Meleagris Gallopavo Algorithm for Solving Optimal Reactive Power Problem

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ABSTRACT
In this paper, Meleagris Gallopavo Algorithm (MGA) is proposed for solving optimal reactive power problem. As a group-mate Meleagris gallopavo follow their poultry to explore food, at the same time it prevent the same ones to eat their own food. Always the overriding individuals have the lead to grab more food and Meleagris gallopavo would arbitrarily pinch the high-quality food which has been already found by other Meleagris gallopavo. In the region of the mother Meleagris gallopavo, Foults always search food. In the Projected Meleagris Gallopavo Algorithm (MGA) additional parameters are eliminated, in order to upsurge the search towards global optimization solution. Proposed Meleagris Gallopavo Algorithm (MGA) has been tested on two modes a. with the voltage stability Evaluation in standard IEEE 30 bus test system, b. Without voltage stability Evaluation in standard IEEE 30, 57, 118 bus test systems & practical 191 test system. Simulation results show clearly the better performance of the proposed Meleagris Gallopavo Algorithm (MGA) in reducing the real power loss, enhancement of static voltage stability Index and particularly voltage profiles within the specified limits.

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1. INTRODUCTION
The main objective in optimal reactive power problem is to minimize the real power loss and to keep the voltage profile within the limits. Various mathematical techniques [1-8] have been utilized to solve the problem but have the complexity in managing inequality constraints. Start form genetic algorithm & all Evolutionary algorithms [9-20] have been applied serially to solve the reactive power problem. But they also had their own advantages & disadvantages in Exploration & Exploitation. This paper proposes Meleagris Gallopavo Algorithm (MGA) to solve reactive power problem. In this projected algorithm both exploration & exploitation has been augmented equally in order to reach near to global optimum solution. As a group-mate Meleagris Gallopavo follow their poultry to explore food, at the same time it prevent the same ones to eat their own food. Always the overriding individuals have the lead to grab more food and Meleagris Gallopavo would arbitrarily pinch the high-quality food which has been already found by other Meleagris Gallopavo. In the region of the mother Meleagris Gallopavo, Foults always search food. In the Projected Meleagris Gallopavo Algorithm (MGA) additional parameters are eliminated, in order to upsurge the search
Towards global optimization solution. Proposed Meleagris Gallopavo Algorithm (MGA) has been tested on two modes a. with considering voltage stability Evaluation in standard IEEE 30 bus test system, b. Without considering voltage stability Evaluation in standard IEEE 30, 57, 118 bus test systems & practical 191 test system. Simulation results show clearly the better performance of the proposed Meleagris Gallopavo Algorithm (MGA) in reducing the real power loss, enhancement of static voltage stability Index and particularly voltage profiles are within the specified limits.

2. VOLTAGE STABILITY EVALUATION

2.1. Voltage Stability Evaluation by Modal Analysis

For voltage stability enhancement in power systems Modal analysis methodology [25] has been used. The steady state system power flow equations are given by.

\[
\begin{bmatrix}
\Delta P \\
\Delta Q
\end{bmatrix} =
\begin{bmatrix}
I_{p\theta} & I_{pV} \\
I_{q\theta} & I_{QV}
\end{bmatrix}
\begin{bmatrix}
\Delta \theta \\
\Delta V
\end{bmatrix}
\]

(1)

Where

\( \Delta P = \) change in bus real power incrementally.
\( \Delta Q = \) change in bus reactive Power injection incrementally.
\( \Delta \theta = \) change in bus voltage angle incrementally.
\( \Delta V = \) change in bus voltage Magnitude incrementally.

Sub-matrices of the System voltage stability are \( J_{p\theta} \), \( J_{pV} \), \( J_{q\theta} \), \( J_{QV} \) jacobian matrix and it affected by both P and Q.

Assume \( \Delta P = 0 \), to reduce equation (1) then,

\[
\Delta Q = \left[ I_{QV} - J_{QV}I_{p\theta}^{-1}I_{pV} \right] \Delta V = J_{R} \Delta V
\]

(2)

\[
\Delta V = J^{-1} - \Delta Q
\]

(3)

Where

\( J_{R} = \left( I_{QV} - J_{Q\theta}I_{p\theta}^{-1}I_{QV} \right) \)

(4)

\( J_{R} \) is called the reduced Jacobian matrix of the system.

