ODFF: Opposition and Dimension based Firefly for Optimal Reactive Power Dispatch

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Abstract: In Optimal Reactive Power Dispatch (ORPD) system, the main objective arises from the reduction of active power loss and the voltage deviation. In this paper, Opposition and Dimension based Firefly (ODFF) is proposed to achieve the objective. The experimentation is carried out in IEEE 14 and IEEE 39 benchmark bus system. The result obtained from the proposed OFDA is compared with the conventional methods like Genetic Algorithm (GA), Particle Swarm Optimization (PSO), Firefly (FF) and Artificial Bee Colony (ABC). Further, the comparative result proved that the proposed ODFF method provides less active power loss and voltage deviation with high convergence speed than those achieved by the existing methods.

Keywords: OFDM, Active power loss, Voltage deviation, ODFF

1. Introduction

The process of generation, transmission and distribution of power in the electrical power system is a complex task. The less use of power resources are made to withstand the security and reliability of the system [2]. Recently, (ORPD) has become as the continually increasing attention over developments of the power system. ORPD is one of the non- linear problems that should attain the minimum active power loss and voltage stability and maximum voltage deviation [25] [26]. Hence, the system is mainly controlled by the continuous and discrete control variables which include the generator bus voltages, transformer tap settings and reactive power of shunt VAR compensator. Those variables are controlled to satisfy both the equality and in equality constraints [27] [28] [29] [30].

Various classical optimization techniques such as linear programming [10], non- linear programming [8], quadratic programming [13], decomposition approach [12], diverse- integer programming [7], Newton-based method [9], dynamic programming [11] etc were used earlier to solve the ORPD problems. Since numerous local optima are present in ORPD, these aforesaid techniques are not possible to examine the global optima of the system. Further, in recent time, several meta-heuristic algorithms were implemented to overcome the limitations arising under the classical optimization methods. Those methods includes Bacterial Foraging algorithm (BFA) [15], Adaptive Genetic algorithm (AGA) [14], Particle Swarm Optimization (PSO) [16], Quantum- inspired Evolutionary algorithm (QFA) [17], Hybrid PSO (HPSO) [18], Evolutionary Programming (EP) [19] etc.

Later other advanced algorithms such as Differential Evolution (DE) [24], Chaotic Parallel Vector Evaluated Interactive Honey Bee Mating Optimization (CPVEIHBMO) [22], Enhance Firefly [20], Quasi- Oppositional Differential Evolution (QODE) [21], Hybrid Fuzzy Multi- Objective EA [23] etc were implemented by several researchers to solve the problems of the ORPD. But still the challenges such as computational complexity, non-linear and no- convex problems exist in ORPD system.

2. Literature Review

2.1 Related Works

In 2016, Brett and Alejandro [1] have proposed the branch flow modelling approach to maintain the reactive power in the distributed energy resources of the ORPD system. They have started the implementation in the ORPD system with balanced condition. The optimal power flow (OPF) was considered as the main problem, and have used the convex quadratic programming (QP) to maintain the operating condition of the system. The computation of QP was solved by the distribution algorithm that is based on the Alternating Direction Method of Multipliers (ADMM). Further, they have used the same procedure to solve the OPF problem of ORPD system under unbalanced condition.

In 2016, Seyed et al. [3] have brought about the stochastic multi- objective ORPD (SMO-ORPD) approach to control the ORPD problems in the wind integrated power system. They have considered the main objectives such as reduction of active power loss and voltage stability. The combination of - constraint method and fuzzy satisfying approach were used to solve the proposed optimization. The implementation was done using IEEE-57 bus system and those were performed under the GAMS environment. The ability of the proposed method to deal with the minimization of active power loss and voltage stability was proved precisely by comparing the proposed method with the conventional intelligent search- based algorithms.

In 2015, Aparajita Mukherjee and Vivekananda Mukherjee [4] have suggested the chaotic krill herd algorithm (CKHA) which is one of the evolutionary- based techniques to control the problems concerning the ORPD. Here the variables such as voltages of bus, transformer tap positions and reactive power sources were measured for the experimentation. They have implemented the algorithm to minimize the active power loss and voltage deviation and improving the voltage stability index. The efficiency and convergence speed of the algorithm was achieved by comparing the proposed method with the existing algorithms.

