Available online at http://jurnal.ahmar.id/index.php/asci

Journal of Applied Science, Engineering, Technology, and Education

ISSN 2685-0591 (Online)

Journal of Applied Science, Engineering, Technology, and Education Vol. 3 No. 2 (2021)
https://doi.org/10.35877/454RI.asci113

Solving Optimal Reactive Power Dispatch Problem by Chaotic Based Brain Storm Optimization Algorithm

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Abstract

In this work Chaotic Predator-Prey Brain Storm Optimization (CPS) algorithm is proposed to solve optimal reactive power dispatch problem. Predator–Prey Brain Storm Optimization position cluster centers to execute as predators, accordingly it will progress towards enhanced positions, although the left over thoughts do as preys; consequently they move far from their neighboring predators. In the projected algorithm chaotic theory has been applied to enhance the quality of the exploration. Ergodicity and indiscretion are utilized in the CPS algorithm, such that projected algorithm will not get trapped in the local optimal solution. Chaotic predator-prey brain storm optimization (CPS) algorithm has been tested in standard IEEE 30 bus test system and results show the projected algorithm reduced the real power loss effectively.

Keywords: optimal reactive power, Transmission loss, chaotic predator-prey brain storm optimization algorithm

1. Introduction

The main objective of optimal reactive power problem is to minimize the real power loss and bus voltage deviation. To till date various methodologies has been applied to solve the Optimal Reactive Power problem. The key aspect of solving Reactive Power problem is to reduce the real power loss. Previously many types of mathematical methodologies [1-6] have been utilized to solve the reactive power problem. Then evolutionary algorithms [7-16] have been applied to solve the reactive power problem. This paper proposes chaotic predator-prey brain storm optimization (CPS) algorithm to solve optimal reactive power dispatch problem. Predator–Prey Brain Storm Optimization position cluster centres to execute as predators, accordingly it will progress towards enhanced positions, although the left over thoughts do as preys; consequently they move far from their neighbouring predators. In the projected algorithm chaotic theory has been applied to enhance the quality of the exploration. All the way through crossover, $y_i^{\prime}, z_i^{\prime}$ are engendered together both the preceding and recently produced one are calculated then the preceding one is exchanged by the most outstanding one. Ergodicity and indiscretion are utilized in the CPS algorithm, such that projected algorithm will not get trapped in the local optimal solution. Chaotic search will be introduced to the exploration in the

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neighbourhood of the present best solution to prefer superior solution for subsequent generation. Chaotic predator-prey brain storm optimization (CPS) algorithm has been tested in standard IEEE 30 bus test system and results show the projected algorithm reduced the real power loss effectively.

2.Problem formulation

Objective function of the problem is mathematically defined in general mode by,

$$Minimization\ \tilde{F}(\bar{x}, \bar{y}) \tag{1}$$

Subject to

$$E(\bar{x}, \bar{y}) = 0 \tag{2}$$

$$I(\bar{x}, \bar{y}) = 0 \tag{3}$$

$$x = \left[VG_1, \ldots, VG_{Ng}; QC_1, \ldots, QC_{Nc}; T_1, \ldots, T_{N_T}\right] \tag{4}$$

$$y = \left[PG_{slack}; VL_1, \ldots, VL_{N_{Load}}; QG_1, \ldots, QG_{Ng}; SL_1, \ldots, SL_{N_T}\right] \tag{5}$$

$$OF_1 = P_{Min} = Min\left[\sum_m^{NTL} G_m\left[V_i^2 + V_j^2 - 2 * V_i V_j \cos\emptyset_{ij}\right]\right] \tag{6}$$

$$OF_2 = Min\left[\sum_{i=1}^{N_{LB}}\left|V_{Lk} - V_{Lk}^{desired}\right|^2 + \sum_{i=1}^{Ng}\left|Q_{GK} - Q_{KG}^{Lim}\right|^2\right] \tag{7}$$

$$OF_3 = Min\ L_{Max} \tag{8}$$

$$L_{Max} = Max\left[L_j\right]; j = 1; N_{LB} \tag{9}$$

$$\begin{cases} L_j = 1 - \sum_{i=1}^{NPV} F_{ji}\frac{V_i}{V_j} \\ F_{ji} = -[Y_1]^1[Y_2] \end{cases} \tag{10}$$

