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Hybridization of Genetic Particle Swarm Optimization Algorithm with Symbiotic Organisms Search Algorithm for Solving Optimal Reactive Power Dispatch Problem

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Abstract

In this work Hybridization of Genetic Particle Swarm Optimization Algorithm with Symbiotic Organisms Search Algorithm (HGPSOS) has been done for solving the power dispatch problem. Genetic particle swarm optimization problem has been hybridized with Symbiotic organisms search (SOS) algorithm to solve the problem. Genetic particle swarm optimization algorithm is formed by combining the Particle swarm optimization algorithm (PSO) with genetic algorithm (GA). Symbiotic organisms search algorithm is based on the actions between two different organisms in the ecosystem- mutualism, commensalism and parasitism. Exploration process has been instigated capriciously and every organism specifies a solution with fitness value. Projected HGPSOS algorithm improves the quality of the search. Proposed HGPSOS algorithm is tested in IEEE 30, bus test system- power loss minimization, voltage deviation minimization and voltage stability enhancement has been attained.

Keywords: Optimal Reactive Power, Transmission Loss, Particle swarm optimization algorithm, genetic algorithm, Symbiotic organisms search algorithm

1. Introduction

In this work Hybridization of Genetic Particle Swarm Optimization Algorithm with Symbiotic Organisms Search Algorithm (HGPSOS) has been done to solve the optimal reactive power dispatch problem. Real power loss minimization problem and voltage stability enhancement are the main objectives of this work. Different conventional methods like Newton's method, interior point method; successive quadratic programming method [1-6] and Evolutionary algorithms like gravitational search, particle swarm optimization, symbiotic organism search algorithm [7-20] are utilized to solve the problem. Genetic particle swarm optimization algorithm is formed by combining the Particle swarm optimization algorithm (PSO) with genetic algorithm (GA) and capriciously engenders the population with stochastic acceleration of particle towards best particle of the swarm. Then Genetic particle swarm optimization problem has been hybridized with Symbiotic organisms search (SOS) algorithm to solve the problem. In SOS Three

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stages mutualism, commensalism and parasitism will create new-fangled solutions and it has been rationalized when it is finer to previous solution. Projected HGPSOS algorithm improves the quality of the search. Mainly exploration and exploitation has been balanced. Proposed HGPSOS algorithm has been tested in standard IEEE 30 bus test system minimization of power loss, voltage deviation minimization, and voltage stability enhancement results has been attained.

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:

$$E(\bar{x},\bar{y}) = 0 \tag{2}$$
$$I(\bar{x},\bar{y}) = 0 \tag{3}$$
$$x = \left[VG_1,\ldots,VG_{Ng};QC_1,\ldots,QC_{Nc};T_1,\ldots,T_{N_T}\right] \tag{4}$$
$$y = \left[PG_{slack};VL_1,\ldots,VL_{N_{Load}};QG_1,\ldots,QG_{Ng};SL_1,\ldots,SL_{N_T}\right] \tag{5}$$

The fitness function (OF_1) is defined to reduce the power loss (MW) in the system is written as,

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

Minimization of Voltage deviation fitness function (OF_2) is given by,

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

Then the voltage stability index (L-index) fitness function (OF_3) is given by,

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

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

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

Such that

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

Then the equality constraints are

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

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

Inequality constraints

$$\mathbf{P_{gslack}^{min} \le P_{gslack} \le P_{gslack}^{max}} \tag{14}$$

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

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

$$\mathbf{T_i^{min} \le T_i \le T_i^{max}, i \in N_T} \quad (17)$$

$$Q_c^{min} \le Q_c \le Q_C^{max}, i \in N_C \quad (18)$$

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

$$VG_i^{min} \le VG_i \le VG_i^{max}, i \in N_g \quad (20)$$

Then the multi objective fitness (MOF) function has been defined by,

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

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

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

3. Hybridization Of Genetic Particle Swarm Optimization Algorithm with Symbiotic Organisms Search Algorithm

In this work Hybridization of Genetic Particle Swarm Optimization Algorithm with Symbiotic Organisms Search Algorithm (HGPSOS) has been done to solve the problem.