2.2. Modes of Voltage Instability

By computing the Eigen values and Eigen vectors voltage Stability characteristics of the system have been identified.

\[ J_{R} = \xi \wedge \eta \]

(5)

Where,

\( \xi = \) right eigenvector matrix of \( J_{R} \)
\( \eta = \) left eigenvector matrix of \( J_{R} \)
\( \wedge = \) diagonal eigenvalue matrix of \( J_{R} \) and

\[
J_{R}^{-1} = \xi \wedge^{-1} \eta
\]

(6)

From the equations (5) and (8), we can write,

\[
\Delta V = \xi \wedge^{-1} \eta \Delta Q
\]

(7)

Or

\[
\Delta V = \sum_{i} \frac{\xi_{i}\eta_{i}}{\xi_{i}} \Delta Q
\]

(8)

Where \( \xi_{i} \) is the ith column right eigenvector and \( \eta_{i} \) the ith row left eigenvector of \( J_{R} \).
$\lambda_i$ is the $i$th Eigen value of $JR$.

The $i$th modal reactive power variation is given by,

$$\Delta Q_{mi} = K_i \xi_i$$  \hspace{1cm} (9)

where,

$$K_i = \sum_j \xi_{ij}^2 - 1$$ \hspace{1cm} (10)

Where

$\xi_{ij}$ is the $j$th element of $\xi_i$

The corresponding $i$th modal voltage variation is mathematically given by,

$$\Delta V_{mi} = [1/\lambda_i] \Delta Q_{mi}$$ \hspace{1cm} (11)

When $|\lambda_i| = 0$ then the $i$th modal voltage will get collapsed.

In Equation (8), assume $\Delta Q = ek$ where ek has all its elements zero except the $k$th one being 1. Then,

$$\Delta V = \sum_i \eta_{ik} \xi_{i\lambda_i}$$ \hspace{1cm} (12)

Where $\eta_{ik}$ the $k$th element of $\eta_i$

$V$–$Q$ sensitivity at bus $k$ is given by,

$$\frac{\partial V_k}{\partial Q_k} = \sum_i \eta_{ik} \xi_{i\lambda_i} = \sum_i P_{ki} / \lambda_i$$ \hspace{1cm} (13)

3. PROBLEM FORMULATION

The key objectives of the reactive power dispatch problem is to minimize the system real power loss and also to maximize the static voltage stability margin (SVSM).

3.1. Minimization of Real Power Loss

Real power loss ($P_{loss}$) Minimization in transmission lines is mathematically given as,

$$P_{loss} = \sum_{k=1}^{n} g_k (V_i^2 + V_j^2 - 2V_i V_j \cos \theta_{ij})$$  \hspace{1cm} (14)

Where $n$ is the number of transmission lines, $g_k$ is the conductance of branch $k$, $V_i$ and $V_j$ are voltage magnitude at bus $i$ and bus $j$, and $\theta_{ij}$ is the voltage angle difference between bus $i$ and bus $j$.

3.2. Minimization of Voltage Deviation

At load buses minimization of the voltage deviation magnitudes (VD) is stated as follows,

Minimize $VD = \sum_{k=1}^{nl} |V_k - 1.0|$  \hspace{1cm} (15)

Where $nl$ is the number of load busses and $V_k$ is the voltage magnitude at bus $k$.

3.3. System Constraints

These are the following constraints subjected to objective function as given below. Load flow equality constraints:

$$P_{Gi} - P_{Di} - \sum_{j=1}^{nb} V_j g_{ij} \left[ \frac{G_{ij} \cos \theta_{ij}}{\sin \theta_{ij}} + B_{ij} \right] = 0, i = 1, 2, ..., nb$$  \hspace{1cm} (16)

$$Q_{Gi} - Q_{Di} - \sum_{j=1}^{nb} V_j g_{ij} \left[ \frac{G_{ij} \sin \theta_{ij}}{\cos \theta_{ij}} + B_{ij} \right] = 0, i = 1, 2, ..., nb$$  \hspace{1cm} (17)

Where, $nb$ is the number of buses, $PG$ and $QG$ are the real and reactive power of the generator, $PD$ and $QD$ are the real and reactive load of the generator, and $Gij$ and $Bij$ are the mutual conductance and
susceptance between bus i and bus j. 

Generator bus voltage ($V_{Gi}$) inequality constraint:

$$V_{Gi}^{\text{min}} \leq V_{Gi} \leq V_{Gi}^{\text{max}}, i \in \text{ng} \quad (18)$$

Load bus voltage ($V_{Li}$) inequality constraint:

$$V_{Li}^{\text{min}} \leq V_{Li} \leq V_{Li}^{\text{max}}, i \in \text{nl} \quad (19)$$

Switchable reactive power compensations ($Q_{Ci}$) inequality constraint:

$$Q_{Ci}^{\text{min}} \leq Q_{Ci} \leq Q_{Ci}^{\text{max}}, i \in \text{nc} \quad (20)$$

Reactive power generation ($Q_{Gi}$) inequality constraint:

$$Q_{Gi}^{\text{min}} \leq Q_{Gi} \leq Q_{Gi}^{\text{max}}, i \in \text{ng} \quad (21)$$

Transformers tap setting ($T_i$) inequality constraint:

$$T_i^{\text{min}} \leq T_i \leq T_i^{\text{max}}, i \in \text{nt} \quad (22)$$

Transmission line flow ($S_{Li}$) inequality constraint:

$$S_{Li}^{\text{min}} \leq S_{Li} \leq S_{Li}^{\text{max}}, i \in \text{nl} \quad (23)$$

Where, nc, ng and nt are numbers of the switchable reactive power sources, generators and transformers.

