Optimal Reactive Power Dispatch of Interconnected Power System Using Firefly Algorithm

S. N. V. S. K. Chaitanya, R. Ashok Bakkiyaraj, and B. Venkateswara Rao

Abstract In this paper, the multi objective optimization of minimization of real power transmission line loss and voltage deviation at the buses is achieved with the application of Firefly Algorithm (FA), which is a Meta heuristic algorithm. Through this nature inspired algorithm, the control parameters such as voltages at the generator buses, tap settings of transformers and the rating of reactive power compensation devices are controlled. Because of the intrinsic properties of FA, the output is said to be effective than other optimization techniques present. The proposed FA for the multi objective optimization is implemented on the IEEE 30 bus system.

Keywords Firefly algorithm · Multi objective optimization · Optimal reactive power dispatch · Real power loss · Voltage deviation

1 Introduction

With the constant increase in demand of power, burden on transmission lines, losses in the lines also increases, Das and Roy (2018) [1]. Measures must be taken such that transmission line losses are minimized instead of generating an additional power to meet the required demand which leads to effective usage of the input fuel and economically advantageous by Anbarasan and Jaya bharathi (2017) [2]. By dispatching the reactive power optimally even voltages are maintained in the rated limits. Along with conventional optimization methods, many heuristic techniques were also implemented as seen in below. Sundaram Pandya and Ranjith Roy (2015) recalled with ORPD with the main objective of declination of real power loss [3]. The same was applied to IEEE—14, 30, 57 and IEEE—39 New England bus test systems and are compared with various optimization techniques.

S. N. V. S. K. Chaitanya (✉) · B. Venkateswara Rao
Department of EEE, V R Siddhartha Engineering College (Autonomous), Vijayawada, Andhra Pradesh, India
e-mail: snvskchaitanya@gmail.com

R. Ashok Bakkiyaraj
Department of Electrical Engineering, Annamalai University, Chidambaram, Tamil Nadu, India

V. Komanapalli et al. (eds.), *Advances in Automation, Signal Processing, Instrumentation, and Control*, Lecture Notes in Electrical Engineering 700,
https://doi.org/10.1007/978-981-15-8221-9_22

Rebecca Ng Shin Mei, Mohd Herwan Sulaiman, Zuriani Mustaffa, Hamdan Daniyal (2017) introduced a newly surfaced optimization known as moth-flame optimization technique which is addressed to solve the problem of ORPD [4]. This technique makes use of moment of moths that travel during dark time and is applied to IEEE bus systems 30, 57. B. Shaw, V. Mukherjee, S. P. Ghoshal (2014) gave a solution for ORPD [5] by using an opposition based gravitational search algorithm which is based on the gravity and masses interaction which is further modified to opposition-based gravitational search algorithm and this study is applied on IEEE test systems −30 and 57. N. Sinsuphan, U. Leeton, T. Kulworawanichpang (2013) [6] discussed the overall power flow using Improved Harmony Search algorithm inspired by musicians improvisation formulated by Geem and was tested on five standard IEEE systems. K. Valipour and A. Ghasemi (2017) took harmony search algorithm further as modified harmony search algorithm for better results [7]. Dr. K. Lenin (2018) contributed to minimization of real power loss using upgraded red shaver swarm optimization algorithm based on the red shaver behavior and this was implemented on IEEE 30 bus system [8].

In this paper authors presents the usage of other nature inspired methodology known as Firefly algorithm is implemented which serves as the alternative to the present optimization techniques. Firefly algorithm is advantageous due to its ability of automatic sub division and dealing with multimodality. The paper presented is organized as stated:

Section 2: Formulation of ORPD problem
Section 3: Firefly Algorithm
Section 4: Simulation results
Section 5: Conclusions.

2 Problem Formulation

2.1 Objective Function

For minimization of real power loss the objective function is expressed as

$$F_1 = \text{Min}\{P_{\text{Loss}}(a, b)\} = \sum_{m=1}^{N_l} P_{\text{loss}} \tag{1}$$

For reliable operation of any system, the voltages must be within the acceptable limits. In order to minimize the total voltage deviation, then the objective function is expressed as

$$F_2 = \text{Min}\{V_{\text{deviation}}(a, b)\} = \sum_{n=1}^{N_b} \left|V_n - V_{\text{spec}}\right| \tag{2}$$

