Real power loss diminution by predestination of particles wavering search algorithm

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ABSTRACT

In this work Predestination of Particles Wavering Search (PPS) algorithm has been applied to solve optimal reactive power problem. PPS algorithm has been modeled based on the motion of the particles in the exploration space. Normally the movement of the particle is based on gradient and swarming motion. Particles are permitted to progress in steady velocity in gradient-based progress, but when the outcome is poor when compared to previous upshot, immediately particle rapidity will be upturned with semi of the magnitude and it will help to reach local optimal solution and it is expressed as wavering movement. In standard IEEE 14, 30, 57,118,300 bus systems Proposed Predestination of Particles Wavering Search (PPS) algorithm is evaluated and simulation results show the PPS reduced the power loss efficiently.

Keywords:
Optimal reactive power
Predestination of particles wavering search algorithm
Transmission loss

1. INTRODUCTION

Reactive power problem plays a key role in secure and economic operations of power system. Optimal reactive power problem has been solved by variety of types of methods [1-6]. Nevertheless numerous 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, but the main problem is many algorithms get stuck in local optimal solution & failed to balance the Exploration & Exploitation during the search of global solution. In this work, Predestination of Particles Wavering Search (PPS) algorithm has been applied to solve optimal reactive power problem. PPS algorithm has been modeled based on the motion of the particles in the exploration space. Particles will arbitrarily move in the exploration space in many algorithms which has been already applied to many optimization problems. In the PPS algorithm particles are distributed in the exploration space consistently. In an atom how the electrons positioned in the centre accordingly particles are in the exploration space. Normally the movement of the particle is based on gradient and swarming motion [16, 17]. When the gradient method failed then swarming is executed by inducing the particle shift towards the global most excellent position by modernizing the velocity. Validity of the Proposed Predestination of Particles Wavering Search (PPS) algorithm has been tested in standard IEEE 14, 30, 57,118, 300 bus systems and results show the projected PPS reduced the power loss effectively.

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2. **PROBLEM FORMULATION**

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

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

(1)

Voltage deviation given as follows:

\[ F = P_L + \omega_v \times \text{Voltage Deviation} \]  

(2)

Voltage deviation given by:

\[ \text{Voltage Deviation} = \sum_{i=1}^{Npq} |V_i - 1| \]  

(3)

*Constraint (Equality)*

\[ P_G = P_D + P_L \]  

(4)

*Constraints (Inequality)*

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

(5)

\[ Q_{gi}^{\text{min}} \leq Q_{gi} \leq Q_{gi}^{\text{max}}, i \in \text{N}_g \]  

(6)

\[ V_i^{\text{min}} \leq V_i \leq V_i^{\text{max}}, i \in \text{N} \]  

(7)

\[ T_i^{\text{min}} \leq T_i \leq T_i^{\text{max}}, i \in \text{N}_T \]  

(8)

\[ Q_c^{\text{min}} \leq Q_c \leq Q_c^{\text{max}}, i \in \text{N}_C \]  

(9)

3. **PREDESTINATION OF PARTICLES WAVING SEARCH ALGORITHM**

Predestination of Particles Waving Search (PPS) algorithm has been modeled based on the motion of the particles in the exploration space. Particles will arbitrarily move in the exploration space in many algorithms which has been already applied to many optimization problems. In the PPS algorithm particles are distributed in the exploration space consistently. In an atom how the electrons positioned in the centre accordingly particles are in the exploration space. Normally the movement of the particle is based on gradient and swarming motion. Particles velocity has been initiated as follows,

\[ \text{velocity}_i^0 = \left( y_{best} - y_i^0 \right) \]  

(10)

