} \quad (15)$$

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 6, June 2017

where x_{ik} is the k^{th} component of the i^{th} firefly (x_i). The movement of a firefly 'i' is attracted to another more attractive (brighter) firefly 'j', is determined by

$$x_{i+1} = x_i + \beta_0 e^{-\gamma . r_{ij}^2}(x_j - x_i) + \alpha(rand - 0.5) \quad (16)$$

where the second term is due to the attraction while the third term is the randomization with α being the randomization parameter. Rand is a random number generator uniformly distributed in the range of [0, 1]. For most cases in the implementation,

$$\beta_0 = 1 \quad \text{and} \quad \alpha = [0,1]$$

Furthermore, the randomization term can easily be extended to a normal distribution N (0, 1) or other distributions. The parameter γ characterizes the variation of the attractiveness, and its value is crucially important in determining the speed of the convergence and how the FFA behaves. In most applications, it typically varies from 0.001 to 100.

IV. SIMULATION RESULTS

FFA based results of the ORPD problem for Ploss, TVD and L-index minimisation objective of this test system is presented in Table 1. These results are compared with those offered by the algorithms such as KHA and CKHA.

Table.1.Best control variable settings for power loss, TVD and L-index minimisation.

Control variables	KHA [18]	CKHA [18]	Proposed FPA For Loss Minimization	Proposed FPA For TVD Minimization	Proposed FPA For L-index Minimization
V_{G1}	1.05	1.05	1.05	1.05	1.05
V_{G2}	1.0381	1.0473	1.0278	1.0256	1.02389
V_{G5}	1.011	1.0293	1.0293	1.0238	1.0229
V_{G8}	1.025	1.035	1.028	1.016	1.012
V_{G11}	1.05	1.05	1.05	1.05	1.05
V_{G13}	1.05	1.05	1.05	1.05	1.05
T_{11}	0.9541	0.9916	0.9686	0.9538	0.947
T_{12}	1.0412	0.9538	1.9538	1.9486	1.9369
T_{15}	0.9514	0.9603	0.9331	0.9327	0.9347
T_{36}	0.9541	0.967	0.948	0.946	0.946
QC_{10}	0.0089	0.0092	0.0092	0.0091	0.0097
QC_{12}	0	0	0	0	0
QC_{15}	0.0141	0.0153	0.0148	0.0139	0.0127
QC_{17}	0.04989	0.0497	0.0495	0.0492	0.0482
QC_{20}	0.0314	0.0302	0.0301	0.03	0.03
QC_{21}	0.0345	0.05	0.045	0.043	0.041
QC_{23}	0.0241	0.0134	0.0234	0.0281	0.0238
QC_{24}	0.05	0.05	0.05	0.05	0.05
QC_{29}	0.0107	0.0121	0.0111	0.0118	0.0116
Ploss, MW	3.65	3.24	***3.20***	3.52	3.70
TVD, pu	1.3415	1.3364	1.3852	***1.3252***	1.3583
L-index, pu	0.1425	0.1402	0.1413	0.1424	***0.13866***

