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A New Meta Heuristic Dragonfly Optimizaion Algorithm for Optimal Reactive Power Dispatch Problem

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Abstract

This research accesses a novel approach of utilising an advanced Meta–heuristic Optimization technique with a single objective to pledge with optimal reactive power dispatch problem in electrical power system network. The prime focus of reactive power dispatch is to curtail the total active power loss in transmission lines. In this detailed study, the dragonfly algorithm was realized on standard IEEE-14 bus and 30 bus systems. The outcome of dragonfly algorithm lucidly indicate the capablity of increasing the antecedent random population size for a liable global optimization problem, focalized close to the global optimum and contributing precise outcome results related to another popular algorithm.

1. INTRODUCTION

Generally the electrical power is generated, transmitted, distributed and utilized in day-to-day activities in bulk amount in power system network. Transferring the electrical power from generation end to utilizing end is a great challenge for power system operators in routine task due to load variations. The load variations are arising in power system network due to weather conditions, social activities and industrial need- based. Therefore, the power system structure is complicated in nature. In such a complicated network of large scale power system network, during the past few decacdes, the role of a system operator has been of offering considerable challenges. The system operators are faced with the objective of assuring dispatch of sufficient power supply to the utilizing end with accuracy, quality, network security, system stability, reliability and economically. In addition, if sudden disturbance like load variations, contingency occurs, they should (i) maintain the specified voltage limits in interconnected system for steady state and transient state conditions (ii) maintain the active power flow limits in complex interconnected transmission line configurations, (iii) minimize the total active power loss in power lines. İn order to enable realize these specific conditions and outcomes, the reactive power optimum variables are obtained from reactive power compensation apparatus as voltages of generator output, switchable VAR compensators and regulating transformers in a complex interconnected power system fulfilling the set of specified operational constraints. Therefore, the reactive power supply in optimal power flow problem [1, 2] and reactive power optimization problem outcome results are decisive factors for economical operation in huge power system stucture.
In the past few decades many researchers and scholars have concentrated on reactive power optimization algorithm for obtaining good solution of reactive power dispatch problems. Generally the optimization algorithms are divided on the basis of conventional methods and intelligent optimization algorithms. The conventional method algorithm techniques like linear and nonlinear programming method, mixed integer programming method, Newton’s method and interior point method etc.., [3-8] were used to obtain the

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optimal solutions. Due to the diverse nature of complex variables during mathematical problem formulation, computational compexities, issues related to obtaining rapid convergence etc, the need for obtaining precise outcome of stated results and seeking global optimum have become imperative to ensure credible and optimal soultions to solve the nonlinear, non-convex and wide range type of global

Nomenclature

ORPD	Optimal reactive power dispatch	θ_i, θ_j	Voltage phase angle of buses 'i' and 'j ' respectively
EP	Evolutionary programme	Nl	Sum of transmission lines
SARGA	Self-adaptive real coded genetic algorithm	n_b	Sum of buses in system network
DEA	Differential evolutionary algorithm	n_{pv}	Sum of generator buses
GSA	Gravitational search algorithm	n_{pq}	Sum of load buses
IP	Interior point method	g_{ij}	Mutual conductance between bus 'i' and 'j'
PSO	Particle swarm optimization	b_{ij}	Suceptence between bus 'i' and 'j'
P_L	Total power loss in transmission lines	P_{gi},Q_{gi}	Generated Real and reactive power at bus 'i'
K	Power line between bus 'i' and 'j'	P_{di},Q_{di}	Real and reactive power demand at bus 'i'
G_k	Conductance of power line 'k' between bus 'i' and 'j'	Q_{ci}	The reactive power compensation source at bus 'i'
T_k	Regulating transformer 'k'	n_g	Sum of generator buses
V_i	Magnitude of voltage at bus 'i'	n_t	Sum of regulating transformers
V_j	Magnitude of voltage at bus 'j'	n_c	Sum of compensator device
		S_l	Power line (l) apparent power flow

optimization problem. Further, their data processing steps are too long and overpriced in vast power system network. So the new intelligent algorithms are realized for global optimal solution in reactive power dispatch problems. These execution of such algorithms demonstrate capability of handling different subjective constraints, and sacrifice the global optimal solution in single simulation run in reactive power optimization problem. Few meta heuristic algorithms have been lately exercised for realizing reactive power dispatch problem. Algorithms such as Self-adaptive real coded genetic algorithm [9,10], PSO algorithm [11-13], Differential evolution algorithm [14-20], Artificial bee colony algorithm [21, 22], GSA algorithm [23], Hybrid Tabu search simulated annealing algorithm [24], cuckoo search algorithm [25], Ant lion optimization algoirthm [26], gaussian bare-bones water cycle algorithm[27] etc have been notably seized for researcher's absorption and been adequate in obtained global optimal solution. A number of valid publications in this area have not attained appropriate outcomes. To the best of the understanding of the authors of this research, there has been no substantial study to simulate and discern informative analysis based on dragonflies in providing solutions to ORPD problems. The dragonflies are swarm infrequently and are among the sumptuous insects. This paper first desires to study the premier nature of dragonflies' swarms and then, to propose the dragonfly algorithm and analyze its nature. In this algorithm, no free lunch theorem (NFL) guides the optimization problem. By comparing all the above algorithms, the Dragonfly optimization algorithm results have been identified as good solutions for reactive power dispatch problems.

