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Blackfish Optimization Algorithm for Solving Reactive Power Problem

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Abstract

In this paper Blackfish Algorithm (BA) has been utilized to solve the optimal reactive power problem. BA is inspired from bubble net hunting strategy of the black fish. In this algorithm roulette wheel selection method has been used to improve the convergence rate. The proposed BA has been tested in standard IEEE 30 bus test system and simulation results show clearly about the better performance of the proposed algorithm in reducing the real power loss with control variables within the limits.

***Keywords**: Blackfish Algorithm, bubble net hunting strategy, optimal reactive power, transmission loss*

1. Introduction

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 like linear programming, gradient method (Alsac et al., 1973; Lee et al., 1985; Monticelli et al., 1987; Deeb et al., 1990; Hobson, 1980; Lee et al., 1993; Mangoli et al., 1993; Canizares et al., 1996) [1-8] has been utilized to solve the reactive power problem, but they lack in handling the constraints to reach a global optimization solution. In the next level various types of evolutionary algorithms (Berizzi et al., 2012; Roy et al., 2012; Hu et al., 2010; Eleftherios et al., 2010) [9-12] has been applied to solve the reactive power problem. This paper propose Blackfish algorithm (BA) for solving reactive power problem. BA is inspired by the bubble-net hunting strategy of Black fish (Seyedali Mirjalili et al., 2016) [13]. BA utilizes roulette wheel selection method to improve the speed of convergence. Proposed BA algorithm has been evaluated on standard IEEE 30 bus test system. The simulation results show that the proposed approach outperforms all the entitled reported algorithms in minimization of real power loss.

2. Objective Function

2.1. Active Power Loss

The objective of the reactive power dispatch problem is to minimize the active power loss and can be defined in equations as follows:

$$F = P_L = \sum_{k\in Nbr} g_k \left(V_i^2 + V_j^2 - 2V_iV_j\cos\theta_{ij}\right) \quad (1)$$

Where F- objective function, P_L – power loss, g_k - conductance of branch,V_i and V_j are voltages at buses i,j, Nbr- total number of transmission lines in power systems.

2.3. Voltage Profile Improvement

To minimize the voltage deviation in PQ buses, the objective function (F) can be written as:

$$F = P_L + \omega_v \times VD \quad (2)$$

Where VD - voltage deviation, ω_v- is a weighting factor of voltage deviation.
And the Voltage deviation given by:

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$$VD = \sum_{i=1}^{Npq} |V_i - 1| \quad (3)$$

Where Npq- number of load buses

2.3. Equality Constraint

The equality constraint of the problem is indicated by the power balance equation as follows:

$$P_G = P_D + P_L \quad (4)$$

Where P_G- total power generation, P_D - total power demand.

2.4. Inequality Constraints

The inequality constraint implies the limits on components in the power system in addition to the limits created to make sure system security. Upper and lower bounds on the active power of slack bus (P_g), and reactive power of generators (Q_g) are written as follows:

$$P_{gslack}^{min} \leq P_{gslack} \leq P_{gslack}^{max} \quad (5)$$

$$Q_{gi}^{min} \leq Q_{gi} \leq Q_{gi}^{max}, i \in N_g \quad (6)$$

Upper and lower bounds on the bus voltage magnitudes (V_i) is given by:

$$V_i^{min} \leq V_i \leq V_i^{max}, i \in N \quad (7)$$

Upper and lower bounds on the transformers tap ratios (T_i) is given by:

$$T_i^{min} \leq T_i \leq T_i^{max}, i \in N_T \quad (8)$$

Upper and lower bounds on the compensators (Q_c) is given by:

$$Q_c^{min} \leq Q_c \leq Q_C^{max}, i \in N_C \quad (9)$$

Where N is the total number of buses, N_g is the total number of generators, N_T is the total number of Transformers, N_c is the total number of shunt reactive compensators.

3. Blackfish Algorithm (BA)

It inspired from the bubble-net hunting strategy of black fish. Algorithm describes the special hunting behaviour of Black fish, and bubbles which causes the creation of '9-shaped path' while encircling prey during hunting. Black fish went down in water roughly 10-16 meters and then it start to produce bubbles in a spiral shape encircles prey and then through the bubbles and it moves towards upward of the surface. Mathematic model of BA is given as follows [13]:

Encompassing prey equation

Black fish enfolds the prey then appraises its position towards the optimum solution over the sequence of swelling number of iteration from start to a maximum number of iteration [13].

$$\vec{E} = \left| F.\vec{Y} * (t) - Y(t) \right| \quad (10)$$

$$\vec{Y}(t+1) = \vec{Y} * (t) - \vec{B}.\vec{E} \quad (11)$$

Where $\vec{B}, \vec{E}$ are coefficient vectors, t is a present iteration, $\vec{y} * (t)$ is position vector of the optimum solution and $Y(t)$ is position vector.

