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ENRICHED BLACK HOLE ALGORITHM FOR DIMINUTION OF REAL POWER LOSS

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Abstract

This paper presents an Enriched Black Hole (EBH) algorithm for solving reactive power flow problem. The Black Hole Algorithm starts with a preliminary population of contestant and for all iteration of the black hole algorithm, the most excellent candidate is favored to be the black hole, which followed by pulling further candidates around it, called stars. If a star move very close to the black hole, it will be consumed by the black hole and is vanished undyingly. In such a case, a new star - candidate solution is arbitrarily created and placed in the exploration space and starts a new search. Black hole algorithm is feeble to carry out global search completely in the large size problem spaces. So the enhancement in the amalgamation process in black hole algorithm has to be done. In this work, black hole algorithm will be enhanced, using stars gravities information. For this aim, a kind of gravitational force between stars is defined and the movement of stars to the black hole is adjusted during the penetration of solution space. In order to evaluate the projected Enriched Black Hole (EBH) algorithm, it has been tested in Standard IEEE 57,118 bus systems and compared to other standard reported algorithms. Simulation results reveal about the Enriched performance of the projected algorithm in plummeting the real power loss.

Keywords: Optimal Reactive Power; Transmission Loss; Enriched Black Hole.

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1. Introduction

Optimal reactive power dispatch problem is one of the difficult optimization problems in power systems. The sources of the reactive power are the generators, synchronous condensers, capacitors, static compensators and tap changing transformers. The problem that has to be solved in a reactive power optimization is to determine the required reactive generation at various locations so as to optimize the objective function. Here the reactive power dispatch problem involves best utilization of the existing generator bus voltage magnitudes, transformer tap setting and the output of reactive power sources so as to minimize the loss and to enhance the voltage stability of the system. It involves a non linear optimization problem. Various mathematical techniques have been adopted to solve this optimal reactive power dispatch problem. These include the gradient method [1-2], Newton method [3] and linear programming [4-7].The gradient and Newton methods suffer from the difficulty in handling inequality constraints. To apply linear programming, the input- output function is to be expressed as a set of linear functions which may lead to loss of accuracy. Recently Global Optimization techniques such as genetic algorithms have been proposed to solve the reactive power flow problem [8, 9]. In this paper, Enriched Black Hole (EBH) algorithm utilized for solving reactive power problem. The fundamental design of a black hole is basically an area of space that has so much mass concerted in it and there is no means for a close by object to get away from the gravitational heave. In black hole algorithm (BHA) [10-15] begins with a preliminary population of candidate solutions to an optimization problem. Black hole algorithm is feeble to carry out global search completely in the large size problem spaces. So the enhancement in the amalgamation process in black hole algorithm has to be done. In this work, black hole algorithm will be enhanced, using stars gravities information. For this aim, a kind of gravitational force between stars is defined and the movement of stars to the black hole is adjusted during the penetration of solution space. The performance of Enriched Black Hole (EBH) algorithm has been evaluated in Standard IEEE 57,118 bus systems & the results analysis shows that our proposed approach outperforms all approach explored in this paper.

2. Objective Function

Active Power Loss

Main aim of the reactive power dispatch problem is to reduce the active power loss in the transmission network, which can be described as:

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

Where g_k: is the conductance of branch between nodes i and j, Nbr: is the total number of transmission lines in power systems.

Voltage Profile Improvement

For minimization of the voltage deviation in PQ buses, the objective function turns into:

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

Where ω_v: is a weighting factor of voltage deviation.
VD is the voltage deviation given by:

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

Equality Constraint

The equality constraint of the Reactive power problem is represented by the power balance equation, and can be written as, where the total power generation must cover the total power demand and total power loss:

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

Where, P_G - Total Power Generation, P_D-Total Power Demand, P_L – Total Power Loss.