Particle swarm optimization (PSO) is based on social interaction of as bird flocking. It uses a number of particles in the explore space to find most excellent solution. But in their alleyway always look for the most excellent solution. PSO scientifically model as follows:

$$v_i^{t+1} = w v_i^t + c_1 \times rand \times (pbest_i - x_i^t) + c_2 \times rand \times (gbest - x_i^t) \quad (24)$$

$$x_i^{t+1} = x_i^t + v_i^{t+1} \quad (25)$$

Genetic algorithm (GA) is a well-known and frequently used evolutionary computation technique. GA is stimulated by the principles of genetics and evolution, and imitates the reproduction behavior observed in biological populations.

Both the properties of PSO and GA have been combined to improve the quality of the solution [21, 22].

$$C_1 r_1 + C_2 r_2 > 0 \quad (26)$$

$$\frac{C_1 r_1 + C_2 r_2}{2} - \omega < 0.98 \quad (27)$$

$$\omega < 1 \quad (28)$$

Knowing that $r_1, r_2 \in [0,1]$, then

$$0 < C_1 + C_2 < 3.96 \quad (29)$$

$$\frac{c_1 + c_2}{2} - 1 < \omega < 1 \quad (30)$$

Then,

$$\omega^{t+1} = K_W \omega^t \quad (31)$$

Mutation probability (P_{mi}) is allocated

$$P_{mi} = 0.49\ x \left[\frac{F_{maximum} - F_i}{F_{maximum} - F_{average}}\right] \quad if\ F_i \geq F_{average} \quad (32)$$

$$P_{mi} = \left[\frac{F_{average} - F_i}{F_{maximum} - F_{average}}\right] \quad if\ F_i < F_{average} \quad (33)$$

$$x_i^{(1,t+1)} = x_i^{(1,t)} + (r_i - 0.49)\Delta_i \quad (34)$$

$$\Delta_i = 0.5\ x\ (\max(x_i) - \min(x_i)) \quad (35)$$

$$\Delta_i = (0.025 \sim 0.075)\ x\ ave\ (x_i) \quad (36)$$

a. Initialization of population
b. Then pbest with best value is taken as gbest
c. Fitness function is computed.
d. Fitness value of each particle is estimated with its pbest value.
e. Consequently function value is found
f. Afterward's, the velocity and location of the particle is rationalized
g. When maximum number of iteration reached then stop otherwise loop to step c until convergence.
h. New Population size particles are formed by combing action.
i. Generation = generation + 1, then step c is carried out.
j. Output the most excellent solution

Symbiotic organisms search algorithm is based on the actions between two different organisms in the ecosystem-mutualism, commensalism and parasitism [23-25]. Exploration process has been instigated capriciously and every organism specifies a solution with fitness value. Three stages mutualism, commensalism and parasitism will create new-fangled solutions and it has been rationalized when it is finer to previous solution.

Two different organisms will gain each other in the mutualism phase. Y_i & Y_j indicate the ith & jth organism and chosen capriciously.

$$Y_i^{new} = Y_i + random\ (0,1) \times (Y_{Best} - Mutual\ vector\ (MV) \times benefit\ factor\ (BF_1)) \quad (37)$$

$$Y_j^{new} = Y_j + random\ (0,1) \times (Y_{Best} - Mutual\ vector\ (MV) \times benefit\ factor\ (BF_2)) \quad (38)$$

$$Mutual\ vector\ (MV) = \frac{benefit\ factor\ (BF_1) + benefit\ factor\ (BF_2)}{2} \quad (39)$$

One organism will be gained but other organism may be incapacitated in commensalism phase. In this phase Y_i & Y_j signify the ith & jth organism and Y_i profited then Y_j is incapacitated.

$$Y_i^{new} = Y_i + random\ (-1,1) \times (Y_{Best} - Y_j) \quad (40)$$

Subsequently in the parasitism phase one organism will be gained but other organism will be incapacitated.

