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Solving optimal reactive power problem by enhanced fruit fly optimization algorithm and status of material algorithm

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ABSTRACT

This paper proposes enhanced fruit fly optimization algorithm (EFF) and status of material algorithm (SMA) to solve the optimal reactive power problem. Fruit fly optimization algorithm is based on the food finding behavior of the fruit fly. There are two steps in food finding procedure of fruit fly: At first it smells the food source by means of osphresis organ and it flies in that direction; afterwards, when it gets closer to the food site, through its sensitive vision it will find the food. At the beginning of the run by diminishing the inertia weight from a large value to a small value, will lead to enhance the global search capability and more local search ability will be in process the end of the run of the EFF algorithm. Then SMA is projected to solve the problem. Three state of material are solid, liquid, and gas. For evolution procedure direction vector operator assign a direction to every molecule consecutively to guide the particle progression. Collision operator imitates the collisions factor in which molecules are interacting to each other. Proposed enhanced EFF, SMA has been tested in standard IEEE 30 bus test system and simulation results show the projected algorithms reduced the real power loss considerably.

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1. INTRODUCTION

Reactive power problem plays an important role in secure and economic operations of power system. Numerous types of methods [1-6] have been utilized to solve the optimal reactive power problem. However many scientific difficulties are found while solving problem due to an assortment of constraints. Evolutionary techniques [7-15] are applied to solve the reactive power problem. This paper proposes enhanced fruit fly optimization algorithm, status of material algorithm to solve the optimal reactive power problem. Fruit fly optimization algorithm is based on the food finding behavior of the fruit fly. When compare to other species fruit fly is better to in vision and osphresis. In the projected enhanced fruit fly optimization algorithm (EFF), linear generation mechanism of candidate solution is incorporated with fruit fly algorithm. In order to maintain the balance between global and local search an inertia weight is applied in the procedure. For global search large inertia weight is utilized and small inertia weight applied for local search. At the beginning of the run by diminishing the inertia weight from a large value to a small value, will lead to enhance the global search capability and more local search ability will be in process the end of the run. Then status of material algorithm (SMA) is utilized to solve the optimal reactive power problem. Three state of material are solid, liquid, and gas. In gas there is no precise shape, but fit into the entire

container in which it is restricted. Development is tested by the molecules represent the utmost allowable displacement ρ1 amongst the particles. Intermolecular forces restricted in liquid state, than in gas state. There will be sufficient energy for the molecules to shift reasonably to each other but a mobile structure will reign. Throughout the container the shape of the liquid can be accessed. Molecules denote a particle movement ρ2 within the liquid state. Molecules are crammed collectively with forces amongst the particles are being tough enough cannot move liberally only can vibrate in the solid state. Solid state has a steady, unambiguous shape and possesses specific volume. Solids can only modify their shape by applying force, and particles are capable to vibrate taking into account of a minimum ρ3 distance. Collision operator imitates the collisions factor in which molecules are interacting to each other. In arbitrary behaviour of molecules, capricious positions are formed subsequent to a probabilistic condition which considers capricious locations within a realistic exploration space. Proposed enhanced fruit fly optimization algorithm (EFF), status of material algorithm (SMA) has been tested in standard IEEE 30 bus test system and simulation results show the projected algorithms reduced the real power loss considerably.

2. PROBLEM FORMULATION

Objective of the problem is to reduce the true power loss:

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

Voltage deviation given as follows:

$$F = P_L + \omega_v \times \text{Voltage Deviation} \quad (2)$$

Voltage deviation given by:

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

Constraint (equality):

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

Constraints (inequality):

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

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

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

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

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

3. ENHANCED FRUIT FLY OPTIMIZATION ALGORITHM

Fruit fly optimization algorithm is based on the food finding behavior of the fruit fly. When compare to other species fruit fly is better to in vision and osphresis [16]. There are two steps in food finding procedure of fruit fly: at first it smells the food source by means of osphresis organ and it flies in that direction; afterwards, when it gets closer to the food site, through its sensitive vision it will find the food. Modeled algorithm of the fruit fly optimization has been given below:

a. Initialization of parameters
b. Candidate solutions are engendered
c. Location of fruit fly swarm at preliminary level

$$x\_axis = random\ (LR)\ ;\ y\_axis = random\ (LR) \quad (10)$$

d. Confer capricious direction and distance for finding the food by an individual fruit fly

$$x_i = x\_axis + random\ (FR)\ ;\ y_i = y\_axis + random\ (FR) \quad (11)$$

e. From the origin compute the distance of food location

$$Distance_{\ i} = \sqrt{x_i^2 + y_i^2} \quad (12)$$

f. Value of the smell concentration judgment is found by,

$$S_i = \frac{1}{Distance_i} \quad (13)$$

$$S_i = \frac{1}{\sqrt{(x\_axis + random\ (FR))^2 + (y\_axis + random\ (FR))^2}} \quad (14)$$

