International Journal of Applied Power Engineering (IJAPE)
Vol.7, No.2, August 2018, pp. 99~110
ISSN: 2252-8792 DOI: 10.11591/ijape.v7.i2.pp99-110

Meleagris Gallopavo Algorithm for Solving Optimal Reactive Power Problem

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

Article Info

Article history:

Received Jan 10, 2018
Revised Feb 16, 2018
Accepted Feb 28, 2018

Keyword:

Meleagris Gallopavo Algorithm
Optimal reactive power
Poultry
Transmission loss

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, Poults always search for food. In the projected MGA additional parameters are eliminated, in order to upsurge the search towards global optimization solution. Proposed 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 MGA in reducing the real power loss, enhancement of static voltage stability Index and particularly voltage profiles within the specified limits.

Corresponding Author:

K. Lenin,
Department of EEE,
Prasad V. Potluri Siddhartha Institute of Technology,
Kanuru, Vijayawada, Andhra Pradesh -520007, India.
Email: gklenin@gmail.com

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, Poults always search for food. In the projected MGA additional parameters are eliminated, in order to upsurge the search towards global optimization solution. Proposed 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 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.

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J_{p\theta} & J_{pv} \\ J_{q\theta} & J_{QV} \end{bmatrix} \begin{bmatrix} \Delta\theta \\ \Delta V \end{bmatrix} \tag{1}$$

Where

ΔP=change in bus real power incrementally.

ΔQ=change in bus reactive Power injection incrementally.

Δθ=change in bus voltage angle incrementally.

ΔV=change in bus voltage Magnitude incrementally.

sub-matrixes of the System voltage stability are Jpθ , JPV , JQθ , JQV jacobian matrix and it affected by both P and Q.

Assume ΔP=0, to reduce equation (1) then,

$$\Delta Q = \left[J_{QV} - J_{Q\theta} J_{P\theta^{-1}} J_{PV}\right] \Delta V = J_R \Delta V \tag{2}$$

$$\Delta V = J^{-1} - \Delta Q \tag{3}$$

Where

$$J_R = \left(J_{QV} - J_{Q\theta} J_{P\theta^{-1}} JPV\right) \tag{4}$$

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.

$$J_R = \xi \wedge \eta \tag{5}$$

Where,

ξ=right eigenvector matrix of JR

η=left eigenvector matrix of JR

ʌ=diagonal eigenvalue matrix of JR and

$$J_{R^{-1}} = \xi \wedge^{-1} \eta \tag{6}$$

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

$$\Delta V = \xi \wedge^{-1} \eta \Delta Q \tag{7}$$

Or

$$\Delta V = \sum_I \frac{\xi_i \eta_i}{\lambda_i} \Delta Q \tag{8}$$

Where ξi is the ith column right eigenvector and η the ith row left eigenvector of JR.

λi is the ith Eigen value of JR.

The ith modal reactive power variation is given by,

$$\Delta Q_{mi} = K_i \xi_i \tag{9}$$

where,

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

Where
ξji is the jth element of ξi
The corresponding ith modal voltage variation is mathematically given by,

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

When | λi |=0 then the ith modal voltage will get collapsed.
In Equation (8), assume ΔQ=ek where ek has all its elements zero except the kth one being 1. Then,

$$\Delta V = \sum_i \frac{\eta_{1k}\ \xi_1}{\lambda_1} \quad (12)$$

η_{1k} k th element of η_1
V–Q sensitivity at bus k is given by,

$$\frac{\partial V_K}{\partial Q_K} = \sum_i \frac{\eta_{1k}\ \xi_1}{\lambda_1} = \sum_i \frac{P_{ki}}{\lambda_1} \quad (13)$$

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 (Ploss) Minimization in transmission lines is mathematically given as,

$$P_{loss=} \sum_{\substack{k=1 \\ k=(i,j)}}^{n} g_{k(V_i^2+V_j^2-2V_i\,V_j\,\cos\theta_{ij})} \quad (14)$$

Where n is the number of transmission lines, gk is the conductance of branch k, Vi and Vj are voltage magnitude at bus i and bus j, and θij 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,