### 4. MELEAGRIS GALLOPAVO ALGORITHM (MGA)

Meleagris Gallopavo Algorithm (MGA) is based on the Meleagris Gallopavo behaviour. It consists of several groups and each group encompass a leading male Meleagris Gallopavo, couple of Meleagris Gallopavo, and Poults. Depend on the fitness values of the Meleagris Gallopavo they divide themselves into several groups and identity of the Meleagris Gallopavo (leading male Meleagris Gallopavo, couple of Meleagris Gallopavo, and Poults) has been determined. Based upon the best fitness values Meleagris Gallopavo would be acted as poultry, & also as head poultry in a group. And which has worst fitness values would be designated as Poults. Remaining all would be the common Meleagris Gallopavo and it arbitrarily chooses which group to live in. Mother-child relationship between the Female Meleagris Gallopavo and the Poults is also arbitrarily established as shown in Figure 1, 2, 3.

![Figure 1. Meleagris Gallopavo](image1)

![Figure 2. Female Meleagris Gallopavo with Poults](image2)

![Figure 3. Meleagris Gallopavo in Group](image3)

Supremacy relationship and mother-child relationship in a group will remain unchanged & only update every several (G) time steps. In the as a group-mate Meleagris Gallopavo follow their poultry (leading
me male Meleagris Gallopavo) to explore food, at the same time it prevent the same ones to eat their own food. Always the overriding individuals have the lead to grab more food and Meleagris Gallopavo would arbitrarily pinch the high-quality food which has been already found by other Meleagris Gallopavo. In the region of the mother Meleagris Gallopavo Poult would always search for food. In the Projected Meleagris Gallopavo Algorithm (MGA) additional parameters are eliminated, in order to upsurge the search towards global optimization solution.

Always advantages for the dominant individuals in grab the food. Better fitness poultry will have high priority for food access when compared with worse fitness values poultry. It has been simulated that the poultry with better fitness values can explore for food in a wider range of places than that of the with poultry worse fitness values. This can be articulated mathematically as follows.

\[
y_{ij}^{t+1} = y_{ij}^t \ast (1 + \text{Rand}(0, \sigma^2))
\]  
(24)

\[
\sigma^2 = \left\{ \begin{array}{ll}
1 & f_i \leq f_k \text{ otherwise } k \in [1, N], k \neq 1 \\
\exp\left(\frac{f_k - f_i}{\epsilon |f_i + \epsilon|}\right) & \end{array} \right.
\]  
(25)

Where \(\text{Rand}(0, \sigma^2)\) is a Gaussian distribution [21] with mean 0 and standard deviation \(\sigma^2\), \(\epsilon\), which is used to shun the zero-division-error & the smallest constant \(k\), a poultry index, is arbitrarily selected from the poultry group, \(f\) is the fitness value of the corresponding \(y\). Hens, follow their group-mate poultry to explore for food. Furthermore, they would also arbitrarily steal the good food found by other Meleagris Gallopavo. Dominant Meleagris Gallopavo would have high advantage in competing for food than the more passive ones. This phenomenon can be formulated mathematically as follows.

\[
y_{ij}^{t+1} = y_{ij}^t + S1 \ast \text{Rand} \ast \left( y_{r,i,j}^t - y_{ij}^t \right) + S2 \ast \text{Rand} \ast \left( y_{r+2,i,j}^t - y_{ij}^t \right)
\]  
(26)

\[
S1 = \exp\left(\frac{f_i - f_i^*}{\epsilon \left| \text{abs}(f_i) + \epsilon \right|}\right)
\]  
(27)

\[
S2 = \exp(f_{i,2} - f_i)
\]  
(28)

Where \(\text{Rand}\) is a uniform random number over \(r^2 \in [0, 1]\), is an index of the poultry, which is the \(i\)th Meleagris Gallopavo’s group-mate, \(r^2 \in [0, 1]\), is an index of the Meleagris Gallopavo, which is arbitrarily chosen from the swarm \(r^t \neq r^2\).