g. Individual fruit fly smell concentration is calculated by,

$$Smell_i = objectivefunction(S_i) \quad (15)$$

h. Among the fruit fly swarm discover out the fruit fly with maximum smell concentration,

$$[smell\ best, best\ index] = maximum(smell) \quad (16)$$

i. By using vision towards that location fruit fly swarm flies,

$$smell\ best = best\ smell \quad (17)$$

$$x\_axis = x(best\ index) \quad (18)$$

$$y\_axis = y(best\ index) \quad (19)$$

j. Replicate the implementation of steps b-i. When the smell concentration is not superior to the preceding iterative smell concentration any longer or when the iterative number reaches the maximum number of iterations, the flow will stop.

In the projected enhanced fruit fly optimization algorithm (EFF), linear generation mechanism of candidate solution is incorporated with fruit fly algorithm. In order to maintain the balance between global and local search an inertia weight is applied in the procedure. For global search large inertia weight is utilized and small inertia weight applied for local search. At the beginning of the run by diminishing the inertia weight from a large value to a small value, will lead to enhance the global search capability and more local search ability will be in process the end of the run.

a. Initialization of parameters
b. Candidate solutions are engendered through linear generation mechanism
c. Location of fruit fly swarm at preliminary level

$$x\_axis' = n * random \quad (20)$$

d. Confer capricious direction and distance for finding the food by an individual fruit fly

$$x_i' = x\_axis' + \omega * random\ ;\omega = \omega_o * \alpha^{generation} \quad (21)$$

e. Value of the smell concentration judgment is found by

$$S_i' = x_i' = x\_axis' + \omega * random \quad (22)$$

k. Individual fruit fly smell concentration is calculated by,

$$Smell_i' = objectivefunction(S_i') \quad (23)$$

l. Among the fruit fly swarm discover out the fruit fly with maximum smell concentration,

$$[smell\ best', best\ index'] = maximum(smell') \quad (24)$$

m. Maintain the maximum concentration value and x'coordinate. subsequently, by using vision the fruit fly swarm flies in the direction of that location:

$$smell\ best' = best\ smell' \tag{25}$$

$$x\_axis' = x(best\ index)' \tag{26}$$

n. Replicate the implementation of Steps b-i. When the smell concentration is not superior to the preceding iterative smell concentration any longer or when the iterative number reaches the maximum number of iterations, the flow will stop.

4. STATUS OF MATERIAL ALGORITHM

Conventionally, three state of material are solid, liquid, and gas. In gas there is no specific shape, but fit into the whole container in which it is restricted. Progression is tested by the molecules symbolize the utmost allowable displacement $\rho 1$ amongst the particles. Intermolecular forces are extra restricted in liquid state, than in gas state. There will be enough energy for the molecules to shift comparatively to each other but a mobile structure will prevail. Through the container the shape of the liquid can be accessed. Molecules symbolize a particle movement $\rho 2$ inside the liquid state. Molecules are crammed collectively with forces amongst the particles are being tough enough cannot move liberally only can vibrate in the solid state. Solid state has a steady, unambiguous shape and possesses specific volume. Solids can only modify their shape by applying force, and particles are capable to vibrate taking into account of a minimum $\rho 3$ distance [17].

In the proposed method status of material algorithm (SMA), for evolution procedure direction vector operator assign a direction to every molecule consecutively to guide the particle progression. Collision operator imitates the collisions factor in which molecules are interacting to each other. In arbitrary behaviour of molecules, capricious positions are formed subsequent to a probabilistic condition which considers capricious locations within a realistic exploration space. Primarily within the range of [-1, 1], all the direction vectors $\left(G = \left\{g_1, g_2, .., g_{N_p}\right\}\right)$ are arbitrarily chosen. Molecules experience numerous attraction forces and new-fangled direction vector is calculated by:

$$g_i^{k+1} = g_i^k \cdot \left(1 - \frac{k}{gen}\right) \cdot 0.5 + a_i \tag{27}$$

$$a_i = (Q^{best} - Q_i)/\|Q^{best} - Q_i\|, \tag{28}$$

Velocity $V_i$of every molecule is calculated by,

$$V_i = g_i \cdot v_{init} \tag{29}$$

Initial velocity $v_{initial}$magnitude computed by,

$$v_{initial} = \frac{\sum_{j=1}^{n}\left(b_j^{high} - b_j^{low}\right)}{n} \cdot \beta \tag{30}$$