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Inequality Constraints

Inequality constraints define the limitations in power system components and power system security. Upper and lower bounds on the active power of slack bus, and reactive power of generators are written as follows:

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

$$Q_{gi}^{min} \leq Q_{gi} \leq Q_{gi}^{max}, i \in N_g \tag{6}$$

Upper and lower bounds on the bus voltage magnitudes are described as follows:

$$V_i^{min} \leq V_i \leq V_i^{max}, i \in N \tag{7}$$

Upper and lower bounds on the transformers tap ratios are given as follows:

$$T_i^{min} \leq T_i \leq T_i^{max}, i \in N_T \tag{8}$$

Upper and lower bounds on the compensators reactive powers are written as follows:

$$Q_c^{min} \leq Q_c \leq Q_C^{max}, i \in N_C \tag{9}$$

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

3. Black Hole Algorithm

The Black Hole Algorithm (BHA) is a population-based technique that has some similar characteristics with other population-based techniques. The same as with other population-based algorithms, a population of candidate solutions to a specified problem is formed and scattered arbitrarily in the exploration space. The population-based algorithms develop the produced population in the way of the optimal solution via exact method. In the BHA algorithm the progression of the population is done by moving all the candidates in the direction of the best candidate in every iteration, which is, the black hole and replace with those candidates that come into within the range of the black hole by recently produced candidates in the exploration space. In the BHA the most outstanding candidate among all the candidates at every iteration is selected as a black hole and all the other candidates form the regular stars. The formation of the black hole is not arbitrary and it is one of the authentic candidates of the population. Then, all the candidates are stirred towards the black hole based on their existing location and an arbitrary number. Alike to other population-based algorithms, black hole algorithm (BHA) is an arbitrarily produced population of candidate solutions – the stars – are located in the exploration space of the problem. Subsequent initialization, the fitness values of the population are calculated and the most outstanding candidate in the population, which has the most outstanding fitness value, is selected to be the black hole and the rest form the regular stars. The black hole has the ability to take in the stars that surround it.

After initializing the black hole and stars, the black hole begin to take up the stars surround it and all the stars start moving in the direction of the black hole.

The amalgamation of stars by the black hole is formulated as follows:

$$X_i(t+1) = X_i(t) + rand \times \left(X_{BH} -, X_i(t)\right) \; i = 1,2,..,N \tag{10}$$

Where $x_i(t)$ and $x_i(t+1)$ are the locations of the ith star at iterations t and t + 1, respectively. x_{BH} is the location of the black hole in the explore space. $rand$ is a arbitrary number in the interval [0, 1]. N is the number of stars (candidate solutions).

While moving in the direction of the black hole, a star might reach a position with lower cost than the black hole. In such a case, the black hole moves about to the position of that star and vice versa. Then the BHA algorithm will go on with the black hole in the fresh location and then stars start moving in the direction of this fresh location. In addition, there is a possibility of crossing the event horizon at some stage of moving stars towards the black hole. Every star (candidate solution) that crosses the event horizon of the black hole will be sucked by the black hole. Every time a candidate (star) expire – it is sucked in by the black hole – an additional candidate solution (star) is born and dispersed arbitrarily in the explore space and starts a fresh search. This is done to maintain the number of candidate solutions constant. Subsequent iteration takes place after all the stars have been moved.

The radius of the event horizon in the black hole algorithm is computed using the following equation:

$$R = \frac{f_{BH}}{\sum_{i=1}^{N} f_i} \tag{11}$$

Where f_{BH} is the fitness value of the black hole and fi is the fitness value of the ith star. N is the number of stars (candidate solutions). When the distance between a candidate solution and the black hole (best candidate) is less than R, that candidate is collapsed and a new candidate is created and distributed randomly in the search space. Based on the above explanation the key steps in the BHA algorithm are concise as follows:

a) Initialize a population of stars with arbitrary locations in the explore space
Loop
b) For every star, calculate the objective function
c) Pick the most excellent star that has the most excellent fitness value as the black hole
d) Modify the position of every star according to Eq. (10)
e) If a star attains a position with lower cost than the black hole, then swap their locations
f) If a star crosses the event horizon of the black hole, substitute it with a fresh star in an arbitrary location in the search space
g) If a stop criterion is met, exit the loop
End loop