$$L_{Max} = Max\left[1 - [Y_1]^{-1}[Y_2] \times \frac{V_i}{V_j}\right] \tag{11}$$

$$0 = PG_i - PD_i - V_i \sum_{j \in N_B} V_j\left[G_{ij}\cos\left[\emptyset_i - \emptyset_j\right] + B_{ij}\sin\left[\emptyset_i - \emptyset_j\right]\right] \tag{12}$$

$$0 = QG_i - QD_i - V_i \sum_{j \in N_B} V_j\left[G_{ij}\sin\left[\emptyset_i - \emptyset_j\right] + B_{ij}\cos\left[\emptyset_i - \emptyset_j\right]\right] \tag{13}$$

$$P_{gslack}^{min} \le P_{gslack} \le P_{gsl}^{ma} \tag{14}$$

$$Q_{gi}^{min} \le Q_{gi} \le Q_{gi}^{max}, i \in \tag{15}$$

$$VL_i^{min} \le VL_i \le VL_i^{max}, i \in \tag{16}$$

$$T_i^{min} \le T_i \le T_i^{max}, i \in \tag{17}$$

$$Q_c^{min} \le Q_c \le Q_C^{max}, i \in N_C \tag{18}$$

$$|SL_i| \le S_{L_i}^{max}, i \in N_{TL} \tag{19}$$

$$VG_i^{min} \le VG_i \le VG_i^{max}, i \in N_g \tag{20}$$

$$MOF = OF_1 + x_i OF_2 + y OF_3 = OF_1 + \left[\sum_{i=1}^{NL} x_v\left[VL_i - VL_i^{min}\right]^2 + \sum_{i=1}^{NG} x_g\left[QG_i - QG_i^{min}\right]^2\right] + x_f OF_3 \tag{21}$$

$$VL_i^{min} = \begin{cases} VL_i^{max}, VL_i > VL_i^{max} \\ VL_i^{min}, VL_i < VL_i^{min} \end{cases} \tag{22}$$

$$QG_i^{min} = \begin{cases} QG_i^{max}, QG_i > QG_i^{max} \\ QG_i^{min}, QG_i < QG_i^{min} \end{cases} \quad (23)$$

3. Chaotic predator-prey brain storm optimization algorithm

Within the exploration space a set of ideas are randomly produced. Brain storm optimization algorithm population (BSO) population is defined as, $Y = \{y_i = [y_{i1}, \ldots, y_{id}] | y_i \in B, 1 \le i \le P_{size}\}$ in this y_i represent the *i*th idea of the population, $B = Z^G$ point out the idea in solution space, P_{size}- population size. Initial population Y (0) and the *n*th iteration population indicated as Y (*n*). For each evaluated idea Fitness value $f(y_i)$ calculated. Brain storm optimization algorithm [17] generally uses assemblage, substitute, generate, cross, and choosing operators.

New-fangled idea is generated by;

$$y_{i,d} = z_d + \xi_d \times P(\mu, \sigma)_d \quad (24)$$

$$z_d = \begin{cases} z_{i,d} \text{ "1" } cluster \\ \omega_1 z_{i1d} + \omega_2 z_{i2d} \ 2 \ cluster \end{cases} \quad (25)$$

$$\xi = logsig\left(\frac{0.500 \times iteration_{maximum} - i}{k}\right) \times rand\ (0,1) \quad (26)$$

When there is formation of new idea, a crossover between novel one and the preceding one is conducted. Through crossover, preceding and recently created one are calculated and when the stop condition reached then Brain storm optimization algorithm will stop otherwise once again procedure will be repeated. In this work Predator–Prey Brain Storm Optimization position cluster centers to execute as predators, accordingly it will progress towards enhanced positions, although the left over thoughts do as preys; consequently they move far from their neighboring predators. In the projected algorithm chaotic theory has been applied to enhance the quality of the exploration.

$$y_{predator_i,d} = z_d + \xi_d \times P(\mu, \sigma)_d + \omega_{predator}\left(z_{gbest,d} - z_d\right) \quad (27)$$

$$y_{prey_i,d} = z_d + \xi_d \times P(\mu, \sigma)_d - P_a sgn\left(z_{center,d} - z_d\right) e^{-b|z_{center,d} - z_d|} \quad (28)$$

$$a = z_{span} \quad (29)$$

$$b = \frac{100}{z_{span}} \quad (30)$$

Ergodicity and indiscretion are utilized in the CPS algorithm, such that projected algorithm will not get trapped in the local optimal solution.

$$ch_{n+1} = 4ch_n(1 - ch_n) \quad (31)$$

At every generation end, chaotic exploration will be set up to search in the neighborhood current most excellent solution to choose better-quality solution for following generation. As soon as local most excellent is attained then there won't be any stop in the procedure and also attaining the optimal solution time will be sequentially condensed.