Particles are permitted to progress in steady velocity in gradient-based progress, but when the outcome is poor when compared to previous upshot, immediately particle rapidity will be upturned with semi of the magnitude and it will help to reach local optimal solution and it is expressed as wavering movement. Particle moves from point of slope \( y_1 \) to \( y_2 \), then it end’s in negative fitness slope and when the particle velocity is multiplied by the value -0.50, subsequently the particle moves from \( y_2 \) to \( y_3 \), then sequentially it end’s in positive fitness slope, through this motion particle reach \( y_4 \) afterwards a negative fitness slope attained again by the particle then once again by -0.50 the particle velocity will be multiplied. Next at \( y_5 \) particle will attain, now the particle fitness will be positive slope, then in the same way particle continues its motion and it reach the point \( y_6 \), Once particle reaches the local optimal point \( y_{optimal} \) then the velocity will be reversed again. When the gradient method failed then swarming is executed by inducing the particle shift towards the global most excellent position by modernizing the velocity as given below,

\[ \text{velocity}_i^{t+1} = \text{velocity}_i^t + \left( y_{best} - y_i^t \right) \]  

(11)
When the progress develops into constructive subsequently particle prolong to discover any more local optimal solution, and this procedure persist until maximum number of evaluation has been attained. Predestination of Particles Wavering Search (PPS) algorithm defined as follows,

Step 1: In the exploration space Initiate the particle’s position with reference to boundary limits

Step 2: i=1; k =1

Step 3: Iterative procedure:
With respect to upper and lower boundaries particle positions are initiated
While (i <= sum of particles)
Particles possible combinations has to be discovered
For c=1: sum of combinations
With respect to positions and combinations alter the positions of the particle \( y_i \) as elevated values
i ++
End for

if (k > dimensions) / when no boundary combinations are found then leave the loop /
Break
End if
End while

Step 4: Between two particles which has been already initiated some more particles are present, then factor based procedure is applied to reorganize the particle positions

Particles number are factorized
f=factor (n) ; n = sum of particles ; f is an array to store the factor values
Iterative procedure:
While (i <= n)
For c=1: sum of factors (with reference to length of “f”)
For j=1: dimensions (p)
For i = 1:f(c)
\( y_{i}(j) = \text{minimum}(j) + k^{*}(\text{maximum}(j) - \text{minimum}(j))/(f(c) + 1) \)
i++
End
End

if i >n then when no boundary combinations are found then leave the loop
Repeat step 4 with Minimum and Maximum are exchanged
Break
End if
End for
End while

Then with suitable parameters projected Predestination of Particles Wavering Search (PPS) algorithm is applied to solve the optimal reactive power problem as shown below,

Step 1: Initialization of parameters

Step 2: In the exploration space Initiate the particle’s position with reference to boundary limits

Step 3: Particles fitness values are computed and most excellent particle will be identified

Step 4: Velocity of the particles are initialized through \( \text{velocity}_i^0 = \left[ \frac{\text{best} - x^0_i}{2} \right] \)

Step 5: Iterative procedure
While (computation number < maximum number of computation)
For i = 1; sum of particles
By augmenting the velocity to the present position determine new-fangled position
With reference to new-fangled position particle fitness should be calculated
Augmentations of computation counter, and then modernize global most excellent solution
When (slope = = unknown) then modernize slope of the particle with reference to new fitness to be positive or negative; Otherwise when (slope = = positive)
When (new-fangled fitness inferior than previous fitness); Then modernize velocity by \( \text{velocity} + \frac{\text{velocity}}{2} \); modernize the slope with reference to new-fangled fitness to be negative; otherwise (slope = = negative)
When (new-fangled fitness inferior than the previous fitness)
Then modernize velocity by \( \text{velocity} + (\text{global most excellent position} - \text{present position})/2 \)
Update slope to be unknown

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End if
End for
End while
Step 6: Global most excellent particle position found with fitness value
Step 7; Output the result

4. SIMULATION RESULTS

In standard IEEE 14 bus system the validity of the projected Predestination of Particles Wavering Search (PPS) algorithm has been tested, 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.