In 2016, M. Basu [5] has adopted the multi- objective differential evolution (MODE) in order to solve the problems under the ORPD system. Those problems were solved by reducing the voltage deviation and active power loss and enhancing the voltage stability. They have varied the control variables such as transformer tap settings, terminal voltages of the transformer, reactive power output of shunt VAR compensators. The experimentation was carried out in IEEE 30-bus, 57-bus and 118-test bus systems. The superior dispatch decisions were acquired by the proposed algorithm when compared with strength pareto evolutionary algorithm 2 (SPEA 2) on the root of pareto-optimal solutions.

In 2015, Mohd Herwan et al. [6] have developed the gray wolf optimizer (GWO) which is one of the new meta-heuristic techniques done to solve the issue arising from the ORPD. The group of control variables such as ratio of transformer taps settings and the generator voltages were varied to perform the experimentation. Those variables were varied to attain the minimized power loss and voltage deviation, and the corresponding experiment was prepared in IEEE 30 and IEEE 118- test bus system. The supremacy of the GWO algorithm was achieved when compared with other algorithms.

2.2 Review

The review stated the operation of different algorithms applied to solve the problem of ORPD. A number of recent methods such as ADMM [1], SMO-ORPD [3], CKHA [4], MODE [5], and GWO [6] were effectively reported in the literature. However some problems stay as the main challenges that affect the operation of ORPD. General challenges under ORPD includes the slow regulation corresponds to control voltage deviation, problems regarding the uncertain parameters, scheduling of hydro thermal problems, geometric optimization problem, derivative control etc. Therefore, ORPD system requires an improved method to handle those challenges in an efficient manner.

3. Model of ORPD

The general objective of ORPD is the minimization of active power loss and voltage deviation and the maximization of voltage stability index which is represented in eq. (1) where A denotes active power loss and B denotes deviation of voltage.

$$O_b = a \ A + (1 \quad a \ )B \tag{1}$$

The selected variables are responsible for creating the in equality and equality constraints. The vectors of the dependant variables are expressed in eq. (2) where Pd_G represents the slack bus power,

Vd_{lj} indicates the voltage of bus PQ $j = 1,2....NPQ$, Qd_{Gj} denotes the reactive power output of the generator $j = 1,2...NG$, NG and NPQ is the count of generator bus and PQ buses.

$$X = [Pd_{G1}, Vd_{l\ 1}........Vd_{l\ NPQ}, Qd_{G\ 1}......Qd_{G\ NG}] \tag{2}$$

The vector of control variables are expressed in eq. (3) where Vc_{Gj} denotes the terminal voltage of the voltage controlled bus, $j = 1,2....NG$, Qc_{Cj} indicates the output of the shunt VAR compensator $j = 1,2....NC$, Tc_i denotes the tap setting of the tap changing transformer $j = 1,2....NG$, NC and NT are the count of shunt VAR compensators and the tap settings transformers.

$$U = [Vc_{G\ 1},.....Vc_{G\ NG}, Qc_{C\ 1}....Qc_{C\ NC}, Tc_1,.....Tc_{NT}] \tag{3}$$

Minimization of active power loss: The formulation for the minimization of active power loss is represented in eq. (4) where g_i is the ith division conductance between k^{th} and l^{th} buses, δ_k and δ_l are the voltage phase angles of the kth and l^{th} bus and N is the count of transmission lines.

$$A = \sum_{i=1}^{N} g_i [V_k^2 + V_l^2 \quad 2V_k V_l \cos(\delta_k \quad \delta_l)] \tag{4}$$

Minimization of voltage deviation: The formulation for the minimization of voltage deviation corresponds to the voltage magnitude V_u corresponding to the reference voltage V_{ref} is represented in eq. (5) where LB denotes the count of load buses $\psi(x)$ represents the step function expressed in eq. (6).