This paper is catalogued as follows: The intention function and ORPD problem is interpreted in section II. The Dragonfly algorithm is explained in section III. The Dragonfly algorithm fulfillment part is discussed in section IV. The test system end result determination and discussions are conferred in section V. Finally, the closure is liable in section VI.

2. OPTIMAL REACTIVE POWER DISPATCH PROBLEM FORMULATION

The ORPD problem is a non-linear, non-convex and wide range type of global optimization problem [28-29]. From the standard IEEE busdata, linedata with boundary limits (Table -2) the best optimum control variables are captured by reactive power optimization algorithm. These outcome results are realized to lessen the active power loss in interconnected transmission lines while fulfilling the set of specified operational limits.The reactive power dispatch problem could be illustrated like this

Minimize

$$F(x,u) = P_{Loss}(x,u)$$

Subject to

$$G(x,u) = 0 \; and \; H(x,u) \leq 0 \tag{1}$$

Where $'f'$ is the intention task that decribes the losses in transmission lines. $g(x,u) = 0,$ express the equality constraints for real power & reactive power flow equation in system network and $h(x,u) \leq 0$ express the inequality constraints for power flow limits in transmission lines and another security limits. In practical, $'x'$ and $'u'$ stand for vector of dependent variables and control variables respectively.
i e $x = [P_{G1}, \; V_{L1} \dots V_{Lnpq} \;\; Q_{G1} \dots Q_{Gnpv}]^T$, $u = [V_{G1}, \; V_{Gnpv}, \; Q_{C1} \dots \; Q_{Cnc}, \; T_1 \dots T_{nt}]^T$ concerning the dependent vector variables are generator bus voltage at slack bus $P_{G,}$ bus voltage magnitude V_L and generator reactive power output Q_G . Similarly vector of control variables are consists generator output voltage V_G , reactive power compensation output Q_C and regulating transformer T. npv- stands for sum of generator buses, npq-stands for sum of load buses, nc-stands for sum of compensating devices and nt- stands for sum of regulating transformers.

2.1. Objective function

The prime proposal of the RPD problem is whole active power loss must be curtail in transmission lines and voltage magnitudes must be in specified limits in entire buses of a power system network by fulfilling all the identified operational constraints. In a practical situation, the reactive power dispatch problem under typical state may be formulated by

$$P_{Loss}(x,u) = \sum_{k=1}^{Nl} G_k [V_i^2 + V_j^2 \; - 2V_i V_j cos(\theta_i - \theta_j] \tag{2}$$

Where Nl-denotes the sum of interconnected transmission lines in integral network, G_k is conductance of transmission lines $'k'$ betwixt bus $'i'$ and $'j'$. V_i and V_j is the magnitude of voltage at bus $'i'$ and $'j'$ respectively. θ_i and θ_j denotes the voltage phase angle of buses $'i'$ and $'j'$ respectively.

2.2. Constraints

The objective of the research study is to utilize the funtion equation (2) to be minimized in conjunction with the sum of equality and inequality constraints by monitoring the related equations during solution formulation. The constraints are chronologically summarized in the subsequent section.

2.3. Equality constraints

$$P_{Gi} - P_{Di} - V_i \sum_{j=1}^{nb} V_j \left(g_{ij} cos\theta_{ij} + b_{ij} sin\theta_{ij}\right) = 0 \quad for \;\; i = 1, \dots\dots, n_{pv} + n_{pq} \tag{3}$$

$$Q_{Gi} - Q_{Di} + Q_{Ci} - V_i \sum_{j=1}^{nb} V_j \left(g_{ij} sin\theta_{ij} - b_{ij} cos\theta_{ij} \right) = 0 \quad for \quad i = 1, \ldots.., n_{pq} \tag{4}$$

where, n_b denotes the sum of buses in system network, n_{pv} denotes the sum of generator buses(PV), and n_{pq} denotes the sum of load buses(PQ), $g_{ij,}$ b_{ij} are the mutual conductance and suceptance betwixt bus $'i'$ and $'j'$ respectively; P_{Gi}, Q_{Gi} are generation of real and reactive power at bus $'i'$; P_{Di}, Q_{Di} are real and reactive power load at bus $'i'$; Q_{Ci} the reactive power restitution source at bus $'i'$;