Step a: initialization of parameters
Step b: appraisal of ideas,
Step c: Probabilistic comparison has been done to swap the cluster center
Step d: Probabilistic comparison has been done to choose one cluster; otherwise, two clusters will be chosen
Step e: Probabilistic comparison has been done to choose the center of the one selected otherwise, pick additional ideas and progress to Step g;

Step f: Through $y_{predator_i,d} = z_d + \xi_d \times P(\mu,\sigma)_d + \omega_{predator}\left(z_{gbest,d} - z_d\right)$ and best idea, update the cluster center(s), and afterward move to Step h;
Step g: Through $y_{prey_i,d} = z_d + \xi_d \times P(\mu,\sigma)_d - P_a sgn\left(z_{center,d} - z_d\right)e^{-b|z_{center,d}-z_d|}$ update the ideas with tendency of rousing away from the neighboring cluster centers.
Step h: freshly produced ideas crossovers with the present idea to produce two more ideas. Then evaluate the ideas, and best one will be preserved and confirmed as the innovative individual.
Step i: Execute the chaotic exploration with reference to $ch_{n+1} = 4ch_n(1 - ch_n)$ succeeding to modify the parameters ranges into (0, 1). Along with the formed chain of ideas, prefer best one and utilize it to exchange the preceding supreme idea
Step j: once "*ideas*" have been rationalized, then go to Step k. Otherwise move to Step d;
Step k: subsequent to evaluation of ideas, update the cluster center;
Step l: once current number of iterations is smaller than maximum number of iterations, subsequently move to Step b. Otherwise algorithm will be terminated and best idea is determined as optimal solution.

4. Simulation results

Projected chaotic predator-prey brain storm optimization (CPS) algorithm has been tested in standard IEEE 30 bus system [18]. Comparison of losses is shown in Table 1.

Table 1- loss comparison

variables	Real Power Loss			
	DE [19]	GSA[19]	APOPSO [19]	CPS
VG1	1.1	1.071	1.100	1.098
VG2	1.09	1.022	1.084	1.042
VG5	1.07	1.040	1.056	1.023
VG8	1.07	1.051	1.076	1.049
VG11	1.1	0.977	1.091	1.090
VG13	5	0.968	1.100	0.989
QC 10	5	1.653	5.000	4.980
QC 12	5	4.3722	5.000	5.000
QC 15	5	0.1199	4.879	4.792
QC 17	5	2.0876	4.976	4.976
QC 20	4.41	0.357	3.821	3.700
QC 21	5	0.2602	4.541	4.662
QC 23	2.8004	0.0000	2.354	2.409
QC 24	5	1.3839	4.654	4.509
QC 29	2.5979	0.0000	2.175	2.160
T11 (6-9)	1.04	1.0985	1.029	1.016
T12 (6-10)	0.9097	0.9824	0.911	0.909
T15 (4-12)	0.98	1.095	0.952	0.949
T36 (28-27)	0.9689	1.0593	0.958	0.947
PLoss (MW)	4.555	4.5143	4.398	4.264

variables	Real Power Loss			
VD (PU)	1.9589	0.87522	1.047	1.041
L-index (PU)	0.5513	0.14109	0.1267	0.1203

5.Conclusion

In this work optimal reactive power dispatch problem has been successfully solved by chaotic predator-prey brain storm optimization (CPS) algorithm. In the projected algorithm chaotic theory has been applied to enhance the quality of the exploration. Ergodicity and indiscretion are utilized in the CPS algorithm, such that projected algorithm will not get trapped in the local optimal solution. Chaotic search will be introduced to the exploration in the neighbourhood of the present best solution to prefer superior solution for subsequent generation. In standard IEEE 30bus system chaotic predator-prey brain storm optimization (CPS) algorithm has been tested and power loss has been reduced efficiently.

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