Diminution of real power loss by novel gentoo penguin algorithm

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ABSTRACT

In this paper Gentoo Penguin Algorithm (GPA) is proposed to solve optimal reactive power problem. Gentoo Penguins preliminary population possesses heat radiation and magnetizes each other by absorption coefficient. Gentoo Penguins will move towards further penguins which possesses low cost (elevated heat concentration) of absorption. Cost is defined by the heat concentration, distance. Gentoo Penguins penguin attraction value is calculated by the amount of heat prevailed between two Gentoo penguins. Gentoo Penguins heat radiation is measured as linear. Less heat is received in longer distance, in little distance, huge heat is received. Gentoo Penguin Algorithm has been tested in standard IEEE 57 bus test system and simulation results show the projected algorithm reduced the real power loss considerably.

Keywords: Gentoo penguin algorithm Optimal reactive power Transmission loss

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1. INTRODUCTION

The main objective of optimal reactive power problem is to minimize the real power loss and bus voltage deviation. To till date various methodologies has been applied to solve the Optimal Reactive Power problem. The key aspect of solving Reactive Power problem is to reduce the real power loss. Previously many types of mathematical methodologies [1-6] have been utilized to solve the reactive power problem, but they lack in handling the constraints to reach global optimization solution. In the next level various types of evolutionary algorithms [7-15] has been applied to solve the reactive power problem. This paper proposes Gentoo Penguin Algorithm (GPA) to solve optimal reactive power problem. Gentoo Penguins will move towards further penguins which possesses low cost (elevated heat concentration) of absorption [16]. Gentoo Penguins preliminary population possesses heat radiation and magnetizes each other by absorption coefficient. Cost is defined by the heat concentration, distance. Gentoo Penguins preliminary population possesses heat radiation and magnetizes each other by absorption coefficient. Attraction is completed, a new-fangled solution is estimated for that heat concentration is modernized. Solutions are arranged sequentially and most excellent is chosen. For heat radiation, movement, heat absorption damping ratio is applied. Gentoo penguin spiral movements throughout the absorption procedure are not droning and have a divergence with consistent distribution. Proposed Gentoo Penguin Algorithm (GPA) has been tested in standard IEEE 57 bus test system and simulation results show the projected algorithm reduced the real power loss effectively.

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2. PROBLEM FORMULATION

Real Power loss reduction is mathematically written by:

\[ F = P_L = \sum_{k \in \text{Nbr}} g_k \left( V_i^2 + V_j^2 - 2V_iV_j \cos \theta_{ij} \right) \]  \hspace{1cm} (1)

with respect to voltage deviation,

\[ F = P_L + \omega_v \times \text{Voltage Deviation} \]  \hspace{1cm} (2)

\[ \text{Voltage Deviation} = \sum_{i=1}^{N_{pq}} |V_i - 1| \]  \hspace{1cm} (3)

constraint (Equality)

\[ P_G = P_D + P_L \]  \hspace{1cm} (4)

constraints (Inequality)

\[ p_{\text{g} \text{sl}} \text{ack}_{\text{min}} \leq p_{\text{g} \text{sl}} \text{ack} \leq p_{\text{g} \text{sl}} \text{ack}_{\text{max}} \]  \hspace{1cm} (5)

\[ Q_{\text{gi}}_{\text{min}} \leq Q_{\text{gi}} \leq Q_{\text{gi}}_{\text{max}}, i \in N_g \]  \hspace{1cm} (6)

\[ V_i_{\text{min}} \leq V_i \leq V_i_{\text{max}}, i \in N \]  \hspace{1cm} (7)

\[ T_i_{\text{min}} \leq T_i \leq T_i_{\text{max}}, i \in N_T \]  \hspace{1cm} (8)

\[ Q_{\text{c}}_{\text{min}} \leq Q_{\text{c}} \leq Q_{\text{c}}_{\text{max}}, i \in N_C \]  \hspace{1cm} (9)

3. GENTOO PENGUIN ALGORITHM

In this proposed approach nature deeds of Gentoo penguin are imitated to model the Gentoo Penguin Algorithm (GPA). Gentoo penguin’s position and cost are computed. Gentoo Penguins will move towards further penguins which possesses low cost (elevated heat concentration) of absorption. Cost is defined by the heat concentration, distance. Attraction is completed, a new-fangled solution is estimated for that heat concentration is modernized. Solutions are arranged sequentially and most excellent is chosen. For heat radiation, movement, heat absorption damping ratio is applied.