2.4 Inequality constraints

The inequality constraints on security confines are liable by

$$P_{Gslack}^{min} \leq P_{Gslack} \leq P_{Gslack}^{max} \tag{5}$$

$$V_i^{min} \leq V_i \leq V_i^{max} \; for \; i = 1 \ldots \ldots \ldots . n_{pq} \tag{6}$$

$$Q_{Gi}^{min} \leq Q_{Gi} \leq Q_{Gi}^{max} \; for \; i = 1 \ldots \ldots \ldots . n_g \tag{7}$$

$$S_l \leq S_l^{max} - for \; l = 1 \ldots n_l \tag{8}$$

The inequality constraints on control variable confines are liable by

$$V_{Gi}^{min} \leq V_{Gi} \leq V_{Gi}^{max} \; for \; i = 1, \ldots . , n_{pv} \tag{9}$$

$$T_k^{min} \leq T_k \leq T_k^{max} \; for \; i = 1, \ldots n_t \tag{10}$$

$$Q_{Ci}^{min} \leq Q_{Ci} \leq Q_{Ci}^{max} \; for \; i = 1, \ldots . n_c \tag{11}$$

where, n_{pv} is sum of generator buses; n_t is sum of regulating transformers; n_c sum of compensating apparatus; S_l is the limit of apparent power flow in interconnected transmission line $'l'$;

Therefore, the equation (2) is reintegrated by the ensuing rearranged expression as,

$$F = P_{Loss} + (P_{Gi,slack} - P_{Gi,slack}^{lim})^2 + \lambda V_i \sum_{i=1}^{Nl} (V_i - V_i^{lim})^2 + \lambda Q_{Gi} \sum_{i=1}^{NG} (Q_{Gi} - Q_{Gi}^{lim})^2 \tag{12}$$

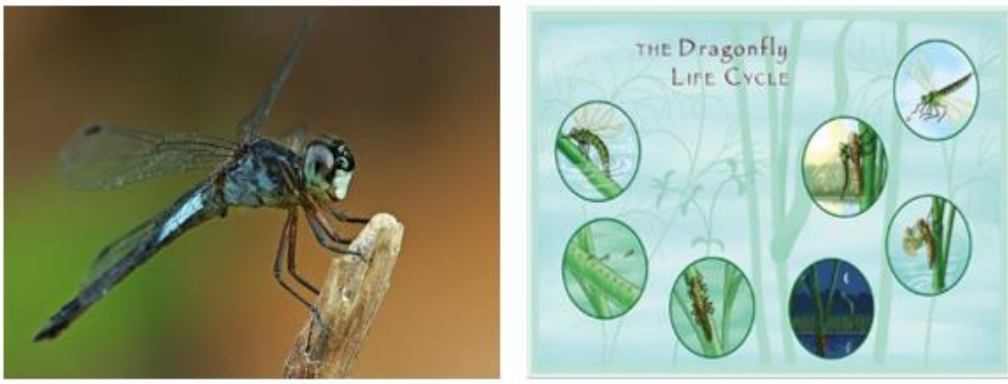
Where λV_i, λQ_{Gi} are the penalty stipulations in equation (12). The λV_i, λQ_{Gi} values are taken from [30]. They are specify as follows:

$$V_i^{lim} = \begin{cases} V_i^{min} & if \; V_i < V_i^{min} \\ V_i^{max} & if \; V_i > V_i^{max} \end{cases}, \qquad Q_i^{lim} = \begin{cases} Q_{Gi}^{min} & if \; Q_{Gi} < Q_{Gi}^{min} \\ Q_{Gi}^{max} & if \; Q_{Gi} > Q_{Gi}^{max} \end{cases}$$

The objective function of the power system is summated by fulfilling the load flow summing with the set of itemized operational constraints stated above.

3. DESCRIPTION OF DRAGONFLY ALGORITHM

The dragonfly algorithm is a newly refined Meta-heuristic technique for explaining optimization problems. This algorithm was refined by Seyedali Mirijali in 2015 [31].
As per the data information, there are three thousand group of insects in this world. The dragonflies are one of the sumptuous insects. The Figure 1(a) and (b) shows the dragonfly's biological clock of different phases, nymph & adult. Most of the life time is in nymph stage and they attain adult stage after the metamorphism. The dragonflies swarm for two reasons. First reason is for hunting and second reason is for moving. The hunting is labeled static swarm (feeding) and the moving is labeled dynamic swarm (movement).



(a) (b)

Figure 1. *a) Snapshot of Real-time image of dragonfly b) Snapshot of dragonfly's life cycle*

In immovable swarm, a few dragonflies form a gang in short space to hunt another flying preys like mosquitoes & butterflies. In movable swarm, a large number of dragonflies form a gang to migrate in particular direction over high space. The prime motivation of the dragonfly algorithm comes from static & dynamic swarming nature. These pair of nature static swarm & dynamic swarm are identical to the prime steps of optimization testing meta-heuristics: expedition & exploitation. The static swarm is considered for the exploration phase & dynamic swarm is considered for exploitation phase. These pair of phases are algorithmically executed for reactive power dispatch problem in this section.
As stated by Reynolds, the three main rules followed by the one another (nature of swarms)

1. Separation: The dragonflies avoid one another due to collision in stationary position from neighborhood.
2. Alignment: Each dragonfly's velocity coordinates with another one in neighborhood
3. Cohesion: The dragonflies fly towards the midpoint of the group of the neighborhood.
4. For survival of any swarm, the prime principles are considered for each one to captivate eatable sources and divert them out from attacker. Based on these two natures, the position updating of each one swarm is exhibited in Figure 2.