$$B = \sum_{u=1}^{LB} P_f \psi(V_{\min} \quad V_k) + P_f \psi(V_k \quad V_{\max}) \tag{5}$$

$$\psi(x) = \begin{matrix} 1; & if & x \geq 0 \\ 0; & otherwise \end{matrix} \tag{6}$$

The formulation for computing the voltage V_k is given in eq. (7) where

$$|V_k|^2 = |V_u|^2 \quad 2(\hat{w}_{uk} P_{uk} + \hat{f}_{uk} Q_{uk}) + c_{uk}(P, Q) \tag{7}$$

$$\hat{w}_{uk} = \text{Re}\{bb^H\} \quad w_{uk} + \text{Im}\{bb^H\} \quad f_{uk} \tag{8}$$

$$\hat{f}_{uk} = \text{Re}\{bb^H\} \quad f_{uk} \quad \text{Im}\{bb^H\} \quad w_{uk} \tag{9}$$

$$b = 1 \quad e^{j2\pi/3} \quad e^{j2\pi/3} \tag{10}$$

$$c_{uk} = [z_{uk}[S_{uk}^*./V_u^*]] \quad [z_{uk}^*[S_{uk_0}./V_u]] \tag{11}$$

$$z_{im} = w + jf \tag{12}$$

$$S_{uk} = [P_{uk} + jQ_{uk}] \quad [\hat{z}_{uk}(P_{uk} \quad jQ_{uk})] \tag{13}$$

$$\hat{z}_{uk} = z_{uk} \quad (b_i b_i^H) \tag{14}$$

There is limit range of voltage that should be used by the power system which is called as the threshold voltage. Moreover, the power system should be fault tolerance. Voltage instability is one of the major problems arising in the power system, which is minimized to enhance the voltage stability index L - index which is represented in eq. (15) where $l = 1,2......., NPQ$, NPV is the sum of PV bus, Y_A and Y_B are the sub matrices.

$$L_l = \left| 1 \quad \sum_{k=1}^{NPV} F_{lk} \frac{V_k}{V_l} \right| \tag{15}$$

$$F_{lk} = [Y_A]^{-1}[Y_B] \tag{16}$$

The formulation for the voltage stability is represented as,

$$C = \max(L_l) \tag{17}$$

Satisfaction under equality and inequality constraints

The formulation for the equality constraints can be represented in eq. (18) and eq. (19), where NB indicates the count of buses, the generation of the active and reactive power is denoted as P_{Gk} and Q_{Gk} of kth bus, active and reactive power demand is denoted as P_{Dk} and Q_{Dk} of kth bus, transfer conductance is denoted as G_{kl} and suspectance is denoted as B_{kl}.

$$P_{Gk} \quad P_{Dk} \quad V_k \sum_{l=1}^{NB} V_l [G_{kl}\cos(\delta_k \quad \delta_l) + B_{kl}\sin(\delta_k \quad \delta_l)] = 0, \qquad k = 1,2........NB \tag{18}$$

$$Q_{Gk} \quad Q_{Dk} \quad V_k \sum_{l=1}^{NB} V_l [G_{kl}\cos(\delta_k \quad \delta_l) + B_{kl}\sin(\delta_k \quad \delta_l)] = 0, \qquad l = 1,2.........NB \tag{19}$$

The formulation of the equality constraints are expressed in following equations. The threshold limit of the output voltage magnitude and power of the generator is expressed as,

$$V_{Gk}^{min} \leq V_{Gk} \leq V_{Gk}^{max}, \quad k = 1,2,....... NG \tag{20}$$

$$Q_{Gk}^{min} \leq Q_{Gk} \leq Q_{Gk}^{max}, \quad k = 1,2,....... NG \tag{21}$$

The resultant output of the shunt VAR compensators are represented as,

$$Q_{Ck}^{min} \leq Q_{Ck} \leq Q_{Ck}^{max}, \quad k = 1,2,....... NC \tag{22}$$