4. Enriched Black Hole Algorithm (EBH)

Black hole algorithm is feeble to carry out global search completely in the large size problem spaces. So the enhancement in the amalgamation process in black hole algorithm has to be done. Two significant characteristics of the swarm-based methods are exploration and exploitation. The exploration is related to penetrating of space, where the exploitation is search for the optimum. The exploration is a significant theme in swarm-based heuristic algorithms. Over time, exploring will be condensed and exploitation aptitude lightens in, so the algorithm alters itself in the semi-optimal points. There should be equilibrium between exploration and exploitation, to keep black hole algorithm protected from trapping in local optima. In this work, black hole algorithm will be enhanced, using stars gravities information. For this aim, a kind of gravitational force between stars is defined and the movement of stars to the black hole is adjusted during the penetration of solution space.

There will be Swarm with N stars. The location of the ith stars (X_i) is defined by Eq. (12).

$$X_i = (star_i, \dots, star_N, blcakhole_d) \tag{12}$$

Where $star_i$ is the position of ith star and $blackhole_d$ is the position of d^{th} black hole, respectively.

At a exact time "t", we define the amalgamation acting on star "i" from star "j" as Eq. (13).

$$E_{ij}^{d} = \xi(t_o) \frac{C_{pi}(t) \times C_{aj}(t) \times \left(star_j(t) - star_i(t)\right)}{\left(D_{ij}(t) + \varepsilon\right)^2 \times \left(C_{pi}(t) + C_{aj}(t)\right)} \times \left(\frac{t_o}{t - t_o}\right)^a \tag{13}$$

Where C_{aj} is the power of star j, C_{pi} is the power associated to star i, $\xi(t_0)$ is preliminary incorporation constant, ε is a small constant, and $D_{ij}(t)$ is distance between two stars i and j. To give a stochastic characteristic to black hole algorithm, entire force is arbitrarily weighted sum of the forces of others (Eq. (14)).

$$E_i^d(t) = \sum_{j=1\ J \neq i}^{N} random_i E_{ij}^d(t) \tag{14}$$

Where $random_j$ is in [0,1]. Hence, the acceleration of the star i at time t, and in direction d^{th}, is given by Eq. (15).

$$a_i^d(t) = \frac{E_i^d(t)}{C_{ii}(t)} \tag{15}$$

Where C_{ii} is the Power of i^{th} star, the next velocity of star is considered as follows. Consequently, position and its velocity are designed based on Eq. (16) and Eq. (17).

$$v_i^d(t+1) = random_i \times v_i^d(t) + a_i^d(t) \tag{16}$$

$$star_i(t+1) = star_i(t) + v_i^d(t+1) \tag{17}$$

Where $random_i$ is in [0, 1]. This arbitrary number is for randomization of the exploration.

5. Simulation Results

At first Enriched Black Hole (EBH) algorithm has been tested in standard IEEE-57 bus power system. The reactive power compensation buses are 18, 25 and 53. Bus 2, 3, 6, 8, 9 and 12 are PV buses and bus 1 is selected as slack-bus. The system variable limits are given in Table 1.

The preliminary conditions for the IEEE-57 bus power system are given as follows:
P_{load} = 12.128 p.u. Q_{load} = 3.062 p.u.

The total initial generations and power losses are obtained as follows:
$\sum P_G$ = 12.472 p.u. $\sum Q_G$ = 3.3164 p.u.
P_{loss} = 0.25872 p.u. Q_{loss} = -1.2074 p.u.

Table 2 shows the various system control variables i.e. generator bus voltages, shunt capacitances and transformer tap settings obtained after optimization which are within the acceptable limits. In Table 3, shows the comparison of optimum results obtained from proposed methods with other optimization techniques. These results indicate the robustness of proposed approaches for providing better optimal solution in case of IEEE-57 bus system.