The above specified nature of each one of the dragonflies is mathematically created as follows

The point of the separation is computed by

$$S_i = -\sum_{j=1}^{N}(X - X_j) \tag{13}$$

Where X is considered for current individual point, X_j is considered for j^{th}point in neighboring individual and $'N'$ is considered for sum of neighboring individuals.

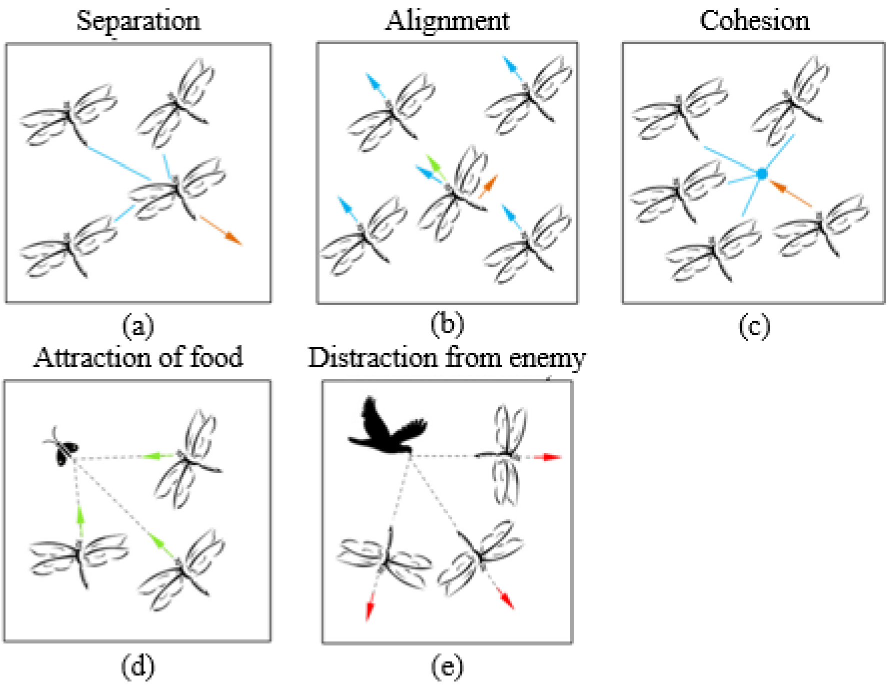


Figure 2. *Primitive corrective patterns between individual in swarm [28](a) to (e)*

The point of the Alignment is computed by

$$A_i = \frac{\sum_{j=1}^{N} V_j}{N} \tag{14}$$

Where V_j – is considered for the velocity of j^{th} neighboring individual

The point of cohesion is computed by

$$C_i = \frac{\sum_{j=1}^{N} X_j}{N} - X \tag{15}$$

Where X is considered for current individual point, and $'N'$ is considered for sum of neighboring individuals and X_j is considered for j^{th} point in neighboring individual

The point of Attraction towards an eatable source is computed by

$$F_i = (X^{+} - X) \tag{16}$$

Where X is considered for current individual point and X^{+} is considered for the point of eatable source.

The point of diversion from attacker is computed by

$$E_i = (X^{-} + X) \tag{17}$$

Where X is considered for current individual point and X^{-} is considered for the point of the attacker.

In view of this the above five combinations of disciplinary instructions are assumed for dragonflies nature. The step (ΔX) is considered for velocity vector and the 'X' is considered for point for updating their artificial position and velocity in search space for dragonflies. The dragonflies is refined based like PSO algorithm.

$$\Delta X_{t+1} = (sS_i + aA_i + cC_i + fF_i + eE_i) + w\Delta X_t \tag{18}$$

Where $'s'$ denotes weight of separation, $'S'$ denotes separation of $'i'$-th individual, $'a'$ denotes the weight of alignment, $'A_i'$ denotes $'i'$ -th individual alignment, $'c'$ denotes weight of cohesion, $'C_i'$ denotes the $'i'$ th individual cohesion, $'f'$ denotes eatable factor, $'F_i'$ is the $'i'$ -th individual eatable source, $'e'$ denotes attacker factor, $'E_i'$ is the $'i'$ -th individual enemy, $'w'$ is denotes weight of inertia and $'t'$ is the iteration number.

The point of vector position is computed afterwards by the step vector.

$$X_{t+1} = X_t + \Delta X_{t+1} \tag{19}$$

Where $'t'$ denotes the current iteration. The different explanative and explorative natures can be obtained during optimization by s-separation factor, a-alignment factor, c-cohesion factor, f-eatable factor and e-attacker factors.

The neighborhood space is expanded likewise. The swarm turn into singular form at the end point of optimization to converge to global optimum. This enables them to choose eatable source as well as fight the attacker. This explanation convergence is close to assuring space of the search area and divert outside non assuring place of the search area. Hence, the dragonflies' algorithm is assured during optimization.If the neighboring results are sufficiently not available, to enhance the impermanence, stochastic nature, and explanative of simulated dragonflies, they need to cross over the search area applying a random walk (Levy flight).