The limit range of the transformer tap settings is represented as,

$$T_k^{min} \leq T_k \leq T_k^{max}, \quad k = 1,2,....... NT \tag{23}$$

The limit range of the magnitude of voltage at and the transmission line is represented as,

$$V_{Lk}^{min} \leq V_{Lk} \leq V_{Lk}^{max}, \quad k = 1,2,....... NPQ \tag{24}$$

$$S_{lk} \leq S_{lk}^{max}, \quad k = 1,2,....... N \tag{25}$$

4. ODFF based ORPD

4.1 Coventional Firefly

Firefly algorithm [31] is one of the meta- heuristic algorithm that follows some basic rules such as, 1) All fireflies are unisexual 2) The attraction among diverse firefly is based on their brightness 3) The brightness of firefly is determined by the calculation of fitness function. The general formulation associated with the firefly algorithm is explained below.

Distance: The distance between the two fireflies k^{th} and l^{th} is calculated by Cartesian distance that is represented in eq. (26) where D denotes the number of dimensions.

$$ds_{kl} = \sqrt{\sum_{m=1}^{D} (v_{k,m} \quad v_{l,m})^2} \tag{26}$$

Attractiveness: The attractiveness of each firefly is expressed in eq. (27) where γ denotes the absorption coefficient of light.

$$\beta(ds) = \beta_0 e^{-\gamma ds^2} \tag{27}$$

Movement: The travelling of kth firefly towards the more attractive l^{th} is calculated using eq. (28) where α represents the randomization parameter, v_k^{new} is the new position of kth firefly and v_k^{old} represents the old position of kth firefly.

$$v_k^{new} = v_k^{old} + \beta_0 e^{\gamma ds^2}(v_k^{old} \quad v_l) + \alpha(rand \quad \frac{1}{2}) \tag{28}$$

The pseudo code of the conventional firefly is given below.

ALGORITHM:1 PSEUDO CODE OF FIREFLY ALGORITHM

Fitness function $f(v)$, $v = (v_1, v_2, ... v_D)$

Begin the initialization of population v_k, $(k = 1, 2.....N)$

Determine the light intensity I_k

Compute the light absorption coefficient γ

While (t<generation)

  | For all k fireflies

    | For all l fireflies

      | If $I_k > I_l$)

        | k^{th} firefly travel towards l^{th} firefly

      | end

Attractiveness depends on distance

Evaluate new solution and update light intensity

    | end

    | end

Find the present best firefly by ranking process

end

4.2 Proposed ODFF Firefly

The main limitation of normal firefly algorithm is that it does not consider all dimensions of a single firefly which leads to the problem of global optima. Instead, the proposed ODFF [32] precisely determines the global optima by the way of finding all the dimension of a single firefly. So here the best solution is the resultant that considers from all dimension of all fireflies and updating of position of all fireflies based on the global best firefly. The ODFF is used to overcome the two main challenges that arise in normal firefly 1) To enhance the convergence rate 2) To update the position of each firefly among diverse dimensions. The opposite position of the firefly is calculated using eq. (29) where, $k = 1, 2...D$, $l = 1, 2....N$.

$$\hat{v}_{kl} = i_l + j_l - v_{kl} \tag{29}$$

Based on the global best firefly, the movement of kth firefly towards the best firefly is represented as,

$$v_k^{new} = v_k^{old} + \beta_0 e^{-\gamma ds^2} (v_k^{old} - Fbestpos) + \alpha(rand - \frac{1}{2}) \tag{30}$$

Here the opposite position of each firefly is computed. The initialization process of firefly in the proposed method is done efficiently, so that the convergence speed is increased and the computational complexity is reduced. The pseudo code of the proposed ODFF algorithm is depicted below.

ALGORITHM:1 PSEUDOCODE OF PROPOSED ODFF

Begin the initialization of the population $v = (v_1, v_2, v_3...v_N)$ with

dimension $v_k = (v_{k1}, v_{k2}, v_{k3},....v_{kN})$.