Coefficient vectors $\vec{B}, \vec{E}$ are computed as follows:

$$\vec{B} = 2\vec{g} * rand - \vec{g} \quad (12)$$

$$\vec{F} = 2 * rand \quad (13)$$

Where $\vec{g}$ is a variable linearly decrease from 2 to 0 over the sequence of iteration and rand is a arbitrary number [0, 1].
Bubble-net deeds of Black fish are modelled by following methods [13]:
Dwindling enclosing mechanism
This process is engaged by reducing linearly the value of 'g 'from 2 to 0. Arbitrary value of vector $\vec{B}$ is range between [-1, 1].
Spiral modernizing position
Scientific spiral equation for position modernizing between Blackfish and prey was helix-shaped movement & is given as follows [13]:

$$\vec{Y}(t+1) = \vec{E}'^{*} e^{bt*} \cos(2\pi l) + \vec{Y} * (t) \quad (14)$$

Where l is an arbitrary number [-1, 1], b is constant defines the logarithmic shape, $\vec{E}' = \left|\vec{Y} * (t) - Y(t)\right|$ expresses the distance between i th Black fish to the prey mean the finest solution so far.
50-50% probability of Black fish will either follow the dwindling enclosing path or logarithmic path during optimization.
Arithmetically it modelled as follows:

$$\vec{Y}(t+1) = \begin{cases} \vec{Y} * \vec{B}\vec{E} & if\ p < 0.50 \\ \vec{E}'^{*} e^{bt*} cos(2\pi l) + \vec{Y} * (t) & if\ p \geq 0.50 \end{cases} \quad (15)$$

Where p is an arbitrary number [0, 1].

Exploration for prey
The vector $\vec{B}$ can be used for exploration to search for prey; vector $\vec{B}$also takes the values greater than one or less than -1. Exploration follows two conditions,

$$\vec{E} = \left|\vec{F}.\overrightarrow{Y_{random}} - \vec{Y}\right| \quad (16)$$

$$\vec{Y}\ (t+1) = \overrightarrow{Y_{random}} - \vec{B}.\vec{E} \quad (17)$$

Following two conditions have been followed in algorithm
$\left|\vec{B}\right| > 1$ Imposes exploration on BA algorithm to find out global optimum.
$\left|\vec{B}\right| < 1$ To update the position of present search agent

4. Simulation Results

Validity of Black fish algorithm has been verified by testing in IEEE 30-bus, 41 branch system and it has 6 generator-bus voltage magnitudes, 4 transformer-tap settings, and 2 bus shunt reactive compensators. Bus 1 is taken as slack bus and 2, 5, 8, 11 and 13 are considered as PV generator buses and others are PQ load buses. Control variables limits are given in Table 1.

Table 1. Primary Variable Limits (Pu)

Variables	Min.	Max.	category
Generator Bus	0.9	1.1	Continuous
Load Bus	0.95	1.05	Continuous
Transformer-Tap	0.90	1.10	Discrete
Shunt Reactive Compensator	- 0.10	0.30	Discrete

In Table 2 the power limits of generators buses are listed.

Table 2. Generators Power Limits

Bus	Pg	Pgmin	Pgmax	Qgmin
1	96.00	49	200	-19
2	79.00	18	79	-19
5	49.00	14	49	-11
8	21.00	11	31	-14
11	21.00	11	28	-12
13	21.00	11	39	-14

Table 3 shows the proposed BA approach successfully kept the control variables within limits. Table 4 list out the overall comparison of the results of optimal solution obtained by various methods.

Table 3. After optimization values of control variables

Control Variables	BA
V1	1.0517
V2	1.0482
V5	1.0279
V8	1.0399
V11	1.0798
V13	1.0527
T4,12	0.00
T6,9	0.01
T6,10	0.90
T28,27	0.91
Q10	0.10
Q24	0.10
Real power loss	4.2879
Voltage deviation	0.9080

Table 4. Comparison of results

Techniques	Real power loss (MW)
SGA(Wu et al., 1998)	4.98
PSO(Zhao et al., 2005)	4.9262
LP(Mahadevan et al., 2010)	5.988
EP(Mahadevan et al., 2010)	4.963
CGA(Mahadevan et al., 2010)	4.980
AGA(Mahadevan et al., 2010)	4.926
CLPSO(Mahadevan et al., 2010)	4.7208
HSA (Khazali et al., 2011)	4.7624
BB-BC (Sakthivel et al., 2013)	4.690
BA	4.2879

5. Conclusion

In this paper, Blackfish algorithm has been effectively applied to solve Optimal Reactive Power Dispatch problem. The proposed BA algorithm has been tested in the standard IEEE 30 bus system. Simulation results show the heftiness of projected Blackfish algorithm in declining the real power loss. The control variables obtained after the optimization by BA are well within the limits.

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