In view of this case, the dragonflies' position is revised by the successive equation.

$$X_{t+1} = X_t + Levy(d) \times X_t \tag{20}$$

Where $'t'$ denotes the current iteration and $'d'$ denotes the dimensions of position vectors.

The point of Levy flight is computed by

$$Levy\,(x) = 0.01 \times \frac{r1 \times \sigma}{|r2|^{1/\beta}} \tag{21}$$

Where $r1$ and $r2$ denotes the two random numerals in [0,1], β –denotes constant (equivalent to 1.5 in this algorithm work) and $'\sigma'$ is computed by

$$\sigma = \frac{\Gamma(1+\beta) \times \sin\frac{\Pi\beta}{2}}{\Gamma\left(\frac{1+\beta}{2}\right) \times \beta \times 2\left(\frac{\beta-1}{2}\right)} \tag{22}$$

Where $\Gamma(x) = (x-1)!$

4. THE PROPOSED ACCESS TO EXPLAIN THE ORPD PROBLEM BY DRAGONFLY ALGORITHM

Step 1: Take the power system problem for minimize loss by ORPD. The power system problem should stipulate, the sum of control variables in reach the confines edge in the system integral of standard IEEE system of busdata and linedata.

Step 2: The ORPD parameters in the system which represent every dragonflies population are named, and they subsist of the voltages at generator output, reactive power compensating apparatus and regulating transformers that are generated randomly in reach their confines. Thus, the i^{th} setting of dragonflies population.

$X_i = [V_{G2}, V_{G3}, \dots, V_{Gn}, \dots, T_1, T_2, \dots n_t, Q_{C1}, Q_{C2}, \dots . Q_{Cn}]$ The entire search space for dragonflies' algorithm having population P is revealed as follows $X = X_1, , \dots X_2, \dots X_p]^T$

Step 3: Compute the step vector of each dragonfly. These corresponding values are related to optimal variables in ORPD problem.

Step 4: The objective function of each dragonfly is calculated by using equation Eq.(12)
Where P_{Loss} is the objective function to be lessen. λV_i and $\lambda Q_{Gi,}$ are penalty terms of the corresponding constraints.

Step 5: The eatable source and attacker can be calculated by using Eq. (16) & (17) for each optimal variables.

Step 6: The parameter values are calculated by using Eq. (18): $'w', 's', 'a', 'c', 'f' \&'e'$

Step 7: The $'S', 'A', 'C'. 'F' \&'E'$ can be calculated by using the Eq. from (13) to (17)

Step 8: The neighboring radius can be calculate by using the Eq.(20)

Step 9: If a dragonfly has a minimum of one adjoining dragonfly revise the velocity applying the Eq. (18)

Step 10: The position vector can be calculated by using Eq. (19)

Step 11: Check the position vector by using Eq. (20)

Step 12: Take and precise the new position occupying on the confines of optimum variables.

Step 13: If the obtained solutions are not fulfilled go to step no 3.

Step 14. If the obtained solutions are satisfied, print the results and stop it.

5. NUMERICAL RESULTS AND DISCUSSIONS

In view of ORPD problem, the dragonfly algorithm access was valued simulation work based on flowchart exhibited in Figure.3 for standard IEEE-14 & IEEE-30 bus systems. The line data and bus data are appropriate from [32]. The simulation results attained by dragonfly algorithm were done in MATLAB 2016 on an Intel (R), core(TM), i5-6200U CPU@ 2.40 GHz.8.0 GB RAM processor. The initial real power losses and optimal variables of boundary limits are given in Table.1 & 2. The ORPD problem was solved with 100 MVA base for the entire system test cases. The Newton-Raphson load flow technique was applied for observing the equality and inequality constraint limitation.

5.1. Case-1 IEEE-14 bus system

In IEEE-14 bus system, there are 5-generator buses (bus 1 is slack bus, 2,3,6 and 8 are generator buses with continual practicing variables), 9-load buses & 20-transmission lines in which three are regulating transformers (4-7,4-9,and 5-6), The modifiable reactive power devices are linked on buses 9 and 14. Altogether 10-optimal control variables are seized from 14-bus system.
In this case, the system parameters from Table.2 and algorithm factors are chosen from [31]. The system parameters are varied on 14 bus according the table no-2. Similarly the dragonfly algorithm swarming factors can also be tuned to suit the values. Next number of population was chosen 50 and iteration was set to 100. The simulation programme was run 50 times. From these outcomes of the algorithm solution, the least value of active power loss and its correlative optimal variables were selected. The real power