| System     | Variables          | Minimum (PU) | Maximum (PU) |
|------------|--------------------|--------------|--------------|
| IEEE 14 Bus| Generator Voltage  | 0.95         | 1.1          |
|            | Transformer Tap    | 0.9          | 1.1          |
|            | VAR Source         | 0            | 0.20         |

| System     | Variables | Q Minimum (PU) | Q Maximum (PU) |
|------------|-----------|---------------|---------------|
| IEEE 14 Bus| 1         | 0             | 10            |
|            | 2         | -40           | 50            |
|            | 3         | 0             | 40            |
|            | 6         | -6            | 24            |
|            | 8         | -6            | 24            |

| Control variables | Base case | MPSO [18] | PSO [18] | EP [18] | SARGA [18] | PPS |
|-------------------|-----------|-----------|----------|---------|------------|-----|
| $V_G-1$           | 1.060     | 1.100     | 1.100    | NR*     | NR*        | 1.012|
| $V_G-2$           | 1.045     | 1.085     | 1.086    | 1.029   | 1.060      | 1.013|
| $V_G-3$           | 1.010     | 1.055     | 1.056    | 1.016   | 1.036      | 1.019|
| $V_G-6$           | 1.070     | 1.069     | 1.067    | 1.097   | 1.099      | 1.024|
| $V_G-8$           | 1.090     | 1.074     | 1.060    | 1.053   | 1.078      | 1.003|
| $Tap$ 8          | 0.978     | 1.018     | 1.019    | 1.04    | 0.95       | 0.904|
| $Tap$ 9          | 0.969     | 0.975     | 0.988    | 0.94    | 0.95       | 0.903|
| $Tap$ 10         | 0.932     | 1.024     | 1.008    | 1.03    | 0.96       | 0.920|
| $Q_C-9$          | 0.19      | 14.64     | 0.185    | 0.18    | 0.06       | 0.145|
| $PG$              | 272.39    | 271.32    | 271.32   | NR*     | NR*        | 271.60|
| $Q_G$ (Mvar)     | 82.44     | 75.79     | 76.79    | NR*     | NR*        | 74.75|
| Reduction in PLoss (%) | 0      | 9.2       | 9.1      | 1.5     | 2.5        | 24.67|
| Total PLoss (Mw) | 13.550    | 12.293    | 12.315   | 13.346  | 13.216     | 10.206|

NR* - Not reported

Then the projected Predestination of Particles Wavering Search (PPS) algorithm has been tested, in IEEE 30 Bus system. Table 4 shows the constraints of control variables, Table 5 shows the limits of reactive power generators and comparison results are presented in Table 6.

| System     | Variables          | Minimum (PU) | Maximum (PU) |
|------------|--------------------|--------------|--------------|
| IEEE 30 Bus| Generator Voltage  | 0.95         | 1.1          |
|            | Transformer Tap    | 0.9          | 1.1          |
|            | VAR Source         | 0            | 0.20         |

| System     | Variables | Q Minimum (PU) | Q Maximum (PU) |
|------------|-----------|---------------|---------------|
| IEEE 30 Bus| 1         | 0             | 10            |
|            | 2         | -40           | 50            |
|            | 5         | -40           | 40            |
|            | 8         | -10           | 40            |
|            | 11        | -6            | 24            |
|            | 13        | -6            | 24            |
Then the proposed Predestination of Particles Wavering Search (PPS) algorithm has been tested, in IEEE 57 Bus system. Table 7 shows the constraints of control variables, Table 8 shows the limits of reactive power generators and comparison results are presented in Table 9.

### Table 7. Constraints of control variables

| System       | Variables     | Minimum (PU) | Maximum (PU) |
|--------------|---------------|--------------|--------------|
| IEEE 57 Bus  | Generator Voltage | 0.95        | 1.1          |
| Transformer Tap | 0.9            | 1.1          |              |
| VAR Source   | 0             | 0.20         |              |

### Table 8. Constrains of reactive power generators

| System       | Variables | Q Minimum (PU) | Q Maximum (PU) |
|--------------|-----------|----------------|----------------|
| IEEE 57 Bus  | 1         | -140           | 200            |
|              | 2         | -17            | 50             |
|              | 3         | -10            | 60             |
|              | 6         | -8             | 25             |
|              | 8         | -140           | 200            |
|              | 9         | -3             | 9              |
|              | 12        | -150           | 155            |