Around the mother Meleagris Gallopavo, Poult move to forage for food. This is formulated by,

\[
y_{ij}^{t+1} = y_{ij}^t + FL \ast \left( y_{m,j}^t - y_{ij}^t \right)
\]  
(29)

Where \(y_{m,j}^t\) stands for the position of the \(i\)th Poult’s mother \(m \in [1, N]\). FL [FL \in (0, 2)] is a parameter, & it indicates that the Poult would follow its mother to forage for food. Consider the individual differences, the FL of each Poult would arbitrarily choose between 0 and 2.

Meleagris Gallopavo group has wide range of exploration & it lead to have global search ability. Number of parameters is reduced but the exploration and exploitation of exploration space can be done by all individual of population. The multi steps are separated be two steps. The first step is diversification (Exploration) in which Meleagris Gallopavo group’s first step is reduced due to the largest area search ability; this reduced form is used to exploring the global optima. Each individual of Meleagris Gallopavo population move to the other position by the best Meleagris Gallopavo and the other Meleagris Gallopavo. The second one is intensification (exploitation) & it evaluates the value from the first step. Since the poultry and Poult group have the local exploration ability, the both group will be utilized to exploit the existing position from the first step. Alike to the first step, each individual of Meleagris Gallopavo population is considered as poultry then as a single Meleagris Gallopavo.

Initialization of Population
Meleagris Gallopavo swarm population are initialized by,

\[
y_{ij} = lb + \text{Rand}(ub - lb)
\]  
(30)

With \(lb\) and \(ub\) are lower bound and upper bound of the exploration space.

Exploration Step
This phase reduces the Meleagris Gallopavo numerous step & used to explore the global optimum by eliminating the Meleagris Gallopavo group parameter. Against two individual of the population each individual of Meleagris Gallopavo population revamp their position and it formulated as,

$$y_{i,j}^* = y_{i,j} + S1 \cdot \text{Rand} \cdot (y_{i,j} - y_{n,j}) + S2 \cdot \text{Rand} \cdot (y_{n,j} - y_{i,j}) \quad (31)$$

With,

$$S1 = \exp \left( \frac{f_i - f_j}{f_i + \varepsilon} \right) \quad (32)$$

$$S2 = \exp (f_n - f_i) \quad (33)$$

\(y_i, y_n \in [1, N]\) is arbitrarily chosen form Meleagris Gallopavo swarm with \(y_i \neq y_l \neq y_n\).

After \(y_{i,j}^*\) obtained, the objective value (fitness value) compared with the fitness value of \(y_{i,j}\). The solution that has the most excellent fitness value is chosen as an individual of new population & it called as individual of the global population \(\{y_{i,j}(g)\}\).

**Exploitation Step**

Through exploration step candidate solution (Meleagris Gallopavo individual) will be obtained & it will be revamped again by exploiting the neighbourhood using the process of reducing poultry and Meleagris Gallopavo formula. Alike with exploration step, this step will also eliminate poultry and Meleagris Gallopavo groups. Local optimum search carried out in two steps, the first step is by using the reduction poultry formula as follows.

$$y_{i,j}^{**} = y_{i,j}^{(g)} \cdot (1 + \text{Rand} \cdot (0, \sigma^2)) \quad (34)$$

$$\sigma^2 = \begin{cases} 1 & f_i^{(g)} \leq f_j^{(g)} \\ \exp \left( \frac{f_i^{(g)} - f_j^{(g)}}{f_i^{(g)} + \varepsilon} \right) & \text{otherwise} \end{cases} \quad l \in [1, N](g), l \neq i \quad (35)$$

The first local optimum solution obtained by exploiting the global optimum population by using the Equation (27). After that the next step is comparing its fitness value with fitness value of previous global optimum solution. The solution which has most excellent fitness value is chosen as individual of the first renewal population that called Local population I \(\{y_{i,j}(l_1)\}\).

After new-fangled local population I \(\{y_{i,j}(l_1)\}\) obtained, subsequently the final step of Meleagris Gallopavo Algorithm (MGA) is to find the more local optimum (the second local optimum) by using the reduced Meleagris Gallopavo formula as follows:

$$y_{i,j}^{***} = y_{i,j}(l_1) + C \cdot (y_{n,j}(l_2) - y_{i,j}(l_1)) \quad (36)$$

\(y_n \in [1, N]\) is arbitrarily chosen from the local population I with \(y_i \neq y_n\) and \(C(C \in (0,2))\).

After the second local optimum obtained, the next step is compares its fitness value with the previous local optimum solution fitness value. The solution which has most excellent fitness value is chosen as individual of the second renewal population that called local population II \(\{y_{i,j}(l_2)\}\). This population is used as the preliminary population for the subsequent iteration until the stopping criteria are met.