Start
Initialization of the parameters

$Organism\ life\ cycle\ ; 1,2, \ldots, Life\ cycle\ size$

For every organism do
Organism position assigned by [Var minimum, var maximum]
For the assigned location opr position compute the fitness value
Fix velocity = 0
Fix the computed position as best experience
End for
Iterations
While (End criterion is not met) do
Apply cross over and produce Cycle $[P_{cs}$, *Life cycle size*$]$
Apply mutation and produce Cycle $[P_{mi}$, *Life cycle size*$]$

$$P_{mi} = 0.49\, x \left[\frac{F_{maximum} - F_i}{F_{maximum} - F_{average}}\right] \quad if\ F_i \geq F_{average}$$

$$P_{mi} = \left[\frac{F_{average} - F_i}{F_{maximum} - F_{average}}\right] \quad if\ F_i < F_{average}$$

Chose the most excellent population by combining the Life cycle C, M and Life cycle

If any new minimum solution obtained then set as best organism
For every organism do
Apply the Particle swarm operator

$$v_i^{t+1} = w v_i^t + c_1 \times rand \times (pbest_i - x_i^t) + c_2 \times rand \times (gbest - x_i^t)$$

$$x_i^{t+1} = x_i^t + v_i^{t+1}$$

$$x_i^{(1,t+1)} = x_i^{(1,t)} + (r_i - 0.49)\Delta_i$$

$$\Delta_i = 0.5\, x\, (\max(x_i) - \min(x_i))$$

$$\Delta_i = (0.025 \sim 0.075)\, x\, ave\,(x_i)$$

Then Update the best organism with the experiences
Apply the mutualism phase

$$Y_i^{new} = Y_i + random\ (0,1) \times (Y_{Best} - Mutual\ vector\,(MV) \times benefit\ factor\,(BF_1))$$

$$Y_j^{new} = Y_j + random\ (0,1) \times (Y_{Best} - Mutual\ vector\,(MV) \times benefit\ factor\,(BF_2))$$

$$Mutual\ vector\,(MV) = \frac{benefit\ factor\,(BF_1) + benefit\ factor\,(BF_2)}{2}$$

Then modernize the organism position
Apply the commensalism phase

$$Y_i^{new} = Y_i + random\ (-1,1) \times (Y_{Best} - Y_j)$$

Calculation of the organism position with respect to parasitic vector
End if
End for
Out put the optimal solution

4. Simulation Results

Projected HGPSOS algorithm has been tested in standard IEEE 30 bus system [26]. It has a sum of active and reactive power consumption of 2.834 and 1.262 per unit on 100 MVA base. Table 1 gives the constraints of control variables; Table 2 gives the system parameters; then Table 3 gives the real power loss comparison. Comparison of different algorithms with reference to voltage stability improvement has been given in Table 4. Then Comparison of values with reference to Voltage Deviation Minimization has been given Table 5. Finally Comparison of values with reference to Multi – objective formulation is given in Table 6.

Table 1. Constraints of control variables

Variables	Minimum (PU)	Maximum (PU)
Generator Voltage	0.95	1.1
Transformer Tap	0.9	1.1
VAR Source	0	5 (MVAR)

Table 2. System parameters

Description	IEEE 30 bus
NB – number of buses	30
NG- Number of generators	6
NT- number of transformers	4
NQ- number of shunt	9
NE- Number of branches	41
PLoss (base case) MW	5.66
Base care for VD (PU)	0.58217

Table 3. Comparison of real power loss with different metaheuristic algorithms

	Real Power Loss			
	DE [27]	GSA [27]	APOPSO [27]	HGPSOS
VG1	1.1	1.071	1.100	1.094
VG2	1.09	1.022	1.084	1.045
VG5	1.07	1.040	1.056	1.026
VG8	1.07	1.051	1.076	1.048
VG11	1.1	0.977	1.091	1.099
VG13	5	0.968	1.100	0.978
QC 10	5	1.653	5.000	4.976
QC 12	5	4.3722	5.000	5.000
QC 15	5	0.1199	4.879	4.789
QC 17	5	2.0876	4.976	4.977
QC 20	4.41	0.357	3.821	3.708
QC 21	5	0.2602	4.541	4.657
QC 23	2.8004	0.0000	2.354	2.409
QC 24	5	1.3839	4.654	4.506
QC 29	2.5979	0.0000	2.175	2.165
T11 (6-9)	1.04	1.0985	1.029	1.014
T12 (6-10)	0.9097	0.9824	0.911	0.905
T15 (4-12)	0.98	1.095	0.952	0.946
T36 (28-27)	0.9689	1.0593	0.958	0.936
PLoss (MW)	4.555	4.5143	4.398	4.232
VD (PU)	1.9589	0.87522	1.047	1.044
L-index (PU)	0.5513	0.14109	0.1267	0.1204

Table 4. Comparison of different algorithms with reference to voltage stability improvement