### Table 9. Simulation results of IEEE−57 system

| Control variables | Base case | MPSO [18] | PSO [18] | EP [18] | SARGA [18] | PPS |
|-------------------|-----------|-----------|----------|---------|------------|-----|
| VG 1              | 1.060     | 1.101     | 1.100    | NR*     | NR*        | 1.013 |
| VG 2              | 1.045     | 1.086     | 1.072    | 1.097   | 1.094      | 1.014 |
| VG 5              | 1.010     | 1.047     | 1.038    | 1.049   | 1.053      | 1.061 |
| VG 8              | 1.010     | 1.057     | 1.048    | 1.033   | 1.059      | 1.005 |
| VG 12             | 1.082     | 1.048     | 1.058    | 1.092   | 1.099      | 1.024 |
| VG 13             | 1.071     | 1.068     | 1.080    | 1.091   | 1.099      | 1.043 |
| Tap11             | 0.978     | 0.983     | 0.987    | 1.01    | 0.99       | 0.904 |
| Tap12             | 0.969     | 1.023     | 1.015    | 1.03    | 1.03       | 0.912 |
| Tap15             | 0.932     | 1.020     | 1.020    | 1.07    | 0.98       | 0.906 |
| Tap36             | 0.968     | 0.988     | 1.012    | 0.99    | 0.96       | 0.905 |
| QC10              | 0.19      | 0.077     | 0.077    | 0.19    | 0.19       | 0.064 |
| QC24              | 0.043     | 0.119     | 0.128    | 0.04    | 0.04       | 0.103 |
| PG (MW)           | 300.9     | 299.54    | 299.54   | NR*     | NR*        | 298.62 |
| QG (Mvar)         | 133.9     | 130.83    | 130.94   | NR*     | NR*        | 130.74 |

Reduction in PLoss (%) | 0.940 | 1.004 | 1.003 | 0.952 | 1.005 | 0.961 |

Total PLoss (Mw) | 17.55 | 16.07 | 16.25 | 16.38 | 16.09 | 14.319 |

NR* - Not reported.
Then the Predestination of Particles Wavering Search (PPS) algorithm has been tested, in IEEE 118 Bus system. Table 10 shows the constraints of control variables and comparison results are presented in Table 11.
In the PPS algorithm particles are distributed in the exploration space and have been tested and power loss has been reduced efficiently. The Predestination of Particles Wavering Search (PPS) algorithm has compared to previous upshot, immediately particle rapidity will be upturned. In standard IEEE 14, 30, 57, 118, 300 bus systems Predestination of Particles Wavering Search (PPS) algorithm has been used to authenticate the good performance of the Predestination of Particles Wavering Search (PPS) algorithm. Table 12 shows the comparison of real power loss obtained after optimization.