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

Where nl is the number of load busses and Vk 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:

$$P_{Gi} - P_{Di} - V_{i\sum_{j=1}^{nb} V_j}\begin{bmatrix} G_{ij} & \cos\theta_{ij} \\ +B_{ij} & \sin\theta_{ij} \end{bmatrix} = 0, i = 1,2 \ldots., nb \quad (16)$$

$$Q_{Gi} - Q_{Di} - V_{i\sum_{j=1}^{nb} V_j}\begin{bmatrix} G_{ij} & \sin\theta_{ij} \\ +B_{ij} & \cos\theta_{ij} \end{bmatrix} = 0, i = 1,2 \ldots., nb \quad (17)$$

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:

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

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

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

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

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

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

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

Transformers tap setting (T_i) inequality constraint:

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

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

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

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

4. MELEAGRIS GALLOPAVO ALGORITHM (MGA)

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.

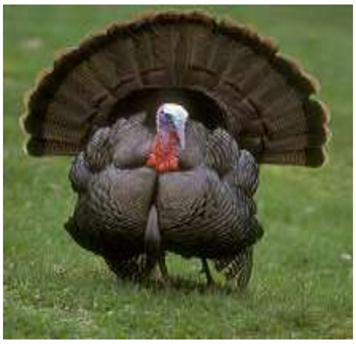

Figure 1. Meleagris gallopavo

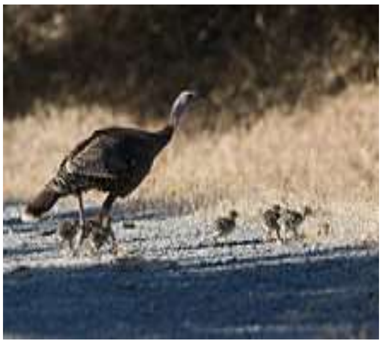

Figure 2. Female meleagris gallopavo with poults

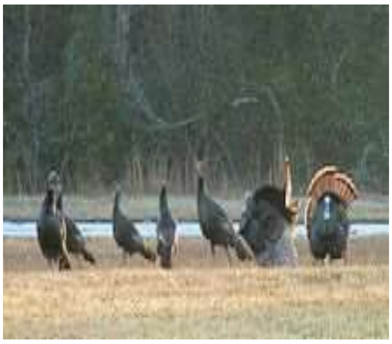

Figure 3. Meleagris gallopavo in group

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 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 Poults always search for food. In the projected 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.

$$y_{i,j}^{t+1} = y_{i,j}^{t} * \left(1 + Rand(0, \sigma^2)\right) \quad (24)$$

$$\sigma^2 = \begin{cases} 1 & f_i \le f_k \\ exp\left(\frac{f_k - f_i}{|f_i + \varepsilon|}\right) & other\ wise \end{cases} \quad k \in [1, N], k \neq 1 \quad (25)$$

Where $Rand(0, \sigma^2)$is a Gaussian distribution [21] with mean 0 and standard deviation σ^2, ε,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,

$$y_{i,j}^{t+1} = y_{i,j}^{t} + S1 * Rand * \left(y_{r^1,j}^{t} - y_{i,j}^{t}\right) + S2 * Rand * \left(y_{r^2,j}^{t} - y_{i,j}^{t}\right) \quad (26)$$

$$S1 = exp\left(\frac{f_i - f_{r^1}}{abs(f_i) + \varepsilon}\right) \quad (27)$$

$$S2 = exp(f_{r^2} - f_i) \quad (28)$$

Where Rand is a uniform random number over $r^1 \in$ [0, 1], is an index of the poultry, which is the ith Meleagris Gallopavo's group-mate, while$r^2 \in$ [0, 1], is an index of the Meleagris Gallopavo, which is arbitrarily chosen from the swarm $r^1 \neq r^2$.