	Voltage stability improvement			
	DE [27]	GSA [27]	APOPSO [27]	HGPSOS
VG1	1.01	0.983	1.011	1.025
VG2	0.99	1.044	1.001	1.017

	Voltage stability improvement			
	DE [27]	GSA [27]	APOPSO [27]	HGPSOS
VG5	1.02	1.020	1.014	1.018
VG8	1.02	0.999	1.009	1.019
VG11	1.01	1.077	0.954	0.945
VG13	1.03	1.044	1.000	1.000
QC 10	4.94	0	4.102	4.105
QC 12	1.0885	0.4735	2.124	2.118
QC 15	4.9985	5	4.512	4.499
QC 17	0.2393	0	0.000	0.000
QC 20	4.99	5	5.000	5.000
QC 21	4.90	0	5.000	5.000
QC 23	4.9863	4.9998	5.000	5.000
QC 24	4.9663	5	5.000	5.000
QC 29	2.2325	5	4.120	4.131
T11 (6-9)	1.02	0.9	0.998	0.985
T12 (6-10)	0.9038	1.1	0.822	0.815
T15 (4-12)	1.01	1.051	0.954	0.946
T36 (28-27)	0.9635	0.9619	0.958	0.947
PLoss (MW)	6.4755	6.9117	5.698	5.421
VD (PU)	0.0911	0.0676	0.087	0.084
L-index (PU)	0.14352	0.1349	0.1377	0.1315

Table 5. Comparison with reference to Voltage Deviation Minimization

	Voltage Deviation Minimization			
	DE [27]	GSA [27]	APOPSO [27]	HGPSOS
VG1	1.09	1.1	1.043	1.034
VG2	1.09	1.1	1.061	1.046
VG5	1.09	1.1	1.061	1.027
VG8	1.04	1.1	1.057	1.048
VG11	1.09	1.1	1.048	1.049
VG13	0.95	1.1	1.091	1.066
QC 10	0.69	5	0.040	0.043
QC 12	4.7163	5	0.039	0.045
QC 15	4.4931	5	0.038	0.037
QC 17	4.51	5	0.040	0.038
QC 20	4.48	5	0.037	0.039
QC 21	4.60	5	0.009	0.016
QC 23	3.8806	5	0.019	0.015
QC 24	3.8806	5	0.011	0.017
QC 29	3.2541	5	0.001	0.008
T11 (6-9)	0.90	0.9	0.919	0.919
T12 (6-10)	0.9029	0.9	0.924	0.917
T15 (4-12)	0.90	0.9	0.938	0.928
T36 (28-27)	0.936	1.0195	0.924	0.921
PLoss (MW)	7.0733	4.9752	4.478	4.235
VD (PU)	1.419	0.21579	1.8579	1.8206
L-index (PU)	0.1246	0.13684	0.1227	0.1179

Table 6. Comparison of values with reference to Multi – objective formulation

	Multi – Objective	
	APOPSO [27]	HGPSOS
VG1	1.020	1.014
VG2	1.033	1.026
VG5	1.000	1.007
VG8	1.004	1.008
VG11	1.032	1.025
VG13	1.028	1.026
QC 10	0.051	0.049
QC 12	0.002	0.004
QC 15	0.044	0.037
QC 17	0.009	0.006
QC 20	0.048	0.034
QC 21	0.041	0.035
QC 23	0.033	0.026
QC 24	0.050	0.037
QC 29	0.015	0.018
T11 (6-9)	1.042	1.043
T12 (6-10)	0.909	0.905
T15 (4-12)	1.023	1.017
T36 (28-27)	0.958	0.938
PLoss (MW)	4.842	4.730
VD (PU)	1.009	1.007
L-index (PU)	0.1192	0.1189

5. Conclusion

In this work reactive power dispatch problem has been lucratively solved by Hybridization of Genetic Particle Swarm Optimization Algorithm with Symbiotic Organisms Search Algorithm (HGPSOS). Genetic particle swarm optimization problem has been hybridized with Symbiotic organisms search (SOS) algorithm to solve the problem. In SOS three stages- mutualism, commensalism and parasitism has created novel solutions and it has been rationalized when it is finer to previous solution. Proposed HGPSOS algorithm has been tested in standard IEEE 30, bus test system power loss reduction, voltage deviation minimization, and voltage stability enhancement has been attained.

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