**Meleagris Gallopavo Algorithm (MGA) for Solving Reactive Power Problem**

a. By using equation (30) Initialize a population of N Meleagris Gallopavo
b. N Meleagris Gallopavo fitness value has been evaluated; \(t = 0\)
c. While \(t < G\)
d. For \(l = 1; N\)
   aa. By Equation (31) explore the global optimum & Selection of individual global population \(\{y_{i,j}(g)\}\) has to be done.
Meleagris Gallopavo Algorithm for Solving Optimal Reactive Power Problem (K. Lenim)

5. SIMULATION RESULTS
5.1. With Considering Voltage Stability Evaluation
At first the efficiency of the proposed Meleagris Gallopavo Algorithm (MGA) has been tested it in standard IEEE-30 bus system with voltage stability evaluation.

Standard IEEE-30 bus system has 6 generator buses, 24 load buses and 41 transmission lines of which four branches are (6-9), (6-10), (4-12) and (28-27) - are with the tap setting transformers. The lower voltage magnitude limits at all buses are 0.95 p.u. and the upper limits are 1.1 for all the PV buses and 1.05 p.u. for all the PQ buses and the reference bus. Table 5 shows Meleagris Gallopavo Algorithm (MGA) reduces real power losses considerably when compared to other standard reported algorithms. In Table 1 optimal values of control variables along with the minimum loss obtained are given & it was found that there are no limit violations in any of the state variables corresponding to this control variables.

Table 2 indicates the optimal values of the control variables & there is no limit violations in state variables. Mainly static voltage stability margin (SVSM) has increased from 0.2478 to 0.2489. contingency analysis was conducted using the control variable setting obtained in case 1 and case 2 to determine the voltage security of the system. In Table 3 the Eigen values equivalents to the four critical contingencies are given. Result reveal about the Eigen value has been improved considerably for all contingencies in the second case.

Table 1. Results of MGA–Optimal Reactive Power Control Variables

| Control Variables | Values of Variable Setting |
|-------------------|-----------------------------|
| V1                | 1.0400                      |
| V2                | 1.0410                      |
| V5                | 1.0400                      |
| V8                | 1.0310                      |
| V11               | 1.0010                      |
| T11               | 1.0000                      |
| T12               | 1.0000                      |
| T15               | 1.0100                      |
| T36               | 1.0100                      |
| Qc10              | 2                           |
| Qc12              | 2                           |
| Qc15              | 3                           |
| Qc17              | 0                           |
| Qc20              | 2                           |
| Qc23              | 3                           |
| Qc24              | 3                           |
| Qc29              | 2                           |
| Real power loss   | 4.2956                      |
| SVSM              | 0.2478                      |

Table 2. Results of MGA-Optimal Control Variables of Voltage Stability Control Reactive Power Dispatch

| Control Variables | Values of Variable setting |
|-------------------|-----------------------------|
| V1                | 1.0440                      |
| V2                | 1.0430                      |
| V5                | 1.0420                      |
| V8                | 1.0360                      |
| V11               | 1.0030                      |
| V13               | 1.0300                      |
| T11               | 0.9900                      |
| T12               | 0.9900                      |
| T15               | 0.9900                      |
| T36               | 0.9900                      |
| Qc10              | 3                           |
| Qc12              | 3                           |
| Qc15              | 3                           |
| Qc17              | 0                           |
| Qc20              | 2                           |
| Qc23              | 2                           |
| Qc24              | 2                           |
| Qc29              | 3                           |
| Real power loss   | 4.9878                      |
| SVSM              | 0.2489                      |
5.2. Without Considering Voltage Stability Evaluation

Validity of the proposed Meleagris Gallopavo Algorithm (MGA) has been verified by testing in standard IEEE 30-bus without considering Voltage stability evaluation.

Standard IEEE 30-bus has 41 branches, 6 generator-bus, 4 transformer-tap settings, with 2 shunt reactive compensators buses, 2, 5, 8, 11 and 13 are considered as PV generator buses & Bus 1 is taken as slack bus, others are PQ load buses. In Table 6 Control variables limits are given.

In Table 7 gives the power limits of generators buses. Table 8 shows the values of control variables. Table 9 narrates the performance of the proposed algorithm. Overall comparison of the results of optimal solution obtained by various methods is given in Table 10.

