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.

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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
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,

\[
\min F(\mathbf{x}, \mathbf{y})
\]

Subject to:

\[
\begin{align*}
E(\mathbf{x}, \mathbf{y}) &= 0 \\
I(\mathbf{x}, \mathbf{y}) &= 0
\end{align*}
\]

\[
x = [V_{G1}, \ldots, V_{GNg}; QC_1, \ldots, QC_{NC}; T_1, \ldots, T_{Ny}]
\]

\[
y = [P_{G\text{slack}}, VL_{1}, \ldots, VL_{N\text{load}}; QG_1, \ldots, QG_{Ng}; SL_1, \ldots, SL_{Ny}]
\]

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

\[
OF_1 = P_{\text{Min}} = \min \left[ \sum_{m} C_m [V_i^2 + V_j^2 - 2 \cdot V_i V_j \cos \theta_{ij}] \right]
\]

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

\[
OF_2 = \min \left[ \sum_{i=1}^{N_{PV}} |V_{k} - V_{\text{desired}}|^2 + \sum_{i=1}^{N_{QG}} |Q_{G} - Q_{\text{limit}}|^2 \right]
\]

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

\[
OF_3 = \min L_{\text{Max}}
\]

\[
L_{\text{Max}} = \max [L_j]; j = 1: N_{LB}
\]

\[
\begin{cases}
L_j = 1 - \sum_{i=1}^{N_{PV}} F_{ji} \frac{V_i}{V_j} \\
F_{ji} = -[V_i]^2[V_j]
\end{cases}
\]

Such that

\[
L_{\text{Max}} = \max \left[ 1 - \left[ \frac{V_i}{V_j} \right] \times \left[ \frac{V_i}{V_j} \right] \right]
\]

Then the equality constraints are

\[
0 = P_{G_i} - PD_i - V_i \sum_{j \in N_G} V_j \left[ G_{ij} \cos \left[ \theta_i - \theta_j \right] + B_{ij} \sin \left[ \theta_i - \theta_j \right] \right]
\]

\[
0 = Q_{G_i} - QD_i - V_i \sum_{j \in N_G} V_j \left[ G_{ij} \sin \left[ \theta_i - \theta_j \right] + B_{ij} \cos \left[ \theta_i - \theta_j \right] \right]
\]

Inequality constraints

\[
P_{\min} \leq P_{\text{slack}} \leq P_{\max}
\]

\[
Q_{G_i} \leq Q_{\text{gi}} \leq Q_{G_i}^{\max}, i \in N_g
\]

\[
VL_{i}^{\min} \leq VL_i \leq VL_{i}^{\max}, i \in N_L
\]
Then the multi objective fitness (MOF) function has been defined by,

\[
MOF = OF_1 + x_1OF_2 + yOF_3 = OF_1 + \left[ \sum_{i=1}^{N_U} x_v (V_L_i - V_L_i^{\text{min}})^2 + \sum_{i=1}^{N_G} x_g (Q_{G_i} - Q_{G_i}^{\text{min}})^2 \right] + x_f OF_3
\]

\[
V_L_i^{\text{min}} = \begin{cases} V_L_i^{\text{max}}, & V_L_i > V_L_i^{\text{max}} \\ V_L_i^{\text{min}}, & V_L_i < V_L_i^{\text{min}} \end{cases}
\]

\[
Q_{G_i}^{\text{min}} = \begin{cases} Q_{G_i}^{\text{max}}, & Q_{G_i} > Q_{G_i}^{\text{max}} \\ Q_{G_i}^{\text{min}}, & Q_{G_i} < Q_{G_i}^{\text{min}} \end{cases}
\]

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:

\[
v_i^{t+1} = w v_i^t + c_1 \times \text{rand} \times (p\text{best}_i - x_i^t) + c_2 \times \text{rand} \times (g\text{best} - x_i^t)
\]

\[
x_i^{t+1} = x_i^t + v_i^{t+1}
\]

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].