Produce the opposite position of population using eq. (29)

Choose the fireflies from the set $\{v, \hat{v}_{kl}\}$

Set the optimization function as $f(v_k) = f(x_{k1}, x_{k2}....x_{kD})$

Determine the value of absorption coefficient γ

Identify F_{best} from the first set of firefly positions

While(t<generation)

  | For every dimension

    | For every firefly

      | Z = Fbestpos

      | Z = v(k, l)

      | If $f(Z) > Fbest$

        | Fbest = f(Z)

        | Fbestpos = Z

      | end

    | end

  | end

Find the present best firefly by ranking process

end

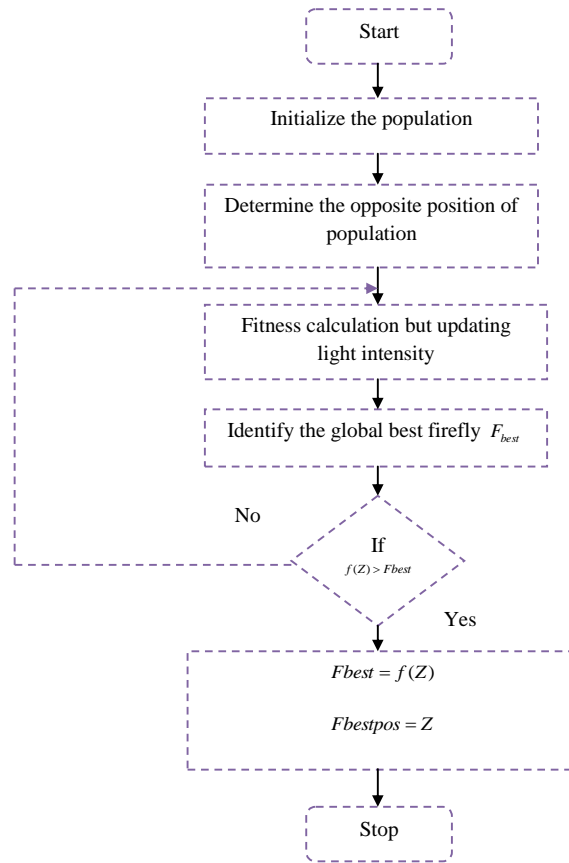The flowchart of the aforementioned pseudo code is shown in fig. 1.

Fig. 1. *Flowchart of ODFF approach*

The description of the ODFF pseudo code and flowchart is explained below.
1 The initialization of the position of the firefly v is selected randomly.
2 Calculate the opposite position $\hat{v}$ of the set of firefly v using eq. (29).
3 The optimization function the firefly is fixed and the absorption coefficient is also calculated.
4 Among the first set of fireflies, identify the global best firefly f_{best}. This best firefly is responsible for the initial population.
5 The update process is done according to the rule given in the pseudo code of the proposed ODFF algorithm. If the update firefly is greater than the global best firefly, then the global best firefly is replaced by the update firefly.
6 The new solutions are evaluated and the fitness function is calculated.
7 The best firefly is determined based on the ranking process.
8 The same procedure is repeated till; it has reached its maximum iteration.

5. Results and Discussions

5.1 Experimental Setup

The proposed ODFF algorithm was simulated in MATLAB under IEEE 14 and IEEE 39 standard test bus systems. The ORD problem was considered in this experiment and the objectives such as active power loss A and the voltage deviation B were determined. The performance of the proposed algorithm was analyzed by comparing it with other conventional algorithms like GA, PSO and ABC. The aforementioned algorithms are vastly dependant on initial solutions, so the result may not be optimum on a single run. So the experimentation was done for 5 times and the best and worst solution corresponding to their execution is determined. Further, the mean and median performance is examined from the best and worst solutions. Subsequently, the standard deviation is also determined to find the trustworthiness of the algorithm.

5.2 Performance Analysis of IEEE 14 Bus System

The proposed ODFF algorithm is performed by fixing the control variables. The analysis of system without ORPD as well as with ORPD is shown in table 1. The control variables are fixed at five generator buses (bus. No. 1, 2, 3, 6, 8), 13th and 3rd voltage magnitude of bus and 8th, 9th and 10th transformer tap settings of bus system.

