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FCC Algorithm for Power Loss Diminution

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Abstract. In this work, the FCC algorithm has been applied to the power problem. Real power loss reduction, voltage deviation minimization, and voltage stability enhancement are the key objectives of the proposed work. The proposed FCC algorithm has been modeled based on the competition, communication among teams, and training procedure within the team. The solution has been created based on the team, players, coach, and substitution tactic. A preliminary solution of the problem is produced, and the initialization of the teams depends on the team's formation with substitute tactics. Mainly fitness function for each solution is computed, and it plays an imperative role in the process of the algorithm. With the performance in the season, promotion and demotion of the teams will be there. Most excellently performed teams will be promoted to a senior division championship, and the most poorly performed team will be demoted to the top lower division league. Ideas and tactics sharing procedure, repositioning procedure, Substitution procedure, seasonal transmit procedure, Promotion and demotion procedure of a team which plays in the confederation cup has been imitated to solve the problem. Similar to an artificial neural network, a learning phase is also applied in the projected algorithm to improve the quality of the solution. Modernization procedure employed sequentially to identify the best solution. With and without voltage stability (L-index) FCC algorithm is evaluated in IEEE 30, bus system. Then the Proposed FCC algorithm has been evaluated in standard IEEE 14, 57,118,300 bus test systems without L-index. Power loss minimization and voltage stability index improvement have been achieved with voltage deviation minimization.

Keywords: optimal reactive power, transmission loss, FCC algorithm.

1 Introduction

Real power loss and voltage deviation minimization with voltage stability augmentation are the main objectives of this work. Previously conventional methods [1–6] are applied to solve the problem. Then these decades, many enhanced versions of genetic algorithm, variant of particle swarm optimization, ant colony algorithm, Frog leaping search algorithm, wolf search algorithm, ant lion algorithm, Butterfly algorithm, honeybee mating algorithm, black hole algorithm, bat algorithm, harmony search algorithm, whale optimization algorithm, water flow algorithm, artificial bee colony algorithm, mine blast algorithm [7–39] are utilized to solve the problem. But the central aspect is balancing the exploration and exploitation in the process of the algorithm. Many evolutionary and swarm-based algorithms fail to balance exploration and exploitation to reach an optimal solution. In this work, the football confederation cup (FCC) algorithm has been applied to solve the optimal reactive power problem. The main aim of the work is to reduce the actual power loss. In the transmission and distribution of the Electrical system, power loss is a significant issue. Reduction of the real power loss along with voltage stability enhancement is a difficult task. Previously many researchers around the world have applied conventional methods for this task, but many difficulties have been faced in handling the constraints, and these decades' evolutionary computation algorithms have been sequentially applied to solve the problem. Many algorithms have been applied, but shortcomings have been identified in balancing the exploration and exploitation. Since a fair trade between exploration and exploitation will guide the process to reach the best solution. The proposed FCC algorithm has been modeled based on the competition, communication among football teams, and training procedure within the team. The solution has been created based on the team, players, coach, and substitution tactic. Mainly fitness function for each solution is being computed, and it will play a vital role. Repositioning procedure, Substitution procedure, Seasonal transmit procedure, Promotion and demotion procedure of a team and the match between any two teams playing in the Confederation Cup is unknown; any team can win at the end a weak team will win over the strong team. The following high strength of the individual ream will reflect in the match, and it will make the team conquer the rival team in the match. The respective team will analyze the past results attained and concentrate on the forthcoming match alone by examining the bench strength with controlled tactics. Coaches are playing the lead role in giving valid input to the team. They share the knowledge and experience to players whenever possible. Also, coaches alter the tactics during the match towards the goal of winning. In team repositioning of the players in the game is done. It will alter and sequentially upgrade the process of the game in a particular match. With and without considering voltage stability index proposed FCC algorithm is tested in IEEE 30, bus system. Then with considering voltage stability index criterion Proposed FCC algorithm has been tested in standard IEEE 14, 30, 57,118,300 bus test systems without considering the voltage stability index. Projected algorithms reduced the power loss effectively. Mainly percentage of real power reduction has been improved when compared to other specified standard algorithms.

2 Research Methodology

2.1 Problem formulation

Linearized steady-state system power flow equations are given by:

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

where ΔP – incremental change in real bus power; ΔQ – incremental change in bus reactive Power injection; $\Delta\theta$ – incremental change in bus voltage angle; ΔV – incremental change in bus voltage Magnitude; $J_{p\theta}$, J_{PV}, $J_{Q\theta}$, J_{QV} – Jacobian matrix are the sub-matrixes of the system voltage stability is affected by both P and Q.