| Table 3. Voltage Stability Under Contingency State |
|-----------------|-----------------|-------------------|
| Sl.No | Contingency | Optimal Voltage Stability | Reactive Control Power Dispatch Setting |
|------|--------------|------------------------|-----------------------------|
| 1    | 28-27        | 0.1452                 | 0.1424                      |
| 2    | 4-12         | 0.1649                 | 0.1651                      |
| 3    | 1-3          | 0.1761                 | 0.1772                      |
| 4    | 2-4          | 0.2024                 | 0.2041                      |

| Table 4. Limit Violation Checking of State Variables |
|-----------------|-----------------|-------------------|
| State variables | Lower limits    | Upper limits      |
|                  | Optimal Voltage Stability | Reactive Control Power Dispatch Setting |
| Q1               | -20             | 152               | 1.3422                      |
| Q2               | -20             | 61                | 8.9900                      |
| Q5               | -15             | 49.92             | 25.920                      |
| Q8               | -10             | 63.52             | 38.8200                     |
| Q11              | -15             | 42                | 2.9300                      |
| Q13              | -15             | 48                | 8.1025                      |
| V3               | 0.95            | 1.05              | 1.0372                      |
| V4               | 0.95            | 1.05              | 1.0372                      |
| V6               | 0.95            | 1.05              | 1.0282                      |
| V7               | 0.95            | 1.05              | 1.0101                      |
| V9               | 0.95            | 1.05              | 1.0462                      |
| V10              | 0.95            | 1.05              | 1.0482                      |
| V12              | 0.95            | 1.05              | 1.0400                      |
| V14              | 0.95            | 1.05              | 1.0474                      |
| V15              | 0.95            | 1.05              | 1.0457                      |
| V16              | 0.95            | 1.05              | 1.0426                      |
| V17              | 0.95            | 1.05              | 1.0382                      |
| V18              | 0.95            | 1.05              | 1.0392                      |
| V19              | 0.95            | 1.05              | 1.0381                      |
| V20              | 0.95            | 1.05              | 1.0112                      |
| V21              | 0.95            | 1.05              | 1.0435                      |
| V22              | 0.95            | 1.05              | 1.0448                      |
| V23              | 0.95            | 1.05              | 1.0472                      |
| V24              | 0.95            | 1.05              | 1.0484                      |
| V25              | 0.95            | 1.05              | 1.0142                      |
| V26              | 0.95            | 1.05              | 1.0494                      |
| V27              | 0.95            | 1.05              | 1.0472                      |
| V28              | 0.95            | 1.05              | 1.0243                      |
| V29              | 0.95            | 1.05              | 1.0392                      |
| V30              | 0.95            | 1.05              | 1.0418                      |

| Table 5. Comparison of Real Power Loss |
|-----------------|-----------------|-------------------|
| Methods         | Minimum loss (MW) |
| Evolutionary programming [22] | 5.0159 |
| Genetic algorithm [23] | 4.665 |
| Real coded GA with Lindex as SVSM [24] | 4.568 |
| Real coded genetic algorithm [25] | 4.5015 |
| Proposed MGA method | 4.2956 |

| Table 6. Primary Variable Limits (PU) |
|-----------------|-----------------|-------------------|
| Variables       | Min. | Max. | category |
| Generator Bus   | 0.95 | 1.1  | Continuous |
| Load Bus        | 0.95 | 1.05 | Continuous |
| Transformer-Tap | 0.9  | 1.1  | Discrete |
| Shunt Reactive Compensator | -0.11 | 0.31 | Discrete |

| Table 7. Generators Power Limits |
|-----------------|-----------------|-------------------|
| Bus | Pgmin | Pgmax | Qgmin | Qgmax |
|------|-------|-------|-------|-------|
| 1    | 96.00 | 200   | 0     | 10    |
| 2    | 79.00 | 79    | -40   | 50    |
| 5    | 58.90 | 49    | -40   | 40    |
| 8    | 21.00 | 31    | -10   | 24    |
| 11   | 21.00 | 62    | -6    | 24    |
| 13   | 21.00 | 39    | -6    | 24    |
Table 8. After Optimization Values of Control Variables

| Control Variables | MGA |
|-------------------|-----|
| V1                | 1.0413 |
| V2                | 1.0419 |
| V5                | 1.0189 |
| V8                | 1.0276 |
| V11               | 1.0684 |
| V13               | 1.0487 |
| T4,12             | 0.00 |
| T6,9              | 0.01 |
| T6,10             | 0.90 |
| T28,27            | 0.91 |
| Q10               | 0.10 |
| Q24               | 0.10 |
| Real power loss   | 4.2702 |
| Voltage deviation | 0.9072 |

Table 9. Performance of MGA

| Iterations | Time taken (sec) | Real power loss |
|------------|------------------|-----------------|
|            | 25               | 9.72            |
|            |                  | 4.2702          |