New-fangled location for every molecule is modernized by,

$$Q_{i,j}^{k+1} = Q_{i,j}^k + v_{i,j} \cdot rand(0,1) \cdot \rho \cdot \left(b_j^{high} - b_j^{low}\right) \tag{31}$$

When two molecules which is shorter than a determined proximity value then Collisions will occur. Consequently, if $\|Q_i - Q_q\| < r$, a collision between molecules i and q is assumed; or else, there won't be collision, in view of $i, q \in \{1, .., N_P\} \neq q$. When collision occurs, every particle direction vector is tailored by swapping their particular direction vectors as follows:

$$g_i = g_q\ and\ g_q = g_i \tag{32}$$

Collision radius computed by,

$$r = \frac{\sum_{j=1}^{n}\left(b_j^{high} - b_j^{low}\right)}{n} \cdot \alpha \tag{33}$$

Within the range [0, 1] an uniform arbitrary number $r_m$is generated and modelled by,

$$Q_{i,j}^{k+1} = \begin{cases} b_j^{low} + rand(0,1) \cdot \left(b_j^{high} - b_j^{low}\right) with\ probability\ H \\ Q_{i,j}^{k+1} with\ porbability\ 1-H \end{cases} \quad (34)$$

Most excellent found individual from the current k population $\mathbf{Q}^{\mathbf{best,k}}$ is compare to the most excellent individual $\mathbf{Q}^{\mathbf{best,k-1}}$ of the previous generation. If $\mathbf{Q}^{\mathbf{best,k}}$ is enhanced than $\mathbf{Q}^{\mathbf{best,k-1}}$ by fitness value, then best **Q** is modernized with $\mathbf{Q}^{\mathbf{best,k}}$, or else $\mathbf{Q}^{\mathbf{best}}$ remains without any change. Consequently, $\mathbf{Q}^{\mathbf{best}}$ stock up the most excellent individual found up to now. Modus operandi map the existing population $\mathbf{Q}^{\boldsymbol{k}}$ to the new-fangled population $\mathbf{Q}^{\boldsymbol{k+1}}$**.** Algorithm obtain the existing population $\mathbf{Q}^{\boldsymbol{k}}$ and the configuration parameters ρ, β, α and *H*, yield the new-fangled population $\mathrm{Q}^{\boldsymbol{k+1}}$**.**

– Common procedure:

Step a: Best element of the population $Q^{best} \in \{Q\}$ has been found

Step b: $v_{initial}$, r are calculated

Step c: By means of the Direction vector operator find the new-fangled molecules

Step d: By utilizing the Collision operator resolve the collisions

Step e: By utilizing the arbitrary positions operator find the new-fangled arbitrary positions

In the optimization procedure, 50% of iterations for the gas state (exploration), 40% of iterations for the liquid state (exploration-exploitation) and 10% of iterations for the solid state (exploitation). Algorithm begins by initializing a set **Q** of N_Q molecule $\left(Q = \left\{Q_1, Q_2, .., Q_{N_q}\right\}\right)$ each molecule position $\mathbf{Q}_i$ is a*n*-dimensional vector containing the parameter values to be optimized. Values are arbitrarily and unvaryingly dispersed between the pre-specified lower preliminary parameter bound $b_j^{low}$and the upper initial parameter bound b_j^{high} as follows,

$$Q_{i,j}^{0} = b_j^{low} + rand(0,1) \cdot \left(b_j^{high} - b_j^{low}\right) \quad (35)$$

– Gas status

Step a: Parameters $\rho \in$ [0.80, 1], β=0.80, α=0.80, and *H*=0.90 are fixed

Step b: Common procedure will be applied

Step c: When 50% of the entire iteration number is ended ($1 \leq k \leq 0.5 \leq$ *generation*), afterwards the procedure continues to the liquid state process; or else go back to step b.

– Liquid status

Step d: Parameters $\rho \in$[0.30, 0.60], β=0.40, α=0.20, and *H*=0.20 are fixed

Step e: Common procedure will be applied

Step f: When 90% (50% from the gas state and 40% from the liquid state) of the entire iteration number is concluded ($0.5 \cdot generation < k \leq 0.9 \cdot generation$), afterwards the procedure continue to the solid state process; if not go back to step e.

– Solid status

Step g: Parameters $\rho \in$[0.0, 0.1] and β=0.1, α=0, and *H*=0 are fixed

Step h: Common procedure will be applied

Step i: If the 100% of the entire iteration number is concluded ($0.9 \cdot gen < k \leq gen$), then the procedure is completed; if not go back to step h.

5. SIMULATION RESULTS

Proposed enhanced fruit fly optimization algorithm (EFF) and status of material algorithm (SMA) has been tested in standard IEEE 30 Bus system [18]. Table 1 shows the constraints of control variables, Table 2 shows the limits of reactive power generators and comparison results are presented in Table 3. Figure 1 gives the comparison of real power loss and Figure 2 gives the reduction of real power loss (%) with reference to base case value.