Rules are framed as follows:

- Gentoo Penguins preliminary population possesses heat radiation and magnetizes each other by absorption coefficient.
- Gentoo Penguins body surface area is considered equally.
- Gentoo Penguins absorb complete heat radiation
- Gentoo Penguins heat radiation is measured as linear.
- Gentoo Penguins penguin attraction value is calculated by the amount of heat prevailed between two Gentoo penguins. Less heat is received in longer distance, in little distance, huge heat is received.
- Gentoo penguin spiral movements throughout the absorption procedure are not droning and have a divergence with consistent distribution.

The surface area of the body of gentoo penguin is determined by,

\[ \text{Area}_{\text{trunk}} = 2\pi \frac{ab}{c} \sin^{-1}e + 2\pi b^2 \]  \hspace{1cm} (10)

COMPUTATION of Break area is done through,

\[ \text{Area}_{\text{break}} = \pi rs \]  \hspace{1cm} (11)

Head area of Gentoo penguin is calculated by,

\[ \text{Area}_{\text{head}} = \pi d^2 - \pi r^2 \]  \hspace{1cm} (12)
calculation of flipper is done through,

\[ \text{Area}_{\text{flipper}} = l \times w \tag{13} \]

depending on the environment it’s been assumed that gentoo penguin is in thermal equilibrium,

\[ q_{\text{total}} = q_{\text{trunk}} + q_{\text{head}} + q_{\text{flippers}} + q_{\text{feet}} \tag{14} \]

from each body of gentoo penguin heat radiation emitted in that particular surface area is calculated by,

\[ Q_{\text{gentoo penguin}} = \text{Area} \cdot \varepsilon \cdot \sigma \cdot T_s^4 \tag{15} \]

receiving the heat photons in the surface area is calculated by,

\[ I = I_o \tag{16} \]

the intensity of the heat established at “I” at distance “r” computed by

\[ I = I_o/r^2 \tag{17} \]

with the preliminary value \( I_o \) when the heat source is linear at distance \( r \),

\[ I = I_o/r \tag{18} \]

attenuation of photon is given by,

\[ I = I_o e^{-\mu x} \tag{19} \]

the attractiveness is defined by,

\[ Q = \text{Area} \cdot \varepsilon \cdot \sigma \cdot T_s^4 \cdot e^{-\mu x} \tag{20} \]

logarithmic spiral movement of gentoo penguin is found by,

\[ r = a e^{b\theta} \tag{21} \]

\[ x = r \cos \theta = a \cos \theta \cdot e^{b\theta} \tag{22} \]

\[ y = r \sin \theta = a \sin \theta \cdot e^{b\theta} \tag{23} \]

distance between two Gentoo penguins “i” and “j” is computed to calculate the spiral movement by,

\[
D_{ij} = \int_{\theta_i}^{\theta_j} ds = \int_{\theta_i}^{\theta_j} \sqrt{\left(\frac{dr}{d\theta}\right)^2 + r^2 d\theta} = \int_{\theta_i}^{\theta_j} \sqrt{a^2 + a^2 e^{2b\theta} + a^2 e^{2b\theta} d\theta} \\
= a\sqrt{b^2 + 1} \int_{\theta_i}^{\theta_j} e^{b\theta} d\theta = \frac{a}{b}\sqrt{b^2 + 1} (e^{b\theta_j} - e^{b\theta_i}) \tag{24} \]

then the distance is calculated by,

\[
D_{ik} = Q \frac{a}{b}\sqrt{b^2 + 1} (e^{b\theta_j} - e^{b\theta_i}) = \int_{\theta_i}^{\theta_j} ds = \frac{a}{b}\sqrt{b^2 + 1} (e^{b\theta_k} - e^{b\theta_i}) \tag{25} \]

\[
\theta = \tan^{-1} \frac{y}{x} \tag{26} \]

\[ x_k = a \cos \theta_k \cdot e^{b\theta_k} \tag{27} \]

\[ y_k = a \sin \theta_k \cdot e^{b\theta_k} \tag{28} \]
then the components of the position is obtained by,

\[
x_k = ae^\left(\frac{-1}{b} \ln\left(1 - Q e^{\frac{b_2^T y_j}{s_j}}\right)\right) \cos \left(\frac{1}{b} \ln\left(1 - Q e^{\frac{b_1^T y_i}{s_i}} + Q e^{\frac{b_2^T y_j}{s_j}}\right)\right)
\]