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 6, June 2017

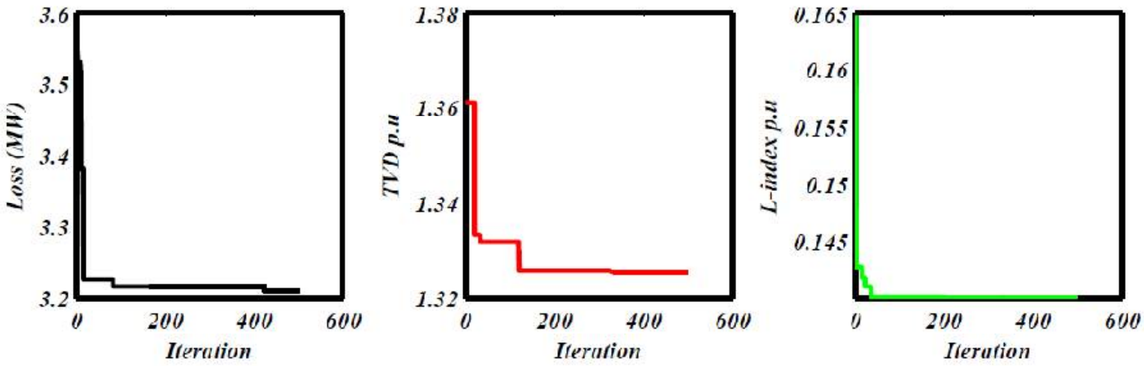

Figure.1.Convergence characteristics of loss, TVD and L-index minimization

V. CONCLUSION

In this paper, FFA is proposed to solve the ORPD problem of power system having varying degree of dimensions and complexities. To check the superiority of the proposed FFA, it is tested on standard IEEE-30 bus power system. Simulation results, as offered by the proposed FFA is compared with other popular techniques recently reported in the recent state-of-the-art literatures and it is proved that this method having better efficiency,flexibility and good stability.

REFERENCES

[1] O.Alsac,and B. Scott, “Optimal load flow with steady state security”, IEEE Transaction. PAS -1973, pp. 745-751.
[2] Lee K Y ,Paru Y M , Oritz J L –A united approach to optimal real and reactive power dispatch , IEEE Transactions on power Apparatus and systems 1985: PAS-104 : 1147-1153
[3] A.Monticelli , M .V.F Pereira ,and S. Granville , “Security constrained optimal power flow with post contingency corrective rescheduling” , IEEE Transactions on Power Systems :PWRS-2, No. 1, pp.175-182.,1987.
[4] Deeb N ,Shahidehpur S.M ,Linear reactive power optimization in a large power network using the decomposition approach. IEEE Transactions on power system 1990: 5(2) : 428-435
[5] E. Hobson ,’Network consrained reactive power control using linear programming, ‘ IEEE Transactions on power systems PAS -99 (4) ,pp 868=877, 1980
[6] K.Y Lee ,Y.M Park , and J.L Oritz, “Fuel –cost optimization for both real and reactive power dispatches” , IEE Proc; 131C,(3), pp.85-93.
[7] M.K. Mangoli, and K.Y. Lee, “Optimal real and reactive power control using linear programming” , Electr.Power Syst.Res, Vol.26, pp.1-10,1993.
[8] S.R.Paranjothi ,and K.Anburaja, “Optimal power flow using refined genetic algorithm”, Electr.Power Compon.Syst , Vol. 30, 1055- 1063,2002.
[9] D. Devaraj, and B. Yeganarayana, “Genetic algorithm based optimal power flow for security enhancement”, IEE proc-Generation.Transmission and. Distribution; 152, 6 November 2005.
[10] D.Devaraj ,’ Improved genetic algorithm for multi – objective reactive power dispatch problem’ European Transactions on electrical power 2007 ; 17: 569-581
[11] C.A. Canizares , A.C.Z.de Souza and V.H. Quintana , “ Comparison of performance indices for detection of proximity to voltage collapse ,’’ vol. 11. no.3 , pp.1441-1450, Aug 1996
[12] B.Gao ,G.K Morison P.Kundur ,’voltage stability evaluation using modal analysis ‘ Transactions on Power Systems ,Vol 7, No .4 ,November 1992.
[13] D Goldberg, “Genetic algorithms in search, optimization and machine learning”, Addison-Wesley,1989.
[14] -Deb,K.(201):Multi-objective optimization using evolutionary algorithms 1st ed.(John Wiley &Sons,Ltd.).
[15] - Eshelman.L.J and Schaffer;J.D.(193): Real coded genetic algorithms and interval schemata. In: foundations of Genetic Algorithms 2, Ed.L.Darrell Whitely (Morgan Kaugmann),PP 187-202
[16] Wu Q H, Ma J T. Power system optimal reactive power dispatch using evolutionary programming. IEEE Transactions on power systems 1995; 10(3): 1243-1248
[17] S.Durairaj, D.Devaraj, P.S.Kannan ,’ Genetic algorithm applications to optimal reactive power dispatch with voltage stability enhancement’ , IE(I) Journal-EL Vol 87,September 2006.
[18] Aparajita Mukherjee, Vivekananda Mukherjee, " Solution of optimal reactive power dispatch by chaotic krill herd algorithm", IET Gener. Transm. Distrib., 2015, Vol. 9, Iss. 15, pp. 2351–2362