Table 1. Constraint values of the control variables

System type	List of variables	Minimum value (PU)	Maximum value (PU)
IEEE 30 Bus	Generator voltage	0.95	1.1
	Transformer tap	0.9	1.1

VAR source	0	0.20

Table 2. Constrains values of the reactive power generators

System type	List of variables	Value of Q minimum (PU)	Value of Q maximum (PU)
IEEE 30 Bus	1	0	10
	2	-40	50
	5	-40	40
	8	-10	40
	11	-6	24
	13	-6	24

Table 3. Simulation results of IEEE-30 system

List of control variables	Base case value	MPSO [19]	PSO [19]	EP [19]	SARGA [19]	EFF	SMA
VG-1	1.060	1.101	1.100	NR*	NR*	1.014	1.021
VG-2	1.045	1.086	1.072	1.097	1.094	1.030	1.029
VG-5	1.010	1.047	1.038	1.049	1.053	1.011	1.010
VG-8	1.010	1.057	1.048	1.033	1.059	1.019	1.018
VG-12	1.082	1.048	1.058	1.092	1.099	1.020	1.016
VG-13	1.071	1.068	1.080	1.091	1.099	1.024	1.020
Tap-11	0.978	0.983	0.987	1.01	0.99	0.942	0.937
Tap-12	0.969	1.023	1.015	1.03	1.03	0.911	0.921
Tap-15	0.932	1.020	1.020	1.07	0.98	0.909	0.914
Tap-36	0.968	0.988	1.012	0.99	0.96	0.917	0.932
QC-10	0.19	0.077	0.077	0.19	0.19	0.090	0.090
QC-24	0.043	0.119	0.128	0.04	0.04	0.105	0.104
PG (MW)	300.9	299.54	299.54	NR*	NR*	298.37	298.41
QG (Mvar)	133.9	130.83	130.94	NR*	NR*	130.18	130.26
Reduction in PLoss (%)	0	8.4	7.4	6.6	8.3	18.23	20.38
Total PLoss (Mw)	17.55	16.07	16.25	16.38	16.09	14.349	13.972

Note: NR*-Not reported

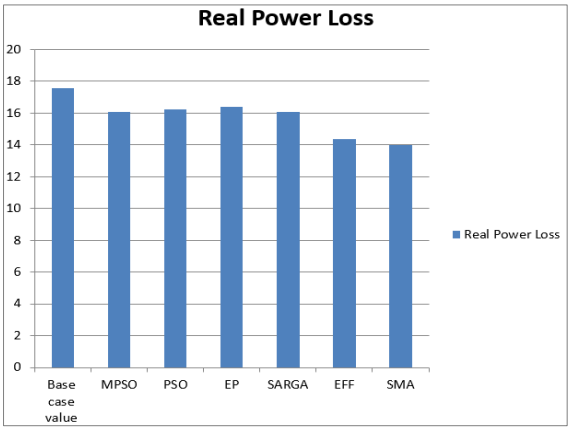

Figure 1. Comparison of real power loss

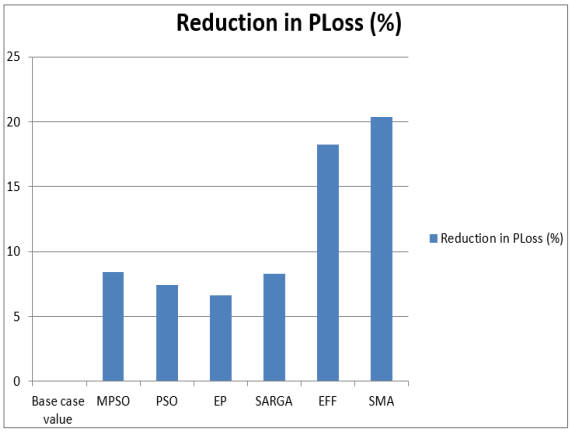

Figure 2. Reduction of real power loss (%) with reference to base case value

6. CONCLUSION

Proposed enhanced fruit fly optimization algorithm (EFF), status of material algorithm (SMA) successfully solved the optimal reactive power problem. In the projected Enhanced Fruit fly optimization algorithm (EFF), linear generation mechanism of candidate solution is incorporated with fruit fly algorithm. Then status of material algorithm (SMA) is projected to solve the problem in which to establish the evolution procedure direction vector operator assigns a direction to every molecule consecutively to guide the particle progression. Proposed enhanced fruit fly optimization algorithm (EFF), status of material algorithm (SMA) has been tested in standard IEEE 30 bus test system and simulation results show the projected algorithms reduced the real power loss considerably.

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