Table 1. *Analysis of system without ORPD and with ORPD of IEEE 14 test bus system*

Control variables		Q,1	Q,2	Q,3	Q,6	Q,8	V,13	V,3	T,8	T,9	T,10
Without ORPD		0	12.7	19	7.5	0	1.05	1.01	0.98	0.98	0.93
With ORPD	GA	1.070	12.327	2.8097	17.172	2.8407	0.9906	0.90079	0.95	0.95	0.95
	PSO	8.862	4.650	8.004	8.165	14.842	0.9605	0.9846	0.94021	1.01	0.93552
	FF	3.703	13.08	7.987	6.6635	15.615	0.9862	1.0997	0.95	0.95	0.95
	ABC	8.577	2.957	3.7	2.033	8.845	0.928	0.947	1.0415	0.9769	0.9836
	ODFF	3.25	9.50	10.28	1.2	18.50	1.5	0.7	0.85	0.932	0.958

The computation of active power loss and the voltage deviation of IEEE test bus system without ORPD and with ORPD of proposed ODFF compared with four conventional algorithms are shown in table 2. In the proposed ODFF method, the active power loss is 0.002% lower than system without ORPD, 0.001% higher than GA, 0.002% lower than PSO, 0.001% higher than FF and 0.001% higher than ABC.

Table 2. *Active power loss and voltage deviation of system without OPRD and with ORPD of IEEE 14 test bus System*

Control variables		A	B	Final fitness
Without ORPD		13.393	1.4817	0.2974
With ORPD	GA	13.364	1.4694	0.29496
	PSO	13.418	1.4868	0.29844
	FF	13.364	1.4694	0.29496
	ABC	13.368	1.5929	0.29496
	ODFF	13.39	1.461	0.2922

The limited voltage used in the system should be 0.97 p.u to1.06 p.u. If the voltage is greater or lower than the threshold, the subsequent penalty should be added. Moreover, , the voltage deviation of the proposed ODFF method is 0.013% better than system without ORPD and 0.005%, 0.017%, 0.005% and 0.08% better than GA, PSO, FF and ABC algorithm. Even though, the active power loss and voltage deviation of the proposed method is higher than some of the conventional algorithm, the final fitness is less compared with conventional algorithms. The final fitness of ODFF is 0.017%, 0.009%, 0.20%, 0.009% and 0.017% better than the system without ORPD, GA, PSO, FF and ABC algorithms. The statistical report of proposed of ODFF algorithm with the conventional algorithms are shown in table 3.

Table 3. *Statistical report of IEEE 14 test bus system of proposed ODFF with conventional algorithms*

Metrics	Best	Worst	Mean	Median	Standard deviation
GA	0.29496	0.29496	0.29496	0.29496	6.674e-09
PSO	0.296	0.29844	0.29694	0.29693	0.00093
FF	0.29496	0.29496	0.29496	0.29496	1.659e-10
ABC	0.29496	0.29496	0.29496	0.29496	3.263e-09
ODFF	0.2920	0.29785	0.2949	0.29432	0.00185

The best case scenario is the occurrence of best convergence from five rounds where as the worst case scenario indicates the poor performance. The resultant output of the best case scenario of the proposed ODFF method is 0.010%, 0.13%, 0.010% and 0.010% better than GA, PSO, FF and ABC. Rather than in case of worst case scenario, the proposed method provides 0.001% better performance than PSO and 0.009% worst performance than GA, FF and ABC. However, the mean and median performance is better than the conventional methods. The mean performance of the proposed ODFF is 0.006% better than PSO and 0.002% better than GA, FF and ABC. The median performance is 0.0021%, 0.008%, 0.002%, and 0.002% better than GA, PSO, FF and ABC. On the other hand, the standard deviation of the proposed method provides worst performance than the conventional methods, but the higher performance of mean and median overcomes the limitation in terms of deviation.

