Power loss reduction by gryllidae optimization algorithm

Kanagasabai Lenin
Department of EEE, Prasad V. Potluri Siddhartha Institute of Technology, India

ABSTRACT
This paper projects Gryllidae Optimization Algorithm (GOA) has been applied to solve optimal reactive power problem. Proposed GOA approach is based on the chirping characteristics of Gryllidae. In common, male Gryllidae chirp, on the other hand some female Gryllidae also do as well. Male Gryllidae draw the females by this sound which they produce. Moreover, they caution the other Gryllidae against dangers with this sound. The hearing organs of the Gryllidae are housed in an expansion of their forelegs. Through this, they bias to the produced fluttering sounds. Proposed Gryllidae Optimization Algorithm (GOA) has been tested in standard IEEE 14, 30 bus test systems and simulation results show that the projected algorithms reduced the real power loss considerably.

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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 [7-17] 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. This paper projects Gryllidae Optimization Algorithm (GOA) has been applied to solve optimal reactive power problem. Proposed algorithm based on the chirping characteristics of Gryllidae and formulated to solve the optimal reactive power problem. In common, male Gryllidae chirp, on the other hand some female Gryllidae also do as well. Male Gryllidae draw the females by this sound which they produce. Male Gryllidae create this sound by chirping the wings and known as stridulating. They attract each other by this sound for mating and keep the others from their nests. Moreover, they caution the other Gryllidae against dangers with this sound. The hearing organs of the Gryllidae are housed in an expansion of their forelegs. Through this, they bias to the produced fluttering sounds. Proposed Gryllidae Optimization Algorithm (GOA) has been tested in standard IEEE 14, 30 bus test systems and simulation results show that the projected algorithms reduced the real power loss considerably.

2. PROBLEM FORMULATION
Objective of the problem is to reduce the true power loss:

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

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voltage deviation given as follows:

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

(2)

voltage deviation given by:

$$\text{Voltage Deviation} = \sum_{i=1}^{Np} |V_i - 1|$$

(3)

constraint (equality)

$$P_G = P_D + P_L$$

(4)

constraints (Inequality)

$$P_{g\text{slack}}^{\text{min}} \leq P_{g\text{slack}} \leq P_{g\text{slack}}^{\text{max}}$$

(5)

$$Q_{gi}^{\text{min}} \leq Q_{gi} \leq Q_{gi}^{\text{max}}, i \in N_g$$

(6)

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

(7)

$$T_i^{\text{min}} \leq T_i \leq T_i^{\text{max}}, i \in N_T$$

(8)

$$Q_c^{\text{min}} \leq Q_c \leq Q_c^{\text{max}}, i \in N_C$$

(9)

3. **GRYLLIDAE OPTIMIZATION ALGORITHM**

Gryllidae optimization algorithm based on the chirping characteristics of Gryllidae and formulated to solve the optimal reactive power problem. In common, male Gryllidae chirp, on the other hand some female Gryllidae also do as well. Male Gryllidae draw the females by this sound which they produce. Male Gryllidae create this sound by chirping the wings and known as stridulating. They attract each other by this sound for mating and keep the others from their nests. Moreover, they caution the other Gryllidae against dangers with this sound. The hearing organs of the Gryllidae are housed in an expansion of their forelegs. Through this, they bias to the produced fluttering sounds. Temperature ($T_f$) in degrees Fahrenheit is calculated from the chirp ($N_c$,(per minute)) by,

$$T_f = 50.00 + \frac{\text{Number of chirps} (N_c) - 40.00}{4.00}$$

(10)

temperature in degrees Celsius ($T_c$), is defined by,

$$T_c = 10.00 + \frac{\text{Number of chirps} (N_c) - 40.00}{7.00}$$

(11)

chirping rate can be calculated based on $T_c$ and $T_f$ is found by,

$$N_c = (T_c - 10.00) \times 7.00 + 40.00$$

(12)

$$N_c = (T_f - 50.00) \times 4.00 + 40.00$$

(13)

velocity of sound is calculated by via the temperature attained with reference to the Dolbear law

$$V = 20.1 \sqrt{273 + T}$$

(14)

frequency of the sound is given by,

$$f = \frac{V}{\lambda}$$

(15)
intensity of the sound inversely proportional to the square of the distance,

\[ I = \frac{W}{4\pi r^2} = \frac{P}{\rho c} \cdot W = I \times 4\pi r^2 \]  