\[
y_k = ae^\left(\frac{-1}{b} \ln\left(1 - Q e^{\frac{b_2^T y_j}{s_j}}\right)\right) \sin \left(\frac{1}{b} \ln\left(1 - Q e^{\frac{b_1^T y_i}{s_i}} + Q e^{\frac{b_2^T y_j}{s_j}}\right)\right)
\]

for spiral movement of Gentoo penguin \(i\) summed with random vector and moved to new position by

\[
x_k = ae^\left(\frac{-1}{b} \ln\left(1 - Q e^{\frac{b_2^T y_j}{s_j}}\right)\right) \cos \left(\frac{1}{b} \ln\left(1 - Q e^{\frac{b_1^T y_i}{s_i}} + Q e^{\frac{b_2^T y_j}{s_j}}\right)\right) + \varphi \epsilon_i
\]

\[
y_k = ae^\left(\frac{-1}{b} \ln\left(1 - Q e^{\frac{b_2^T y_j}{s_j}}\right)\right) \sin \left(\frac{1}{b} \ln\left(1 - Q e^{\frac{b_1^T y_i}{s_i}} + Q e^{\frac{b_2^T y_j}{s_j}}\right)\right) + + \varphi \epsilon_i
\]

a. Start
b. Engender preliminary population array of Gentoo penguin
c. Engender the position of each Gentoo penguin
d. Engender the cost of each Gentoo penguin
e. Find out the preliminary heat absorption coefficient
f. For \(I=1\) to Maximum Iteration do
g. Engender the replicate reproduction of population array;
h. For \(i=1\) to \(n\) population do
 i. For \(j=1\) to \(n\) population do
  j. if \(\text{cost}_i < \text{cost}_j\); then
 k. Compute the heat radiation value by \(Q_{\text{gentoo penguin}} = \text{Area} \cdot \varepsilon \cdot \sigma \cdot T_s^4\)
l. Compute the attractiveness value by \(Q = \text{Area} \cdot \varepsilon \cdot \sigma \cdot T_s^4 \cdot e^{-\mu x}\)
m. Compute the coordinated spiral movement value by

\[
x_k = ae^\left(\frac{-1}{b} \ln\left(1 - Q e^{\frac{b_2^T y_j}{s_j}}\right)\right) \cos \left(\frac{1}{b} \ln\left(1 - Q e^{\frac{b_1^T y_i}{s_i}} + Q e^{\frac{b_2^T y_j}{s_j}}\right)\right)
\]

\[
y_k = ae^\left(\frac{-1}{b} \ln\left(1 - Q e^{\frac{b_2^T y_j}{s_j}}\right)\right) \sin \left(\frac{1}{b} \ln\left(1 - Q e^{\frac{b_1^T y_i}{s_i}} + Q e^{\frac{b_2^T y_j}{s_j}}\right)\right)
\]

n. Find out new-fangled position by,

\[
x_k = ae^\left(\frac{-1}{b} \ln\left(1 - Q e^{\frac{b_2^T y_j}{s_j}}\right)\right) \cos \left(\frac{1}{b} \ln\left(1 - Q e^{\frac{b_1^T y_i}{s_i}} + Q e^{\frac{b_2^T y_j}{s_j}}\right)\right) + \varphi \epsilon_i
\]

\[
y_k = ae^\left(\frac{-1}{b} \ln\left(1 - Q e^{\frac{b_2^T y_j}{s_j}}\right)\right) \sin \left(\frac{1}{b} \ln\left(1 - Q e^{\frac{b_1^T y_i}{s_i}} + Q e^{\frac{b_2^T y_j}{s_j}}\right)\right) + + \varphi \epsilon_i
\]

o. Estimate new-fangled solutions;
p. End
4. SIMULATION STUDY

Proposed Gentoo Penguin Algorithm (GPA) has been tested, in IEEE 57 Bus system [17]. 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 shows the comparison of Real Power Loss and Figure 2 Indicate about the Real power loss reduction in percentage.