For multi objective function above stated 2 functions in Eqs. (1) and (2) are given equal weight age such that

$$F_3 = 0.5 * F_1 + 0.5 * F_2 \tag{3}$$

2.2 Constraints

In order to achieve all the above objectives, the following restraints must be contended. The equality constraint is the basic load flow equation which states that generation of power must meet its demand and losses which is shown in Eqs. 4 and 5 below

$$P_{Gz} - P_{Dz} - V_z \sum_{i=1}^{N_b} V_i \begin{pmatrix} G_{zi} \ \cos\theta_{zi} \\ B_{zi} \ \sin\theta_{zi} \end{pmatrix} = 0 \tag{4}$$

$$Q_{Gz} - Q_{Dz} - V_z \sum_{i=1}^{N_b} V_i \begin{pmatrix} G_{zi} \ \sin\theta_{zi} \\ B_{zi} \ cos\theta_{zi} \end{pmatrix} = 0 \tag{5}$$

The inequality constraints are

$$P_{Gm,}\text{min} \le P_{Gm} \le P_{Gm,}\text{max}; m \in N_g \tag{6}$$

$$Q_{Gm,}\text{min} \le Q_{Gm} \le Q_{Gm,}\text{max}; m \in N_g \tag{7}$$

$$V_{Gm,}\text{min} \le V_{Gm} \le V_{Gm,}\text{max}; m \in N_g \tag{8}$$

$$T_{m,}\text{min} \le T_m \le T_{m,}\text{max}; m \in N_t \tag{9}$$

$$Q_{cm,}\text{min} \le Q_{cm} \le Q_{cm,}\text{max}; m \in N_c \tag{10}$$

N_l, N_b, N_g, N_t, N_c denotes number of lines, buses, generators, Transformers, Capacitors.

3 Firefly Algorithm

Xin-She Yang (2008) developed an algorithm based on its flashing nature of fireflies [9]. Firefly's stands in the superiority compared to other developed meta heuristics techniques because of its three intrinsic idealized properties [10–12].

3.1 Implementation of FA for ORPD

(1) Initialize

- Number of fireflies
- Number of iterations
- Set the values of α, β and
- In this, the values of α, β and γ are considered as 0.2, 0.1 and 1 respectively.

(2) Set the iteration counter $i = 0$ and increase the iteration by $i = i + 1$.
(3) Calculate the fitness result of each firefly by substituting in the objective function stated in Eqs. (1), (2) and (3).
(4) Sort the fireflies depending on their light intensities and for every iteration find the best firefly. Light intensity is varied based on the distance between them.
(5) Move the fireflies (control variables) based on their light intensity.
(6) Continue the process till stopping criteria is reached.

4 Simulation Results and Discussions

4.1 IEEE 30 Bus System

This IEEE 30 bus system comprises of 6 generator buses including slack bus, 4 transformers with tap setting values and 3 reactive power compensation devices. These values are given in Sundaram Pandya and Ranjith Roy (2015) [3]. So, totally in 30 bus system have 13 control variables whose limits are stated below in Table 1.

Table 1 Limits of control variables

Variables	Min in p.u	Max in
Generator voltages	0.9	1.1
Tap settings of transformers	0.95	1.05
Shunt capacitors	0	0.20
Generator voltages	0.9	1.1
Tap settings of transformers	0.95	1.05

Table 2 Parameters of control variables and power loss

Control variables	FA
VG1	1.1000
VG2	1.0845
VG5	1.0538
VG8	1.0627
VG11	1.0935
VG13	1.0816
T4-12	1.0360
T6-9	1.0001
T6-10	1.0192
T27-28	1.0020
QC3in MVAR	20
QC10in MVAR	20
QC24in MVAR	10.5360
RPL	**16.0196**
VD	**1.0572**

Bold indicates the objective function values those are RPL (Real Power Loss) and VD (Voltage Deviation)

Case 1—Minimizing real power loss (RPL)

The control variables in this objective are tuned in order to minimize the real power losses of IEEE 30 bus system. The control variables values are shown in Table 2 along with its convergence characteristics in Fig. 1. Minimum, maximum, mean and standard deviations are shown in Tables 3 and 4.

Case 2—Minimizing voltage deviation (VD)

The bus voltages with its deviated value form 1 p.u are shown in Table 5. More voltage deviation in the system results in weak behavior of the system. Convergence characteristics of the system are shown in Fig. 2.