(16)

sound propagation level found by,

\[ L_p = L_w + 10 \log \left( \frac{Q}{4\pi r^2} \right) \]  

(17)

atmosphere sound absorption is given by,

\[ A_{\text{atmos}} = 7A(f^2r/\Phi)10^{-8} \]  

(18)

free filed sound pressure is given by,

\[ L_p' = L_p - A_{\text{atmos}} \]  

(19)

frequency, velocity, position value obtained by,

\[ f_i = f_{\text{minimum}} + (f_{\text{maximum}} - f_{\text{minimum}})\beta \]  

(20)

\[ v_i^t = v_{i-1}^t + (x_i - x_*) f_i + V_i \]  

(21)

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

(22)

random walk [18] is done through,

\[ x_i = x_{\text{best}} + 0.01 \times \text{random}(0,1) \]  

(23)

in the period of the modernizing procedure, Euclidian distances (r) among all of the Gryllidae in the population were computed by,

\[ K = K_0 e^{-\gamma r^2} \]  

(24)

\[ x_i = x_i + K_0 e^{-\gamma r^2} + \alpha \epsilon_i \]  

(25)

Commence
For i=1 to n do
\[ x_i \leftarrow \text{engender initial solution ( )} \]
End
\[ t_{\text{min}} \leftarrow \text{argmin}_i s(x_i) \]
\[ F_{\text{min}} \leftarrow \text{argmin}_i s(x_i) \]
\[ x_{\text{min}} \leftarrow \text{argmin}_i s(x_i) \]
For i=1 to t do
\[ \text{while}(F_{\text{minimum}} > T_{\text{ol}}) \]
For i=1 to n do
\[ N_i \leftarrow \text{engender random vector} \]
\[ T_i \leftarrow \text{Dolbear law (N_i)} \]
\[ c_i = (5/9)T_i - 32 \]
\[ V_i \leftarrow V \times 20.1 \times \sqrt{2.73 + \ell}, \lambda \leftarrow x_i - x_{\text{best}} \]
\[ F_{\text{maximum}} \leftarrow f = \dot{v}_i, v_i, x_i, f_i \leftarrow f_{\text{minimum}} + (f_{\text{maximum}} - f_{\text{minimum}})\beta, \quad v_i^t = v_{i-1}^t + (x_i - x_*) f_i + V_i \]
\[ x_i^t = x_{i-1}^t + v_i^t \]
\[ \gamma \leftarrow \text{compute the Coefficient} \]
if random[0,1] > \gamma
For j=1 to n do
if \[ s_i < s_j \] then \[ r_j \leftarrow K = K_0 e^{-\gamma r^2} \]
\[ P_S \leftarrow I = \frac{W}{4\pi r^2} = \frac{P}{\rho c}, W = I \times 4\pi r^2 \]
\[ L_P \leftarrow L_p = L_w + 10 \log \left( \frac{Q}{4\pi r^2} \right) \]
\[ A_{\text{atmos}} \leftarrow A_{\text{atmos}} = 7A(f^2r/\Phi)10^{-8} \]
\[ R_L^p \leftarrow L_p' = L_p - A_{\text{atmos}} \]
\[ K_0 \leftarrow R_L^p, K_1 \leftarrow x_i = x_i + Koe^{ry_t} + \alpha \in_i \]
\[ x_i \leftarrow x_i = x_{\text{best}} + 0.01 \times \text{random}(0,1) \]

End
\[ F_{\text{new}} \leftarrow \text{cost function}(x_i) \]
\[ \text{if } (F_{\text{new}} < F_{\text{minimum}}) \]
\[ x_{\text{best}} = x_i \]
\[ F_{\text{minimum}} = F_{\text{new}} \]
End
Find the most excellent solution

End

4. SIMULATION RESULTS

At first in standard IEEE 14 bus system the validity of the proposed Gryllidae Optimization Algorithm (GOA) 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.