Table 1. Constraints of control variables

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

Table 2. Constrains of reactive power generators

| Variables | Q Minimum (PU) | Q Maximum (PU) |
|-----------|----------------|----------------|
| IEEE 57 Bus |               |                |
| 1          | -1.40          | 200            |
| 2          | -17            | 50             |
| 3          | -10            | 60             |
| 6          | -8             | 25             |
| 8          | -1.40          | 200            |
| 9          | -3             | 9              |
| 12         | -1.50          | 155            |

Table 3. Simulation results of IEEE −57 system

| Control variables | Base case | MPOSO [18] | PSO [18] | CGA [18] | AGA [18] | GPA   |
|-------------------|-----------|------------|----------|----------|----------|-------|
| VG 1              | 1.040     | 1.093      | 1.083    | 0.968    | 1.027    | 1.024 |
| VG 2              | 1.010     | 1.086      | 1.071    | 1.049    | 1.111    | 1.027 |
| VG 3              | 0.985     | 1.056      | 1.055    | 1.056    | 1.033    | 1.029 |
| VG 6              | 0.980     | 1.038      | 1.036    | 0.987    | 1.001    | 1.017 |
| VG 8              | 1.005     | 1.066      | 1.059    | 1.022    | 1.051    | 1.028 |
| VG 9              | 0.980     | 1.054      | 1.048    | 0.991    | 1.051    | 1.023 |
| VG 12             | 1.015     | 1.054      | 1.046    | 1.004    | 1.057    | 1.031 |
| Tap 19            | 0.970     | 0.975      | 0.987    | 0.920    | 1.030    | 0.901 |
| Tap 20            | 0.978     | 0.982      | 0.983    | 0.920    | 1.020    | 0.908 |
| Tap 31            | 1.043     | 0.975      | 0.981    | 0.970    | 1.060    | 0.920 |
| Tap 35            | 1.000     | 1.025      | 1.003    | NR*      | NR*      | 1.019 |
| Tap 36            | 1.000     | 1.002      | 0.985    | NR*      | NR*      | 1.028 |
| Tap 37            | 1.043     | 1.007      | 1.009    | 0.900    | 0.990    | 1.021 |
| Tap 41            | 0.967     | 0.994      | 1.007    | 0.910    | 1.100    | 0.912 |
| Tap 46            | 0.975     | 1.013      | 1.018    | 1.100    | 0.980    | 1.021 |
| Tap 54            | 0.955     | 0.988      | 0.986    | 0.940    | 1.010    | 0.934 |
| Tap 58            | 0.955     | 0.979      | 0.992    | 0.950    | 1.080    | 0.931 |
| Tap 59            | 0.900     | 0.983      | 0.990    | 1.030    | 0.940    | 0.942 |
| Tap 65            | 0.930     | 1.015      | 0.997    | 1.090    | 0.950    | 1.048 |
| Tap 66            | 0.895     | 0.975      | 0.984    | 0.900    | 1.050    | 0.919 |
| Tap 71            | 0.958     | 1.020      | 0.990    | 0.900    | 0.950    | 1.028 |
| Tap 73            | 0.958     | 1.001      | 0.988    | 1.000    | 1.010    | 1.036 |
| Tap 76            | 0.980     | 0.979      | 0.980    | 0.960    | 0.940    | 0.945 |
| Tap 80            | 0.940     | 1.002      | 1.017    | 1.000    | 1.000    | 1.028 |
| QC 18             | 0.1       | 0.179      | 0.131    | 0.084    | 0.016    | 0.131 |
| QC 25             | 0.059     | 0.176      | 0.144    | 0.008    | 0.015    | 0.145 |
| QC 53             | 0.063     | 0.141      | 0.162    | 0.053    | 0.038    | 0.102 |
| PG (MW)           | 1278.6    | 1274.4     | 1274.8   | 1276    | 1275     | 1272.12 |
| QC (Mvar)         | 321.08    | 272.27     | 276.58   | 309.1   | 304.4    | 272.26 |
| Reduction in PLoss (%) | 0      | 15.4       | 14.1    | 9.2    | 11.6    | 26.76 |
| Total PLoss (Mw)  | 27.8      | 23.51      | 23.86    | 25.24   | 24.56    | 20.358 |

NR* - Not reported.

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5. CONCLUSION

Gentoo Penguin Algorithm (GPA) successfully solved the optimal reactive power problem. Gentoo Penguins' penguin attraction value is calculated by the amount of heat prevailing between two Gentoo penguins. Less heat is received in longer distances, in little distance, huge heat is received. Depending on the environment its has been assumed that gentoo penguin is in thermal equilibrium. Proposed Gentoo Penguin Algorithm (GPA) has been tested in standard IEEE 57 bus test system and simulation results show the projected algorithm reduced the real power loss efficiently. And reduction of real power loss value is 26.76% when compared to the base value.

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