Table 10. Comparison of Results

| Techniques         | Real power loss (MW) |
|--------------------|-----------------------|
| SGA(Wu et al., 1998) [26] | 4.98 |
| PSO(Zhao et al., 2005) [27] | 4.9262 |
| LP(Mahadevan et al., 2010) [28] | 5.988 |
| EP(Mahadevan et al., 2010) [28] | 4.963 |
| CGA(Mahadevan et al., 2010) [28] | 4.980 |
| AGA(Mahadevan et al., 2010) [28] | 4.926 |
| CLPSO(Mahadevan et al., 2010) [28] | 4.7208 |
| HSA(Khazali et al., 2011) [29] | 4.7624 |
| BB-BC(Sakthivel et al., 2013) [30] | 4.690 |
| MCS(Tejaswini Sharma et al., 2016) [31] | 4.87231 |
| Proposed MGA    | 4.2702             |

Then Meleagris Gallopavo Algorithm (MGA) has been tested in standard IEEE-57 bus power system. 18, 25 and 53 are reactive power compensation buses. PV buses are 2, 3, 6, 8, 9 and 12 and slack-bus is bus 1. In Table 11 system variable limits are given. IEEE-57 preliminary conditions for the bus power system are given as follows:

\[ P_{\text{load}} = 12.110 \text{ p.u.} \quad Q_{\text{load}} = 3.050 \text{ p.u.} \]

Complete sum of initial generations and power losses are attained as follows:

\[ \sum P_L = 12.429 \text{ p.u.} \quad \sum Q_L = 3.3137 \text{ p.u.} \]

\[ P_{\text{loss}} = 0.2585 \text{ p.u.} \quad Q_{\text{loss}} = -1.2059 \text{ p.u.} \]

Control variables values obtained after optimization is given in Table 12. Comparisons of results are shown in Table 13.

Table 11. Variable Limits

| Reactive Power Generation Limits |
|---------------------------------|
| Bus no | 1 | 2 | 3 | 6 | 8 | 9 | 12 |
| Qgmin  | -1.4 | -0.15 | -0.2 | -0.04 | -1.3 | -0.03 | -0.4 |
| Qgmax  | 0.3 | 0.4 | 0.21 | 1 | 0.04 | 1.50 |

| Voltage And Tap Setting Limits |
|--------------------------------|
| Vgmin | 0.9 |
| Vgmax | 1.0 |
| Vpmin | 0.91 |
| Vpmax | 1.05 |
| tkmin | 0.9 |
| tkmax | 1.0 |

| Shunt Capacitor Limits |
|-----------------------|
| Bus no | 18 | 25 | 53 |
| Qcmin | 0 | 0 | 0 |
| Qcmax | 10 | 5.2 | 6.1 |

Table 12. Control Variables Obtained After Optimization

| Control Variables | MGA |
|-------------------|-----|
| V1                | 1.10 |
| V2                | 1.0321 |
| V3                | 1.0314 |
| V6                | 1.0218 |
| V8                | 1.0214 |
| V9                | 1.0010 |
| V12               | 1.0100 |
| Qc18              | 0.0660 |
| Qc25              | 0.2000 |
| Qc53              | 0.0472 |
| T4-18             | 1.0011 |
| T21-20            | 1.0424 |
| T24-25            | 0.8600 |
| T24-26            | 0.8701 |
| T7-29             | 1.0500 |
| T34-32            | 0.8710 |
| T11-41            | 1.0101 |
| T15-45            | 1.0301 |
| T14-46            | 0.9100 |
| T10-51            | 1.0200 |
| T13-49            | 0.9601 |
| T11-43            | 0.9100 |
| T40-56            | 0.9001 |
| T39-57            | 0.9501 |
| T9-55             | 0.9500 |

Table 13. Comparison Results

| S.No. | Optimization Algorithm | Finest Solution | Poorest Solution | Normal Solution |
|-------|------------------------|-----------------|------------------|-----------------|
| 1     | NLP[32]                | 0.25992         | 0.30854          | 0.27859         |
| 2     | CGA[32]                | 0.25244         | 0.27507          | 0.26293         |
| 3     | AGA[32]                | 0.24564         | 0.26671          | 0.25127         |
| 4     | PSON-w[32]             | 0.24270         | 0.26152          | 0.24725         |
| 5     | PSON-cf[32]            | 0.24280         | 0.26032          | 0.24698         |
| 6     | CLPSO[32]              | 0.24515         | 0.24780          | 0.24673         |
| 7     | SPSO-07[32]            | 0.24430         | 0.25457          | 0.24752         |
| 8     | L-DE[32]               | 0.27812         | 0.41909          | 0.33177         |
| 9     | L-SACP-DE[32]          | 0.27915         | 0.36978          | 0.31032         |
| 10    | L-SaDE[32]             | 0.24267         | 0.24391          | 0.24311         |
| 11    | SOA[32]                | 0.24265         | 0.24280          | 0.24270         |
| 12    | LM[33]                 | 0.2484          | 0.2922           | 0.2641          |
| 13    | MBEP1[33]              | 0.2474          | 0.2848           | 0.2643          |
| 14    | MBEP2[33]              | 0.2482          | 0.283            | 0.2592          |
| 15    | BES100[33]             | 0.2438          | 0.263            | 0.2541          |
| 16    | BES200[33]             | 0.3417          | 0.2486           | 0.2443          |
| 17    | Proposed MGA           | 0.22092         | 0.23034          | 0.22218         |