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

$$y_{i,j}^{t+1} = y_{i,j}^{t} + FL * \left(y_{m,j}^{t} - y_{i,j}^{t}\right) \quad (29)$$

Where $y_{m,j}^{t}$, stands for the position of the i-th Poults's mother $m \in [1, N]$. FL$[FL \in (0,2)]$ is a parameter, & it indicates that the Poults 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 Poults 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,

$$y_{i,j} = lb + Rand(ub - lb) \quad (30)$$

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,

$$y_{i,j}(*) = y_{i,j} + S1 * Rand * \left(y_{l.j} - y_{i,j}\right) + S2 * Rand * \left(y_{n,j} - y_{i,j}\right) \quad (31)$$

With,

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

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

$y_l, y_n \in [1, N]$ 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$\left(y_{i,j}(g)\right)$.

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.

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

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

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 $\left(y_{i,j}(l_1)\right)$.

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

$$y_{i,j}(***) = y_{i,j}(l_1) + C * \left(y_{n,j}(l_1) - y_{i,j}(l_1)\right) \quad (36)$$

$y_n \in [1, N]$ is arbitrarily chosen from the local population I with $y_i \neq y_n$ and $C\left(C \in (0,2)\right)$.
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$\left(y_{i,j}(l_2)\right)$. This population is used as the preliminary population for the subsequent iteration until the stopping criteria are met.

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 $i = 1; N$
aa. By Equation (31) explore the global optimum & Selection of individual global population $\left(y_{i,j}(g)\right)$ has to be done.
bb. Exploitation of the local optimum
aaa. By using equation (34) first local optimum has been found & Selection of individual local population I $\left(y_{i,j}(l_1)\right)$ have to be done.
bbb. By using (36) the second local optimum has to be found & Selection of individual local population II $\left(y_{i,j}(l_2)\right)$ have to be done.

e. End For
End While

5. SIMULATION RESULTS

5.1. With considering voltage stability evaluation

At first the efficiency of the proposed 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. 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 5 shows MGA reduces real power losses considerably when compared to other standard reported algorithms.

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
V13	1.0320
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	0.0900
T12	0.0900
T15	0.0900
T36	0.0900
Qc10	3
Qc12	3
Qc15	2
Qc17	3
Qc20	0
Qc23	2
Qc24	2
Qc29	3
Real power loss	4.9878
SVSM	0.2489

Table 3. Voltage Stability Under Contingency State

Sl.No	Contingency	Optimal Reactive Power Dispatch Setting	Voltage Stability Control Reactive 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	limits		Optimal Reactive PowerDispatch Setting	Voltage Stability Control Reactive Power Dispatch Setting
	Lower	upper		
Q1	-20	152	1.3422	-1.3269
Q2	-20	61	8.9900	9.8232
Q5	-15	49.92	25.920	26.001
Q8	-10	63.52	38.8200	40.802
Q11	-15	42	2.9300	5.002
Q13	-15	48	8.1025	6.033
V3	0.95	1.05	1.0372	1.0392
V4	0.95	1.05	1.0307	1.0328
V6	0.95	1.05	1.0282	1.0298
V7	0.95	1.05	1.0101	1.0152
V9	0.95	1.05	1.0462	1.0412
V10	0.95	1.05	1.0482	1.0498
V12	0.95	1.05	1.0400	1.0466
V14	0.95	1.05	1.0474	1.0443
V15	0.95	1.05	1.0457	1.0413
V16	0.95	1.05	1.0426	1.0405
V17	0.95	1.05	1.0382	1.0396
V18	0.95	1.05	1.0392	1.0400
V19	0.95	1.05	1.0381	1.0394
V20	0.95	1.05	1.0112	1.0194
V21	0.95	1.05	1.0435	1.0243
V22	0.95	1.05	1.0448	1.0396
V23	0.95	1.05	1.0472	1.0372
V24	0.95	1.05	1.0484	1.0372
V25	0.95	1.05	1.0142	1.0192
V26	0.95	1.05	1.0494	1.0422
V27	0.95	1.05	1.0472	1.0452
V28	0.95	1.05	1.0243	1.0283
V29	0.95	1.05	1.0439	1.0419
V30	0.95	1.05	1.0418	1.0397

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

5.2. Without considering voltage stability evaluation

Validity of the proposed 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 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	Pg	Pgmin	Pgmax	Qgmin	Qmax
1	96.00	49	200	0	10
2	79.00	18	79	-40	50
5	49.00	14	49	-40	40
8	21.00	11	31	-10	40
11	21.00	11	28	-6	24
13	21.00	11	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	25
Time taken (secs)	9.72
Real power loss	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 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_{load=}$12.110 p.u. Q_{load}=3.050 p.u.