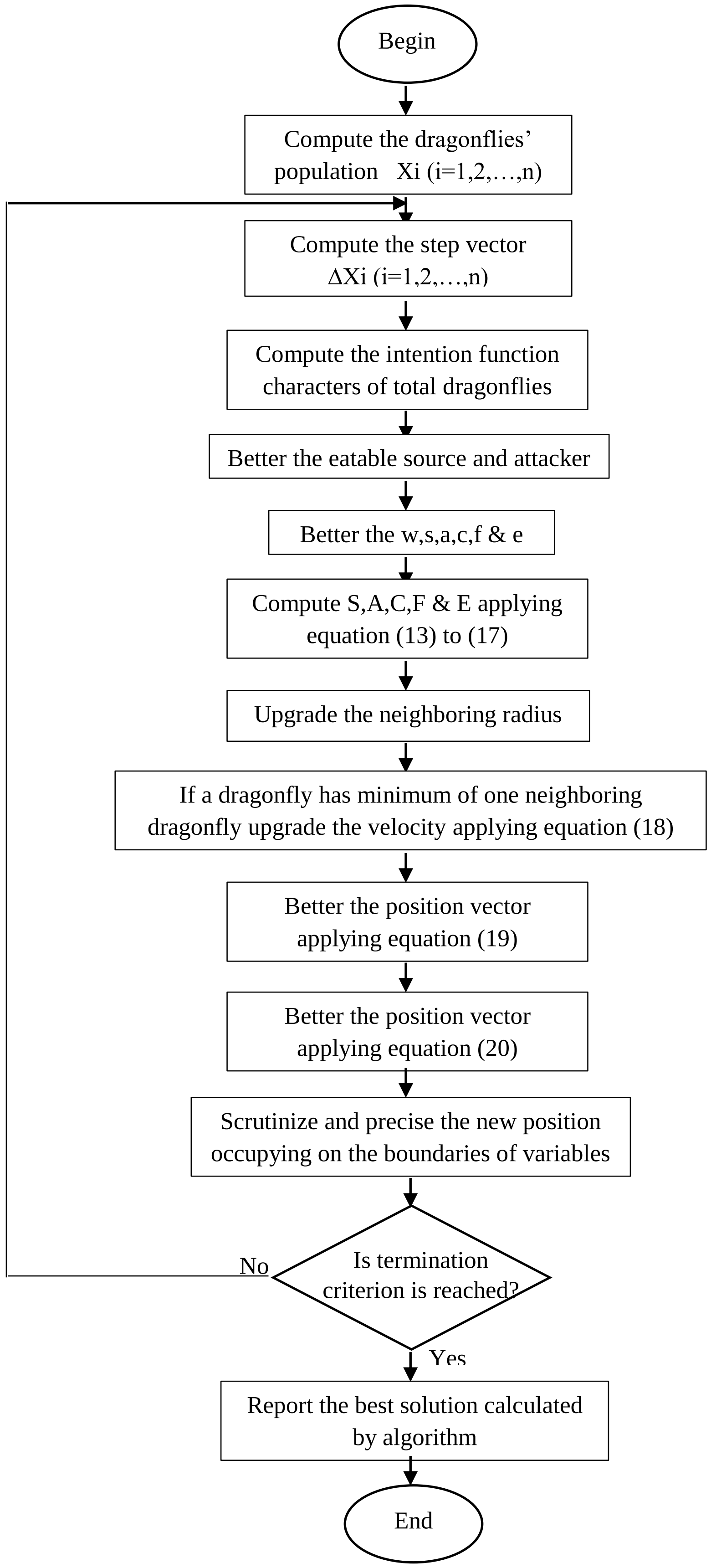


Figure 3. *Flow chart for Dragon fly algorithm*

loss and statistical results of 14-bus system was compared with popular algorithm of same data are given in Tables 3, 4 & 5. It was observed that the loss curtailment improved by 8.63% from IP[33], 8.67% from PSO[33], 8.69% from DEA-strategy5 [33] and the dragonfly algorithm improved from 10.05%, Also from Table 4, we can observe the statistical results, the computational time. (CPU time) The standard deviation shows better values.

From Table. 4 and 5 the proposed dragonfly algorithm optimizations method's outcome results like real power loss, standard deviation and computing time of 14-bus system have given better performance.The convergence characteristics of 14-bus system dragonfly algorithm and DEA [33] is exhibited in Figure 4. The dragonfly algorithm focalized from 10-20 iterations evenly and reaches the best power loss values in earch space by setting the suitable value of algorithm parameter comparing with the DEA-Strategy4,5 &6, PSO in Figure 4.

Table 1. *Test system details*

Control variables	**IEEE – 14 bus**	**IEEE-30 bus**
Number of control variables	10	12
Number of regulating Transformers (T)	3	4
Number of generator buses (V_G)	5	6
Number of reactive power sources (Q_C)	2	2
P_{Loss} Base case (MW)	13.3933	17.5569

Table 2. *Settings of upper and lower limits for control variables*

Bus system	**Control Variables**	**Lower limit (p.u)**	**Upper limit(p.u)**	**Step**
14-bus	T	0.9	1.1	0.01
	V_G	0.9	1.1	-
	Q_{C9}	0	0.18	0.06
	Q_{C14}	0	0.06	0.06
30-bus	T	0.9	1.1	0.02
	V_G	0.9	1.1	-
	Q_{C10}	0	0.20	0.05
	Q_{214}	0	0.04	0.01