\[
C_1 r_1 + C_2 r_2 > 0
\]

\[
\frac{C_1 r_1 + C_2 r_2}{2} - \omega < 0.98
\]

\[
\omega < 1
\]

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

\[
0 < C_1 + C_2 < 3.96
\]

\[
\frac{C_1 + C_2}{2} - 1 < \omega < 1
\]
Then,
\[ \omega^{t+1} = K_W \omega^t \]  
(31)

Mutation probability \( P_{mi} \) is allocated
\[
P_{mi} = 0.49 \times \left[ \frac{F_{\text{maximum}} - F_i}{F_{\text{maximum}} - F_{\text{average}}} \right] \quad \text{if} \quad F_i \geq F_{\text{average}} \]  
(32)
\[
P_{mi} = \left[ \frac{F_{\text{average}} - F_i}{F_{\text{maximum}} - F_{\text{average}}} \right] \quad \text{if} \quad F_i < F_{\text{average}} \]  
(33)

\[
x_i^{(t+1)} = x_i^{(t)} + (\eta - 0.49) \Delta_i \]  
(34)
\[
\Delta_i = 0.5 \times (\max(x_i) - \min(x_i)) \]  
(35)
\[
\Delta_i = (0.025 \sim 0.075) \times \text{ave} (x_i) \]  
(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.

\[
Y_i^{\text{new}} = Y_i + \text{random} (0,1) \times (Y_{\text{best}} - \text{Mutual vector} (MV) \times \text{benefit factor} (BF_1)) \]  
(37)
\[
Y_j^{\text{new}} = Y_j + \text{random} (0,1) \times (Y_{\text{best}} - \text{Mutual vector} (MV) \times \text{benefit factor} (BF_2)) \]  
(38)

\[
\text{Mutual vector} (MV) = \frac{\text{benefit factor} (BF_1) + \text{benefit factor} (BF_2)}{2} \]  
(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.

\[
Y_i^{\text{new}} = Y_i + \text{random} (-1,1) \times (Y_{\text{best}} - Y_j) \]  
(40)

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

Start
Initialization of the parameters

\text{Organism life cycle \( : 1,2,\ldots, \text{Life cycle size} \)}
For every organism do
Organism position assigned by \([\text{Var minimum}, \text{var maximum}]\)
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\([P_{C2}, \text{Life cycle size}]\)
Apply mutation and produce Cycle\([P_{mi}, \text{Life cycle size}]\)

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

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

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

\[
v_{i}^{t+1} = w v_{i}^{t} + c_{1} \times \text{rand} \times (p_{\text{best}i} - x_{i}^{t}) + c_{2} \times \text{rand} \times (g_{\text{best}} - x_{i}^{t})
\]

\[
x_{i}^{t+1} = x_{i}^{t} + v_{i}^{t+1}
\]

\[
x_{i}^{(1t+1)} = x_{i}^{(1t)} + (\eta - 0.49) \Delta t
\]

\[
\Delta t = 0.5 \times (\text{max}(x_{i}) - \text{min}(x_{i}))
\]

\[
\Delta t = (0.025 \sim 0.075) \times \text{ave}(x_{i})
\]

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

\[
Y_{i}^{\text{new}} = Y_{i} + \text{random(0.1)} \times (Y_{\text{Best}} - \text{Mutual vector(MV)} \times \text{benefit factor(BF)}_{i})
\]

\[
Y_{j}^{\text{new}} = Y_{j} + \text{random(0.1)} \times (Y_{\text{Best}} - \text{Mutual vector(MV)} \times \text{benefit factor(BF)}_{j})
\]

\[
\text{Mutual vector(MV)} = \frac{\text{benefit factor(BF)}_{i} + \text{benefit factor(BF)}_{j}}{2}
\]

Then modernize the organism position
Apply the commensalism phase

\[
Y_{i}^{\text{new}} = Y_{i} + \text{random(-1,1)} \times (Y_{\text{Best}} - Y_{j})
\]

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                              | Value         |
|------------------------------------------|---------------|
| 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 case 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

|       | 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

|                | 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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