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

$\sum P_G$=12.429 p.u. $\sum Q_G$=3.3137 p.u.

$P_{loss=}$0.25851 p.u. Q_{loss}=-1.2059 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	-.015	-.02	-0.04	-1.3	-0.03	-0.4
Qgmax	1	0.3	0.4	0.21	1	0.04	1.50
Voltage And Tap Setting Limits							
vgmin	Vgmax	vpqmin		Vpqmax		tkmin	tkmax
0.9	1.0	0.91		1.05		0.9	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	1.0601
T11-43	0.9100
T40-56	0.9001
T39-57	0.9501
T9-55	0.9500

Table 13. Comparison Results

No.	Optimization Algorithm	Finest Solution	Poorest Solution	Normal Solution
1	NLP [32]	0.25902	0.30854	0.27858
2	CGA [32]	0.25244	0.27507	0.26293
3	AGA [32]	0.24564	0.26671	0.25127
4	PSO-w [32]	0.24270	0.26152	0.24725
5	PSO-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

Then 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 MGA in reducing the real power loss.

Table 14. Limitation of Reactive Power Sources

BUS	5	34	37	44	45	46	48
QCMAX	0	14	0	10	10	10	15
QCMIN	-40	0	-25	0	0	0	0
BUS	74	79	82	83	105	107	110
QCMAX	12	20	20	10	20	6	6
QCMIN	0	0	0	0	0	0	0

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 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	1.1000	VG 11	0.9000
VG 2	0.7800	VG 12	1.0000
VG 3	1.0100	VG 13	1.0000
VG 4	1.0100	VG 14	0.9000
VG 5	1.1000	VG 15	1.0000
VG 6	1.1000	VG 16	1.0000
VG 7	1.1000	VG 17	0.9000
VG 8	1.0100	VG 18	1.0000
VG 9	1.1000	VG 19	1.1000
VG 10	1.0100	VG 20	1.1000

T1	1.0000	T21	0.9000	T41	0.9000
T2	1.0000	T22	0.9000	T42	0.9000
T3	1.0000	T23	0.9000	T43	0.9100
T4	1.1000	T24	0.9000	T44	0.9100
T5	1.0000	T25	0.9000	T45	0.9100
T6	1.0000	T26	1.0000	T46	0.9000
T7	1.0000	T27	0.9000	T47	0.9100
T8	1.0100	T28	0.9000	T48	1.0000
T9	1.0000	T29	1.0100	T49	0.9000
T10	1.0000	T30	0.9000	T50	0.9000
T11	0.9000	T31	0.9000	T51	0.9000
T12	1.0000	T32	0.9000	T52	0.9000
T13	1.0100	T33	1.0100	T53	1.0000
T14	1.0100	T34	0.9000	T54	0.9000
T15	1.0100	T35	0.9000	T55	0.9000

Table 17. Optimum Real Power Loss Values Obtained for Practical 191 Utility (Indian) System by MGA

Real power Loss (MW)	MGA
Min	145.4180
Max	147.6780
Average	146.1020

6. CONCLUSION

MGA has been successfully solved reactive power problem. In the projected MGA additional parameters are eliminated, in order to upsurge the search towards global optimization solution. Proposed 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 MGA in reducing the real power loss, enhancement of static voltage stability Index and particularly voltage profiles within the specified limits.

REFERENCES

[1] O. Alsac and B. Stott, "Optimal Load Flow with Steady-State Security," in *IEEE Transactions on Power Apparatus and Systems*, vol. PAS-93, no. 3, pp. 745-751, May 1974.

[2] K. Y. Lee, Y. M. Park and J. L. Ortiz, "A United Approach to Optimal Real and Reactive Power Dispatch," in *IEEE Transactions on Power Apparatus and Systems*, vol. PAS-104, no. 5, pp. 1147-1153, May 1985.