Table 3. *Control variables for IEEE 14-bus for its optimal settings*

Variables	**IP[33]**	**PSO[33]**	**DEA[33] Strategy 5**	**DFA**
V_{G1}	1.1000	1.1000	1.1000	1.1000
V_{G2}	1.0849	1.0847	1.0846	1.0946
V_{G3}	1.0566	1.0558	1.0555	1.0570
V_{G6}	1.1000	1.0999	1.1000	1.0946
V_{G8}	1.0836	1.0828	1.0999	1.1000
T_{4-7}	1.0279	1.0013	0.9951	1.0094
T_{4-9}	0.9201	0.9271	0.9420	0.9000
T_{5-6}	1.0068	1.0036	0.9982	1.0115
Q_9	0.1800	0.1800	0.1800	0.1800
Q_{14}	0.0600	0.0600	0.0593	0.0600
$\mathbf{P_{Loss}}$	**12.2381**	**12.2324**	**12.2294**	**12.0470**

Table 4. *Statistical results of IEEE 14-bus system*

Methods	**Worst P_{Loss} (MW)**	**Avg. P_{Loss} (MW)**	**Best P_{Loss} (MW)**	**Std.dev P_L(MW)**	**cpu time(s)**
IP	12.2381	-	-	-	0.75
PSO	12.2324	13.1470	13.8310	0.0093	5.9500
DEA-Strategy5	12.2294	12.2364	12.2464	0.0032	4.2925
DFA[a]	**12.0470**	**12.1452**	**12.1569**	**0.0026**	**4.0914**

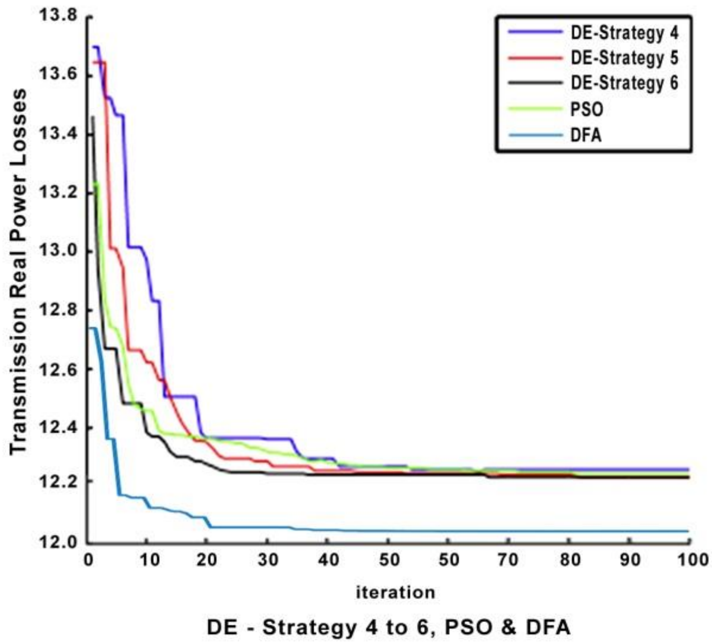


Figure 4. *Convergence characteristics of 14 bus system DEA-Strategy 4,5, 6, PSO and DFA algorithm*

Table 5. *Minimum loss obtained by different methods of IEEE 14-bus*

Test system	**Best**	**Worst**	**Average**
PSO [11]	13.2980	13.3261	13.3023
PSO-CM[11]	13.2634	13.3142	13.2671
PSO-AM [11]	13.2371	13.2550	13.2395
DE [15]	13.2396	13.2476	13.2506
DE [15]	13.2390	13.2750	13.2500
PSO [15]	13.2500	13.4020	13.3520
DEEP [17]	12.4489	12.4507	12.4494
CSSP [18]	12.3868	12.5644	12.4648
DE[22]	12.3712	12.3390	12.3754
DE –ABC [22]	12.3712	12.3712	12.3712
ABC[22]	12.3731	12.2922	12.5837
IP[33]	12.2381	-	-
PSO [33]	12.2324	13.0470	13.2310
DEA [33] Strategy 5	12.2294	12.2464	12.2364
DFA	**12.0470**	**12.1569**	**12.1452**

DFA[a] Proposed method

5.2. Case -2 IEEE – 30 bus system

In IEEE-30 bus system, there are 6-generator buses (bus 1 is slack bus, 2,5,8,11 & 13 are generator buses with continual practicing variables), 24-load buses & 41-transmission lines in which 4 branches (6-9, 6-10,4-12 & 27-28) are regulating transformers. The modifiable reactive power appliances are linked on buses 10 and 24. Altogether 12-optimal control variables are seized from 30-bus system. Likewise, in 30 bus also the system parameters and algorithm swarming factors [31] were chosen from Tables 1&2. Next, number of population size was chosen as 50 and iteration was set to 100. The simulation programme was run 50 times. The least value of active power loss from these outcomes of the algorithm solution and its corresponding optimal variables were selected. The real power loss of 30-bus system was also compared with popular algorithm of same data and the findings are shown in Tables 6,7 and 8. It was observed that the loss curtailment improved from IP[33] 7.63%, PSO[33] 8.13%, DEA strategy-1[33] 8.65% and 9.29% from dragonfly algorithm. From the statistical results and convergence characteristics, the dragonfly algorithm's real power loss is showed better performance by comparing in Tables 6-7.
The convergence feature of 30-bus system dragonfly algorithm best power loss is exhibited in Figure 5. The dragonfly algorithm focalized from 20-25 iterations smoothly and reached the best power loss values in search space by comparing DE – Strategy 1,2 and 3 in Figure 5.