5.3 Performance Analysis of IEEE 39 Bus System

The analysis of system without ORPD and with ORPD of IEEE 39 test bus system is shown in table 4. To obtain the less power loss and voltage deviation, the reactive power of six generator bus (bus no. 31, 32, 35, 38, 33 and 34) and transformer tap settings of 44th, 38th and 35th buses are preset.

Table 4. *Analysis of system without ORPD and with ORPD of IEEE 39 test bus system*

Control variables		Q,31	Q,32	Q,35	Q,38	Q,33	Q,34	T,44	T,38	T,35	T,36
Without ORPD		4.6	0	0	1.0265	0.9972	1.0123	1.025	1.07	1.006	1.006
With ORPD	GA	0.93619	-0.69	0.3843	1.0753	1.088	1.0868	0.96451	1.05	1.0299	1.0418
	PSO	0.33262	-0.50	-0.637	1.0484	0.97989	1.013	0.98367	1.0528	1.0135	1.0187
	FF	0.82819	-0.084	0.85027	1.0259	1.0828	1.0522	0.96451	1.05	1.0299	1.0418
	ABC	0.13958	0.52142	-0.6328	1.1	0.92709	1.045	0.96439	1.05	1.0093	1.0138
	OBL-FF	-0.97	-0.48	-0.752	1.080	1.087	0.895	0.9578	1.03	1.024	1.055

The occurrence of active power loss and voltage deviation of the system without ORPD and with ORPD is shown in table 5. The active power loss of the proposed ODFF method provides 0.0011%, 0.001%, and 0.004% better than the system without ORPD and the system with ORPD that comprises GA, PSO and 0.008% and 0.023% worst performance than FF and ABC. Further, the voltage deviation of the proposed ODFF is 0.140% better than the system without ORPD. Then the proposed method is 0.006%, 0.219% and 0.28% better than GA, PSO and FF, but it generates 0.0379% worst performance than ABC algorithm. Even though, the active power loss and voltage deviation of the proposed method is worst in some cases, the final fitness shows it superiority than the conventional methods. The final fitness of the proposed ODFF method is 0.070%, 0.001%, 0.006%, 0.005% and 0.002% better than GA, PSO, FF and ABC.

Table 5. *Active power loss and voltage deviation of system without OPRD and with ORPD of IEEE 39 test bus system*

Control variables		A	B	Final fitness
Without ORPD		43.591	50.352	38.99
With ORPD	GA	43.147	8.9004	36.298
	PSO	42.755	11.325	36.469
	FF	43.637	12.334	36.304
	ABC	43.28	8.5168	36.327
	ODFF	43.10	8.84	36.248

The statistical report of IEEE 39 bus system of proposed ODFF method with conventional methods is shown in table 6. The best case scenario of the proposed method is 0.005%, 0.0008%, 0.005% and 0.005% better than GA, PSO, FF and ABC approaches. Subsequently, the worst case scenario of the proposed method is 0.007%, 0.005%, 0.009% and 0.005% better than GA, PSO, FF and ABC. Collectively, the mean and median performance of the performance of the proposed method is 0.909%, 0.002% better than the conventional algorithms.

Table 6. *Statistical report of IEEE 39 test bus system of proposed ODFF with conventional algorithms*

Metrics	Best	Worst	Mean	Median	Standard deviation
GA	36.298	36.305	36.301	36.298	0.00359
PSO	36.28	36.491	36.413	36.469	0.09631
FF	36.298	36.313	36.303	36.302	0.00630
ABC	36.298	36.482	36.359	36.327	0.0775
ODFF	36.277	36.277	3.285	36.38	0.00058

6. Conclusion

A method of reducing the active power loss and voltage deviation in ORPD system was presented in this paper. An improved method of firefly called ODFF was used and the corresponding performance was carried out in IEEE 14 and IEEE 39 test bus systems. This method has used the opposition based learning which leads to increase the convergence speed. The performance analysis of the proposed OFF method was compared with the conventional methods like GA, PSO, FF and ABC. Moreover, the statistical report associated with the performance of mean, median and standard deviation was also determined and was analyzed. Hence, the proposed ODFF methods have provided its superiority among the conventional approaches.

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