[3] A. Monticelli, M. V. F. Pereira and S. Granville, "Security-Constrained Optimal Power Flow with Post-Contingency Corrective Rescheduling," in *IEEE Transactions on Power Systems*, vol. 2, no. 1, pp. 175-180, Feb. 1987.

[4] N. Deeb and S. M. Shahidehpour, "Linear reactive power optimization in a large power network using the decomposition approach," in *IEEE Transactions on Power Systems*, vol. 5, no. 2, pp. 428-438, May 1990.

[5] E. Hcbson, "Network Constrained Reactive Power Control Using Linear Programming," in *IEEE Transactions on Power Apparatus and Systems*, vol. PAS-99, no. 3, pp. 868-877, May 1980.

[6] K. Y. Lee, Y. M. Park and J. L. Ortiz, "Fuel-cost minimisation for both real-and reactive-power dispatches," in *IEE Proceedings C - Generation, Transmission and Distribution*, vol. 131, no. 3, pp. 85-93, May 1984.

[7] M. K. Mangoli, K. Y. Lee, "Optimal real and reactive power control using linear programming," *Electric Power Systems Research*, vol. 26, No. 1, pp. 1-10, January 1993.

[8] C. A. Canizares, A. C. Z. De Souza and V. H. Quintana, "Comparison of performance indices for detection of proximity to voltage collapse," in *IEEE Transactions on Power Systems*, vol. 11, no. 3, pp. 1441-1450, Aug. 1996.

[9] K. Anburaja, "Optimal power flow using refined genetic algorithm," *Electric Power Components and System*, vol. 30, no. 10, pp. 1055-1063, 2002.

[10] D. Devaraj and B. Yegnanarayana, "Genetic-algorithm-based optimal power flow for security enhancement," in IEE Proceedings - *Generation, Transmission and Distribution*, vol. 152, no. 6, pp. 899-905, 4 Nov. 2005.

[11] A. Berizzi, C. Bovo, M. Merlo, M. Delfanti, "A ga approach to compare orpf objective functions including secondary voltage regulation," *Electric Power Systems Research*, vol. 84, no. 1, pp. 187–194, 2012.

[12] C. F. Yang, G. G. Lai, C.-H. Lee, C.-T. Su, G. W. Chang, "Optimal setting of reactive compensation devices with an improved voltage stability index for voltage stability enhancement," *International Journal of Electrical Power and Energy Systems*, vol. 37, no. 1, pp. 50–57, 2012.

[13] P. Roy, S. Ghoshal, S. Thakur, "Optimal var control for improvements in voltage profiles and for real power loss minimization using biogeography based optimization," *International Journal of Electrical Power and Energy Systems*, vol. 43, no. 1, pp. 830 – 838, 2012.

[14] B. Venkatesh, G. Sadasivam and M. A. Khan, "A new optimal reactive power scheduling method for loss minimization and voltage stability margin maximization using successive multi-objective fuzzy LP technique," in *IEEE Transactions on Power Systems*, vol. 15, no. 2, pp. 844-851, May 2000.

[15] Wei Yan, Shuai Lu and D. C. Yu, "A novel optimal reactive power dispatch method based on an improved hybrid evolutionary programming technique," in *IEEE Transactions on Power Systems*, vol. 19, no. 2, pp. 913-918, May 2004.

[16] Wei Yan, Fang Liu, C. Y. Chung and K. P. Wong, "A hybrid genetic algorithm-interior point method for optimal reactive power flow," in *IEEE Transactions on Power Systems*, vol. 21, no. 3, pp. 1163-1169, Aug. 2006.

[17] J. Yu, W. Yan, W. Li, C. Y. Chung and K. P. Wong, "An Unfixed Piecewise-Optimal Reactive Power-Flow Model and its Algorithm for AC-DC Systems," in *IEEE Transactions on Power Systems*, vol. 23, no. 1, pp. 170-176, Feb. 2008.

[18] F. Capitanescu, "Assessing Reactive Power Reserves With Respect to Operating Constraints and Voltage Stability," in *IEEE Transactions on Power Systems*, vol. 26, no. 4, pp. 2224-2234, Nov. 2011.