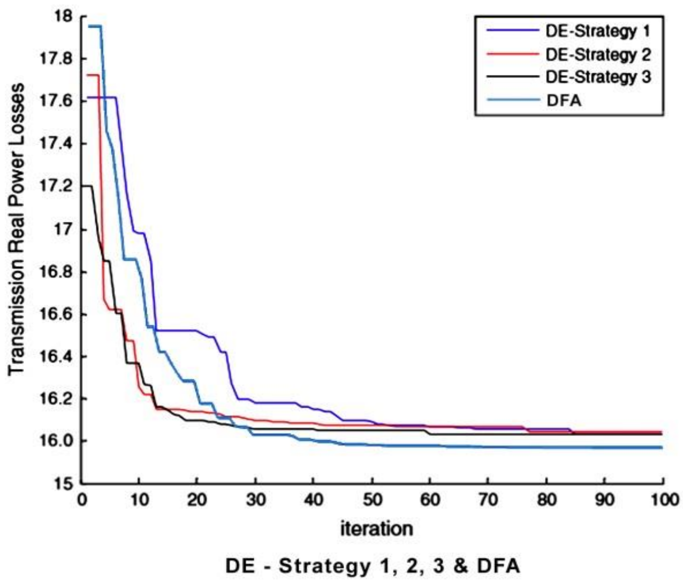


Figure 5. *Convergence characteristics of 30 bus system DEA-Strategy 1,2 & 3, DFA algorithm*

Table 6. *Optimal settings of control variables for IEEE-30 bus*

Variables	IP[33]	PSO[33]	DEA[33] Strategy 1	DFA
V_{G1}	1.0999	1.1000	1.1000	1.1000
V_{G2}	1.0741	1.0742	1.0822	1.0936
V_{G5}	1.0398	1.0418	1.0503	1.0534
V_{G8}	1.0469	1.0483	1.0574	1.0676
V_{G11}	1.0853	1.1000	1.0996	1.0999
V_{G13}	1.0796	1.0999	1.0999	1.1000
T_{6-9}	1.0114	1.0258	1.0817	0.9831
T_{6-10}	0.9834	0.9383	0.9142	0.9000
T_{4-12}	1.0116	0.9787	1.0069	0.9946
T_{28-27}	0.9729	0.9491	0.9628	0.9600
Q_{10}	0.1302	0.1994	0.2000	0.2000
Q_{24}	0.0292	0.0398	0.0399	0.0400
P_{Loss}	**16.2180**	**16.1296**	**16.0386**	**15.9266**

Table 7. *Statistical results of IEEE-30 bus system*

Methods	**Worst P_{Loss} (MW)**	**Avg. P_{Loss} (MW)**	**Best P_{Loss} (MW)**	**Std.dev P_L(MW)**	**Cpu time(s)**
IP	16.2180	-	-	-	0.75
PSO	16.1296	17.5040	17.8190	0.00034	8.45
DEA-Strategy5	16.0386	17.1563	18.6538	0.00025	8.7229
DFA[a]	**15.9266**	**15.9286**	**16.9294**	**0.00055**	**8.6655**

DFA[a] Proposed method

Table 8. *Minimum loss attained by different methods of IEEE-30 bus*

Test system	**Best**	**Worst**	**Average**
EP[14]	16.6759	17.8189	17.2504
CSSP[18]	16.3861	16.4807	16.4148
DE[14]	16.4898	16.5194	16.4939
DE[22]	16.2184	16.6272	16.3176
DE-ABC[22]	16.2163	16.2164	16.2163
ABC[22]	16.2325	17.6930	16.5908
IP[33]	16.218	-	-
PSO[33]	16.1296	16.8190	16.5040
DEA[33] (Strategy 1)	16.0386	18.6538	17.1563
DFA	**15.9266**	**15.9294**	**15.9286**

DFA[a] Proposed method

6. CONCLUSION

This research work reports on a novel approach of utilizing an advanced meta-heuristic dragonfly algorithm and detailed anlaysis has indicated the effective execution of ORPD problem. During the course of the study, the reactive power constraints as generator output voltages, reactive power sources and regulating transformers in 14 bus and 30 bus data was altered and the capability of the algorithm swarming factors were observed and the optimization capability of the algorithm was assessed. The real power loss attained by this novel meta heuristic dragonfly algorithm during the optimization process clearly exhibited enhanced results in comparision to other approach (utilizing the same data) such as IP, PSO, DEA Strategy algorithms. The results of implementation of this algorithm clearly divulge the superior convergence characteristics, frugal number of iterations, ability to generate inherently an efficient process for approaching constraints and data dealing with the optimization approach. Excellent performance capability and interesting results obtained from the algorithm provides exciting avenues for future research to implement the advanced dragonfly algorithm for determing multiplex optimization problems in different fields.

CONFLICTS OF INTEREST

No conflict of interest was declared by the authors.

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