| Control variables | Base case | MPSO [18] | PSO [18] | PSO [18] | CLPSO [18] | PPS |
|-------------------|-----------|-----------|-----------|-----------|-----------|-----|
| $V_G$ 99          | 1.010     | 1.023     | 1.037     | 0.954     | 1.088     | 1.003 |
| $V_G$ 100         | 1.017     | 1.049     | 1.037     | 0.958     | 0.961     | 1.001 |
| $V_G$ 103         | 1.010     | 1.045     | 1.031     | 1.016     | 0.961     | 1.010 |
| $V_G$ 104         | 0.971     | 1.035     | 1.031     | 1.099     | 1.012     | 1.021 |
| $V_G$ 105         | 0.965     | 1.043     | 1.029     | 0.969     | 1.068     | 1.050 |
| $V_G$ 107         | 0.952     | 1.023     | 1.008     | 0.965     | 0.976     | 1.012 |
| $V_G$ 110         | 0.973     | 1.032     | 1.028     | 1.087     | 1.041     | 1.014 |
| $V_G$ 111         | 0.980     | 1.035     | 1.039     | 1.037     | 0.979     | 1.000 |
| $V_G$ 112         | 0.975     | 1.018     | 1.019     | 1.092     | 0.976     | 1.091 |
| $V_G$ 113         | 0.993     | 1.043     | 1.027     | 1.075     | 0.972     | 1.000 |
| $V_G$ 116         | 1.005     | 1.011     | 1.031     | 0.959     | 1.033     | 1.001 |
| $\text{Tap}_8$    | 0.985     | 0.999     | 0.994     | 1.011     | 1.004     | 0.943 |
| $\text{Tap}_{32}$ | 0.960     | 1.017     | 1.013     | 1.090     | 1.060     | 1.000 |
| $\text{Tap}_{36}$ | 0.960     | 0.994     | 0.997     | 1.003     | 1.000     | 0.951 |
| $\text{Tap}_{51}$ | 0.935     | 0.998     | 1.000     | 1.000     | 1.000     | 0.933 |
| $\text{Tap}_{93}$ | 0.960     | 1.000     | 0.997     | 1.008     | 0.992     | 1.002 |
| $\text{Tap}_{95}$ | 0.985     | 0.995     | 1.020     | 1.032     | 1.007     | 0.970 |
| $\text{Tap}_{102}$| 0.935     | 1.024     | 1.004     | 0.944     | 1.061     | 1.001 |
| $\text{Tap}_{107}$| 0.935     | 0.989     | 1.008     | 0.906     | 0.930     | 0.942 |
| $\text{Tap}_{127}$| 0.935     | 1.010     | 1.009     | 0.967     | 0.957     | 1.000 |
| $Q_C$ 34          | 0.140     | 0.049     | 0.048     | 0.093     | 0.117     | 0.002 |
| $Q_C$ 44          | 0.100     | 0.026     | 0.026     | 0.093     | 0.098     | 0.021 |
| $Q_C$ 45          | 0.100     | 0.196     | 0.197     | 0.086     | 0.094     | 0.163 |
| $Q_C$ 46          | 0.100     | 0.117     | 0.118     | 0.089     | 0.026     | 0.120 |
| $Q_C$ 48          | 0.150     | 0.056     | 0.056     | 0.118     | 0.028     | 0.042 |
| $Q_C$ 74          | 0.120     | 0.120     | 0.120     | 0.046     | 0.005     | 0.110 |
| $Q_C$ 79          | 0.200     | 0.139     | 0.140     | 0.105     | 0.141     | 0.102 |
| $Q_C$ 82          | 0.200     | 0.180     | 0.180     | 0.164     | 0.194     | 0.150 |
| $Q_C$ 83          | 0.100     | 0.166     | 0.166     | 0.096     | 0.069     | 0.123 |
| $Q_C$ 105         | 0.200     | 0.189     | 0.190     | 0.089     | 0.090     | 0.151 |
| $Q_C$ 107         | 0.060     | 0.128     | 0.129     | 0.050     | 0.049     | 0.133 |
| $Q_C$ 110         | 0.060     | 0.014     | 0.014     | 0.055     | 0.022     | 0.001 |
| $P_G$(Mw)         | 4374.8    | 4359.3    | 4361.4    | NR*       | NR*       | 4362.10 |
| $Q_G$(MVAR)       | 795.6     | 604.3     | 653.5     | NR*       | NR*       | 610.11 |
| Reduction in PLOSS (%) |          | 0        | 11.7      | 10.1      | 0.6       | 1.3      | 13.84 |
| Total PLOSS (Mw)  | 132.8     | 117.19    | 119.34    | 131.99    | 130.96    | 114.418  |

NR* Not reported.

Then IEEE 300 bus system [18] is used as test system to authenticate the good performance of the Predestination of Particles Wavering Search (PPS) algorithm. Table 12 shows the comparison of real power loss obtained after optimization.

| Parameter | Method EGA [20] | Method EEA [20] | Method CSA [21] | PPS |
|-----------|----------------|----------------|----------------|-----|
| PLOSS (MW)| 646.2998       | 650.6027       | 635.8942       | 610.3371 |

5. CONCLUSION

In this work Predestination of Particles Wavering Search (PPS) algorithm successfully solved the optimal reactive power problem. In the PPS algorithm particles are distributed in the exploration space consistently. In an atom how the electrons positioned in the centre accordingly particles are in the exploration space. Normally the movement of the particle is based on gradient and swarming motion. Particles are permitted to progress in steady velocity in gradient-based progress, but when the outcome is poor when compared to previous upshot, immediately particle rapidity will be upturned. In standard IEEE 14, 30, 57, 118, 300 bus systems Predestination of Particles Wavering Search (PPS) algorithm have been tested and power loss has been reduced efficiently.
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