Case 3—Multi objective function

The multi objective function is considered here. The optimal values that control both the objectives and the convergence curve are shown in Table 6 and Fig. 3 respectively.

$$\text{Optimal value} = 0.5 * 0.1950 + 0.5 * 0.23 = 0.2125 \text{ p.u}$$

Thus, control of variables for minimization of real power losses, voltage deviation and for multi objective is discussed. Through multi objective loss are said to be better than second objective and voltage deviation is reduced considerably compared to the first case thus satisfying control of both the objectives.

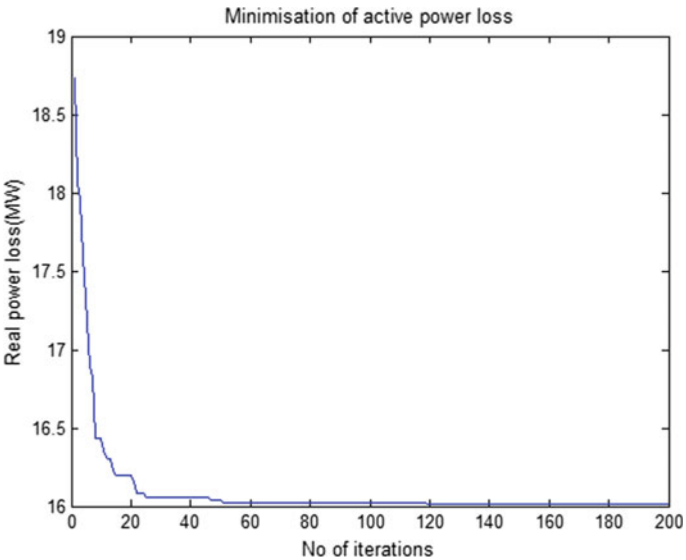

Fig. 1 Graph of convergence for minimization of losses in IEEE 30 bus system with FA

Table 3 Mean and standard deviation of Real Power losses in IEEE 30 bus system with FA

Quantity	Min value in MW	Max value in MW	Mean value in MW	Standard
Real power losses	15.9706	16.099	16.0196	0.0353

Table 4 Comparison of real power loss with different optimization techniques

Technique	Power loss (MW)
SGA by Subbaraj P and Narayana P (2009) [13]	16.0912
PSO by Sundaram Pandya and Ranjith Roy (2015) [3]	16.1810
FA	16.0196

5 Conclusions

In this paper, multi objective function for minimization of real power losses and voltage deviation is performed for IEEE 30 bus systems using FA. The obtained results for minimization of losses are compared with other stated papers and values achieved through FA are found to be superior and it is widely used because of its efficiency.

Table 5 Optimal values of bus voltage deviation of IEEE 30 bus system with FA by minimizing voltage deviation

Bus	Voltage in p.u	Bus	Voltage in p.u
1	0.0021	16	0.0016
2	0.0008	17	0.0027
3	0.0027	18	0.0115
4	0.0079	19	0.0126
5	0.0015	20	0.0076
6	0.0016	21	0.0022
7	0.0082	22	0.0041
8	0.0175	23	0.0021
9	0.0087	24	0.0092
10	0.0107	25	0.0078
11	0.0038	26	0.0100
12	0.0086	27	0.0156
13	0.0167	28	0.0010
14	0.0029	29	0.0044
15	0.0040	30	0.0160
VD		**0.2061**	
RPL		**20.0217**	

Bold indicates the objective function values those are RPL (Real Power Loss) and VD (Voltage Deviation)

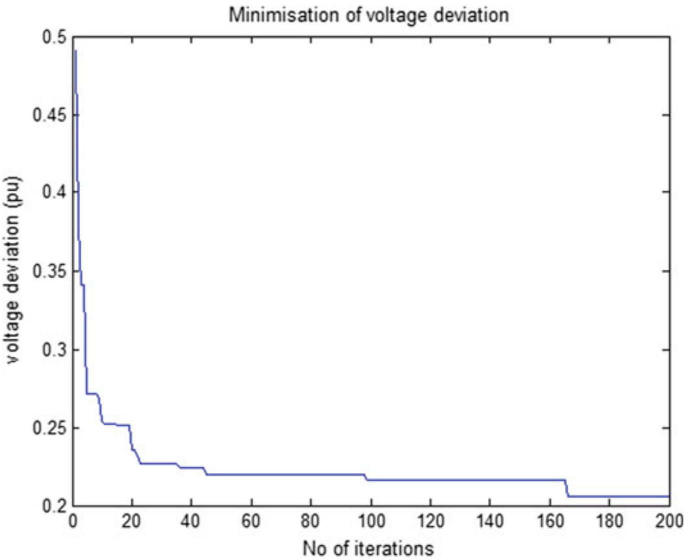

Fig. 2 Convergence curve of minimization of voltage deviation with FA

Table 6 Optimal values of active power loss and voltage deviation by considering multi objective optimization with FA