Meleagris Gallopavo Algorithm for Solving Optimal Reactive Power Problem (K. Lenim)
Then Meleagris Gallopavo Algorithm (MGA) has been tested in standard IEEE 118-bus test system [34]. The system has 54 generator buses, 64 load buses, 186 branches and 9 of them are with the tap setting transformers. The limits of voltage on generator buses are 0.95-1.1 per-unit., and on load buses are 0.95 -1.05 per-unit. The limit of transformer rate is 0.9-1.1, with the changes step of 0.025. In Table 14 the limitations of reactive power source are listed, with the change in step of 0.01.

Comparison results are shown in Table 15 and the results clearly show the better performance of proposed Meleagris Gallopavo Algorithm (MGA) in reducing the real power loss.

| BUS | QCMax | QCMin |
|-----|-------|-------|
| 5   | 0     | -40   |
| 34  | 14    | 0     |
| 37  | 0     | -25   |
| 44  | 10    | 0     |
| 45  | 10    | 0     |
| 46  | 15    | 0     |
| 48  | 0     | 0     |

Table 14. Limitation of Reactive Power Sources

Comparison results are shown in Table 15 and the results clearly show the better performance of proposed Meleagris Gallopavo Algorithm (MGA) in reducing the real power loss.

| BUS | QCMax | QCMin |
|-----|-------|-------|
| 74  | 20    | 10    |
| 79  | 20    | 10    |
| 82  | 10    | 6     |
| 83  | 10    | 6     |
| 105 | 10    | 6     |
| 107 | 10    | 6     |
| 110 | 10    | 6     |

Table 15. Comparison Results

| Active power loss (MW) | BBO [35] | ILSBBO/strategy1 [35] | ILSBBO/strategy1 [35] | Proposed MGA |
|------------------------|----------|------------------------|------------------------|--------------|
| Min                    | 128.77   | 126.98                 | 124.78                 | 118.02       |
| Max                    | 132.64   | 137.34                 | 132.39                 | 121.64       |
| Average                | 130.21   | 130.37                 | 129.22                 | 119.28       |

Then the Meleagris Gallopavo Algorithm (MGA) has been tested in practical 191 test system and the following results have been obtained. In Practical 191 test bus system – Number of Generators = 20, Number of lines = 200, Number of buses = 191 Number of transmission lines = 55. Table 16 shows the optimal control values of practical 191 test system obtained by MGA. And table 17 shows the results about the value of the real power loss by obtained by Meleagris Gallopavo Algorithm (MGA).

Table 16 Optimal Control Values of Practical 191 Utility (Indian) System by MGA

| VG1 | VG 2 | VG 3 | VG 4 | VG 5 | VG 6 | VG 7 | VG 8 | VG 9 | VG 10 |
|-----|------|------|------|------|------|------|------|------|-------|
| 1.1000 | 0.7800 | 1.0100 | 1.0100 | 1.1000 | 1.1000 | 1.1000 | 1.0100 | 1.1000 | 1.1000 |
| VG11 | VG12 | VG13 | VG14 | VG15 | VG16 | VG17 | VG18 | VG19 | VG20 |
| 0.9000 | 1.0000 | 1.0000 | 0.9000 | 1.0000 | 1.0000 | 0.9000 | 1.0000 | 1.1000 | 1.1000 |
| T1 | T2 | T3 | T4 | T5 | T6 | T7 | T8 | T9 | T10 |
| 0.9000 | 0.9000 | 0.9000 | 0.9000 | 0.9000 | 0.9000 | 0.9000 | 0.9000 | 0.9000 | 0.9000 |
6. CONCLUSION

Mealegris Gallopavo Algorithm (MGA) has been successfully solved reactive power problem. In the Projected Mealegris Gallopavo Algorithm (MGA) additional parameters are eliminated, in order to upsurge the search towards global optimization solution. Proposed Mealegris Gallopavo Algorithm (MGA) has been tested on two modes a. with the voltage stability Evaluation in standard IEEE 30 bus test system, b. Without voltage stability Evaluation in standard IEEE 30, 57,118 bus test systems & practical 191 test system. Simulation results show clearly the better performance of the proposed Mealegris Gallopavo Algorithm (MGA) in reducing the real power loss, enhancement of static voltage stability Index and particularly voltage profiles within the specified limits.

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