[19] Z. Hu, X. Wang, G. Taylor, "Stochastic optimal reactive power dispatch: Formulation and solution method," *International Journal of Electrical Power and Energy Systems*, vol. 32, no. 6, pp. 615–621, 2010.

[20] A. Kargarian, M. Raoofat, M. Mohammadi, "Probabilistic reactive power procurement in hybrid electricity markets with uncertain loads," *Electric Power Systems Research*, vol. 82, no. 1, pp. 68–80, 2012.

[21] X. Meng, Y. Liu, X. Gao, H. Zhang, "A New Bio-inspired Algorithm: Chicken Swarm Optimization," Advances in Swarm Intelligence SE, 8794. 2014, pp. 86–94.

[22] Q. H. Wu and J. T. Ma, "Power system optimal reactive power dispatch using evolutionary programming," in *IEEE Transactions on Power Systems*, vol. 10, no. 3, pp. 1243-1249, Aug. 1995.

[23] S. Durairaj, D. Devaraj, P. S. Kannan , "Genetic algorithm applications to optimal reactive power dispatch with voltage stability enhancement", *Journal of the Institution of Engineers (India): Electrical Engineering Division*, vol. 87, pp. 42-47, September 2006.

[24] D. Devaraj, "Improved genetic algorithm for multi–objective reactive power dispatch problem," *European Transactions on electrical power*, vol. 17, pp. 569-581, 2007.

[25] P. Aruna Jeyanthy, Dr. D. Devaraj, "Optimal Reactive Power Dispatch for Voltage Stability Enhancement Using Real Coded Genetic Algorithm," *International Journal of Computer and Electrical Engineering*, vol. 2, No. 4, August, 2010 1793-8163.

[26] Wu. Q. H, Y. J. Cao, J. Y. Wen, 1998, "Optimal reactive power dispatch using an adaptive genetic algorithm," *International Journal of Electrical Power & Energy* Systems, vol 20, no. 8, pp. 563-569, November 1998.

[27] B. Zhao, C. X. Guo and Y. J. Cao, "A multiagent-based particle swarm optimization approach for optimal reactive power dispatch," in *IEEE Transactions on Power Systems*, vol. 20, no. 2, pp. 1070-1078, May 2005.

[28] Mahadevan. K, Kannan P. S, 2010, "Comprehensive Learning Particle Swarm Optimization for Reactive Power Dispatch," *Applied Soft Computing*, vol. 10, no. 2, pp. 641–52, March 2010.

[29] Khazali. A. H, M. Kalantar, "Optimal Reactive Power Dispatch based on Harmony Search Algorithm," *Electrical Power and Energy Systems*, vol. 33, no. 3, pp. 684–692, 2011.

[30] Sakthivel. S, M. Gayathri, V. Manimozhi, 2013, "A Nature Inspired Optimization Algorithm for Reactive Power Control in a Power System," *International Journal of Recent Technology and Engineering*, vol. 2, no. 1, pp29-33, March 2013.

[31] Tejaswini Sharma,Laxmi Srivastava,Shishir Dixit, 2016, "Modified Cuckoo Search Algorithm For Optimal Reactive Power Dispatch," *Proceedings of 38 th IRF International Conference*, Chennai, 2016, pp. 4-8.

[32] C. Dai, W. Chen, Y. Zhu and X. Zhang, "Seeker Optimization Algorithm for Optimal Reactive Power Dispatch," in *IEEE Transactions on Power Systems*, vol. 24, no. 3, pp. 1218-1231, Aug. 2009.

[33] J. R. Gomes and O. R. Saavedra, "Optimal reactive power dispatch using evolutionary computation: extended algorithms," in *IEE Proceedings - Generation, Transmission and Distribution*, vol. 146, no. 6, pp. 586-592, Nov. 1999.

[34] IEEE, "The IEEE 30-bus test system and the IEEE 118-test system," (1993), http://www.ee.washington.edu/trsearch/pstca/.

[35] Jiangtao Cao, Fuli Wang, Ping Li, "An Improved Biogeography-based Optimization Algorithm for Optimal Reactive Power Flow," *International Journal of Control and Automation*,vol. 7, no. 3, pp. 161-176, 2014.