Control variables	FA
VG1	1.0171
VG2	1.0146
VG5	1.0042
VG8	1.0126
VG11	0.9975
VG13	1.0355
T4-12	1.0041
T6-9	0.9933
T6-10	0.9963
T27-28	0.9639
QC3 in MVAR	8.8785
QC10 in MVAR	19.1389
QC24 in MVAR	20
RPL	**19.50**
VD	**0.23**

Bold indicates the objective function values those are RPL (Real Power Loss) and VD (Voltage Deviation)

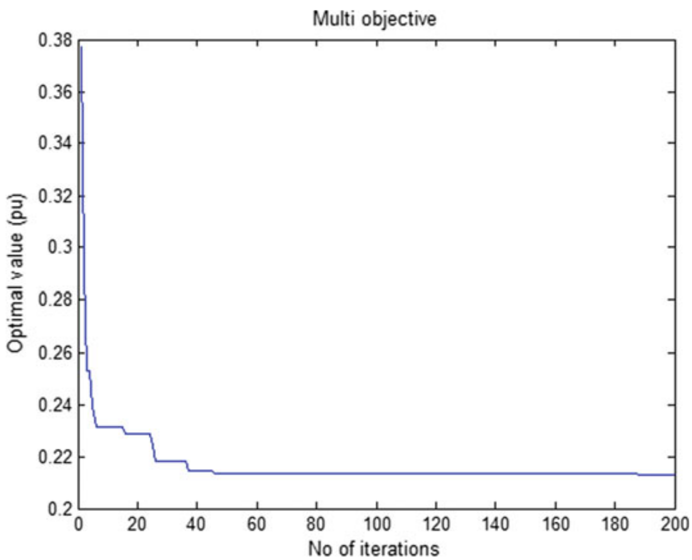

Fig. 3 Convergence characteristics for multi objective function with FA

References

1. Das T, Roy R (2018) Optimal reactive power dispatch using JAYA algorithm. Emerg Trends Electron Devices Comput Tech (EDCT) 1–6
2. Anbarasan P, Jaya bharathi T. (2017) ORPD solved by symbiotic organisam search algorithm. In: International conferences on innovations in power and advanced computing technologies, pp 1–8
3. Pandya S, Roy R (2015) Particle swarm optimisation based optimal reactive power dispatch. In: IEEE international conference on electrical, computer and communication technologies (ICECCT), pp 1–5
4. Mei RNS, Sulaiman MH, Mustaffa Z, Daniyal H (2017) Optimal reactive power dispatch by loss minimization using moth-flame optimization technique. Appl Soft Comput 59:210–222
5. Shaw B, Ghoshal SP, Mukherjee V (2014) Solution of reactive power dispatch of power systems by an opposition-based gravitational search algorithm. Int J Electr Power Energy Syst 55:29–40
6. Sinsuphan N, Leeton U, Kulworawninchpong T (2013) Optimal power flow solution using improved harmony search method. Appl Soft Comput 13:2364–2374
7. Valipour K, Ghashemi A (2017) Using a new modified harmony search algorithm to solve multi objective reactive power dispatch in deterministic and stochastic models. J. AI Data Mining 5:89–100
8. Lenin K (2018) Reduction of real power loss by upgraded red shaver swarm optimization algorithm. Adv Model Anal C 73:84–87
9. Yang XS (2013) Firefly algorithm recent advances and applications. Int J Swarm Intell 1:36–50
10. Gundavarapu V, Bathina V (2015) Thyristor controlled series capacitor for generation reallocation using firefly algorithm to avoid voltage instability. Majlesi J Electr Eng 9:1–9
11. Venkateswara RB, Kumar GN (2015) A comparative study of BAT and firefly algorithms for optimal placement and sizing of static VAR compensator for enhancement of voltage stability. Int J Energy Optim Eng 4:68–84
12. Suresh R, Bhaskaran J (2016) Firefly algorithm applied for optimal reactive power dispatch. Int J Adv Eng Technol 7:19–23
13. Subbaraj P, Narayana P (2009) Optimal reactive power dispatch using self-adaptive real coded genetic algorithm. Electric Power System Research 79:374–381