Then the proposed Gryllidae Optimization Algorithm (GOA) simulated 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.

| Table 1. Constraints of control variables |
|------------------------------------------|
| 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 |

| Table 2. Constrain of reactive power generators |
|-----------------------------------------------|
| System | Variables | Q Minimum (PU) | Q Maximum (PU) |
|--------|-----------|----------------|----------------|
| IEEE 14 Bus | 2 | -40 | 50 |
| 3 | 0 | 40 |
| 6 | -6 | 24 |
| 8 | -6 | 24 |

| Table 3. Simulation results of IEEE −14 system |
|-----------------------------------------------|
| Control variables | Base case | MPSO [19] | PSO [19] | EP [19] | SARGA [19] | GOA |
|-------------------|-----------|-----------|-----------|----------|----------|-----|
| \( V_G \)−1 | 1.060 | 1.100 | 1.100 | NR* | NR* | 1.004 |
| \( V_G \)−2 | 1.045 | 1.085 | 1.086 | 1.029 | 1.060 | 1.014 |
| \( V_G \)−3 | 1.010 | 1.055 | 1.056 | 1.016 | 1.036 | 1.009 |
| \( V_G \)−6 | 1.070 | 1.069 | 1.067 | 1.097 | 1.099 | 1.002 |
| \( V_G \)−8 | 1.090 | 1.074 | 1.060 | 1.053 | 1.078 | 1.011 |
| \( T_{\text{ap}} \) 8 | 0.978 | 1.018 | 1.019 | 1.04 | 0.95 | 0.900 |
| \( T_{\text{ap}} \) 9 | 0.969 | 0.975 | 0.988 | 0.94 | 0.95 | 0.911 |
| \( T_{\text{ap}} \) 10 | 0.932 | 1.024 | 1.008 | 1.03 | 0.96 | 0.901 |
| \( Q_G \)−9 | 0.19 | 14.64 | 0.185 | 0.18 | 0.06 | 0.124 |
| \( PG \) | 272.39 | 271.32 | 271.32 | NR* | NR* | 271.46 |
| \( QG \) (Mvar) | 82.44 | 75.79 | 76.79 | NR* | NR* | 75.04 |
| Reduction in PLoss (%) | 0 | 9.2 | 9.1 | 1.5 | 2.5 | 12.33 |
| Total PLoss (Mw) | 13.550 | 12.293 | 12.315 | 13.346 | 13.216 | 11.879 |

NR* - Not reported.

| Table 4. Constraints of control variables |
|------------------------------------------|
| 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 |
Table 5. Constraints of reactive power generators

| 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 |

Table 6. Simulation results of IEEE -30 system

| Control variables | Base case | MPSEO [19] | PSO [19] | EP [19] | SARGA [19] | GOA |
|-------------------|-----------|------------|----------|---------|------------|-----|
| \( V_{G} \) | 1.060 | 1.101 | 1.100 | NR* | NR* | 1.010 |
| \( V_{G} \) | 1.045 | 1.086 | 1.072 | 1.097 | 1.094 | 1.008 |
| \( V_{G} \) | 1.071 | 1.068 | 1.080 | 1.091 | 1.099 | 1.032 |
| Tap1 | 0.978 | 0.983 | 0.987 | 1.01 | 0.99 | 0.912 |
| Tap2 | 0.969 | 1.023 | 1.015 | 1.03 | 1.03 | 0.905 |
| Tap3 | 0.932 | 1.020 | 1.020 | 1.07 | 0.98 | 0.914 |
| Tap4 | 0.968 | 0.988 | 1.012 | 0.99 | 0.96 | 0.906 |
| QC10 | 1.0 | 0.777 | 0.777 | 0.19 | 0.19 | 0.089 |
| QC24 | 0.043 | 0.119 | 0.128 | 0.04 | 0.04 | 0.101 |
| \( PG \) (MW) | 300.9 | 299.54 | 299.54 | NR* | NR* | 298.59 |
| \( QG \) (Mvar) | 133.9 | 130.83 | 130.94 | NR* | NR* | 131.81 |
| Reduction in PLoss | 0 | 8.4 | 7.4 | 6.6 | 8.3 | 10.05 |
| Total PLoss (MW) | 17.55 | 16.07 | 16.25 | 16.38 | 16.09 | 15.786 |

NR* - Not reported.

5. Conclusion

In this paper Gryllidae Optimization Algorithm (GOA) successfully solved the optimal reactive power problem. Application of the Gryllidae Optimization Algorithm is developed by the inspiration of a type of insect; on the recognizable global engineering problems in the simulation-based nature which has recently participated to the meta-heuristic algorithm approach was confirmed. Proposed Gryllidae Optimization Algorithm (GOA) has been tested in standard IEEE 14, 30 bus test systems and simulation results show that the projected algorithms reduced the real power loss considerably.

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