Table 1: Variable Limits

Reactive Power Generation Limits							
Bus no	1	2	3	6	8	9	12
Qgmin	-1.4	-.015	-.02	-0.04	-1.3	-0.03	-0.4
Qgmax	1	0.3	0.4	0.21	1	0.04	1.50
Voltage And Tap Setting Limits							
vgmin	**Vgmax**	**vpqmin**	**Vpqmax**	**tkmin**	**tkmax**		
0.9	1.0	0.91	1.05	0.9	1.0		
Shunt Capacitor Limits							
Bus no	18	25	53				
Qcmin	0	0	0				
Qcmax	10	5.2	6.1				

Table 2: Control variables obtained after optimization

Control Variables	**EBH**
V1	1.1
V2	1.032
V3	1.030
V6	1.021
V8	1.022
V9	1.009
V12	1.014
Qc18	0.0661
Qc25	0.200
Qc53	0.0470
T4-18	1.009
T21-20	1.044
T24-25	0.862
T24-26	0.872
T7-29	1.052
T34-32	0.874
T11-41	1.013
T15-45	1.030
T14-46	0.910
T10-51	1.020
T13-49	1.060
T11-43	0.910
T40-56	0.900
T39-57	0.950
T9-55	0.950

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Table 3: Comparison results

S.No.	Optimization Algorithm	Finest Solution	Poorest Solution	Normal Solution
1	NLP [16]	0.25902	0.30854	0.27858
2	CGA [16]	0.25244	0.27507	0.26293
3	AGA [16]	0.24564	0.26671	0.25127
4	PSO-w [16]	0.24270	0.26152	0.24725
5	PSO-cf [16]	0.24280	0.26032	0.24698
6	CLPSO [16]	0.24515	0.24780	0.24673
7	SPSO-07 [16]	0.24430	0.25457	0.24752
8	L-DE [16]	0.27812	0.41909	0.33177
9	L-SACP-DE [16]	0.27915	0.36978	0.31032
10	L-SaDE [16]	0.24267	0.24391	0.24311
11	SOA [16]	0.24265	0.24280	0.24270
12	LM [17]	0.2484	0.2922	0.2641
13	MBEP1 [17]	0.2474	0.2848	0.2643
14	MBEP2 [17]	0.2482	0.283	0.2592
15	BES100 [17]	0.2438	0.263	0.2541
16	BES200 [17]	0.3417	0.2486	0.2443
17	Proposed EBH	0.22012	0.23008	0.22214

Then Enriched Black Hole (EBH) algorithm has been tested in standard IEEE 118-bus test system [18].The system has 54 generator buses, 64 load buses, 186 branches and 9 of them are with the tap setting transformers. The limits of voltage on generator buses are 0.95 -1.1 per-unit., and on load buses are 0.95 -1.05 per-unit. The limit of transformer rate is 0.9 -1.1, with the changes step of 0.025. The limitations of reactive power source are listed in Table 4, with the change in step of 0.01.

Table 4: Limitation of reactive power sources

BUS	5	34	37	44	45	46	48
QCMAX	0	14	0	10	10	10	15
QCMIN	-40	0	-25	0	0	0	0
BUS	74	79	82	83	105	107	110
QCMAX	12	20	20	10	20	6	6
QCMIN	0	0	0	0	0	0	0

The statistical comparison results of 50 trial runs have been list in Table 5 and the results clearly show the better performance of proposed Enriched Black Hole (EBH) algorithm in reducing the real power loss.

Table 5: Comparison results

Active power loss (MW)	BBO [19]	ILSBBO/ strategy1 [19]	ILSBBO/ strategy1 [19]	Proposed EBH
Min	128.77	126.98	124.78	117.02
Max	132.64	137.34	132.39	119.88
Average	130.21	130.37	129.22	118.94

6. Conclusion

In this paper a novel approach Enriched Black Hole (EBH) algorithm used to solve reactive power problem, considering various generator constraints, has been successfully applied.The performance of the proposed Enriched Black Hole (EBH) algorithm has been has been tested in standard IEEE 57,118 bus systems and simuation results represent about the reduction of real power loss when compared with other standard reported algorithms and generally volatge profiles are within the limits.

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