However, P is kept constant at each operating point and evaluate voltage stability by considering the incremental relationship between Q and V.

To reduce (1), let $\Delta P = 0$, then

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

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

where the reduced Jacobian matrix of the system:

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

Voltage Constancy characteristics of the system can be identified by calculating the eigenvalues and eigenvectors. Let

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

where ξ – right eigenvector matrix of J_R; η – left eigenvector matrix of J_R; $\wedge$ – diagonal eigenvalue matrix of J_R and

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

From (3) and (6), we have

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

or

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

where ξ_i – the i-th column right eigenvector; η – i-th row left eigenvector of J_R; λ_i – the ith eigenvalue of J_R.

The i-th modal reactive power variation is

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

where

$$K_i = \sum_j \xi_{ij^2} - 1; \tag{10}$$

ξ_{ji} – the j-th element of ξ_i.

The corresponding i-th modal voltage variation is

$$\Delta V_{mi} = [1/\lambda_i]\Delta Q_{mi}. \tag{11}$$

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

$$\Delta V = \sum_i \frac{\eta_{1k}\,\xi_1}{\lambda_1}; \tag{12}$$

η – k-th element of η_1; $V - Q$ sensitivity at bus k.

$$\frac{\partial V_K}{\partial Q_K} = \sum_i \frac{\eta_{1k}\,\xi_1}{\lambda_1} = \sum_i \frac{P_{ki}}{\lambda_1}. \tag{13}$$

The key objective is to diminish the real power loss P_{loss} in transmission lines of a power system. This is mathematically stated as follows:

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

where n – the number of transmission lines; g_k – the conductance of branch k; V_i and V_j – voltage magnitude at bus i and j; θ_{ij} – the voltage angle difference between bus i and j.

It is aimed in this objective that minimizing the Deviations in voltage magnitudes VD at load buses. This is mathematically stated as follows:

$$VD = \sum_{k=1}^{nl}|V_k - 1.0| \rightarrow \min, \tag{15}$$

where nl – the number of load busses; V_k – the voltage magnitude at bus k.

In the minimization process of objective functions, some problem constraints which one is equality, and others are inequality had to be met. Objective functions are subjected to these constraints shown below.

Load flow equality constraints:

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

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

where nb – the number of buses; P_G and Q_G – the real and reactive power of the generator; P_D and Q_D – the real and reactive load of the generator; G_{ij} and B_{ij} – 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:

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

2.2 FCC algorithm

In this work, Football Confederation Cup (FCC) algorithm has been modeled based on the competition, communication among football teams, and training procedure within the team. The solution has been created based on the team, players, coach, and substitution tactic. Mainly fitness function for each solution will be computed, and it will play an important role. The match between any two teams playing in the Confederation Cup is unknown; any team can win at the end also even a weak team will win over the strong team. The next high strength of the individual ream will reflect in the match, and it will make the team conquer the rival team in the match. The respective team will analyze the past results attained and concentrate on the forthcoming match alone by examining the bench strength with controlled tactics. Naturally, when team i beat team j its due to the power or strength of the winning team; similarly, it will be a weak point for the losing team.

A preliminary solution of the problem is created, and the initialization of the teams depends on the team's formation with substitute tactics. Then the preliminary set of teams is denoted as *football_team*^{0} with the population of a number of teams. At first $y_j^{formation}$, $y_j^{substitute}$ of the j-th variable is defined by

$$y_j^{formation} = lower\ bound_j + random\ () \times \times \left(upper\ bound_j - lower\ bound_j\right); \quad (24)$$

$$y_j^{substitute} = lower\ bound_j + random\ () \times \times \left(upper\ bound_j - lower\ bound_j\right). \quad (25)$$

Then the formation, substitute creation can be symbolized in the matrix as follows:

$$formation = \begin{bmatrix} y_{1,1}^{formation} & \cdots & y_{1,j}^{formation} \\ \vdots & \ddots & \vdots \\ y_{i,1}^{formation} & \cdots & y_{i,j}^{formation} \end{bmatrix}; \quad (26)$$

$$substitute = \begin{bmatrix} y_{1,1}^{substitute} & \cdots & y_{1,j}^{substitute} \\ \vdots & \ddots & \vdots \\ y_{i,1}^{substitute} & \cdots & y_{i,j}^{substitute} \end{bmatrix}. \quad (27)$$

Normally there will be a game per week, and each team i formation defined as $y_i^{formation}$ and the strength or power index is described by

$$\varphi(i) = \frac{f\left(y_i^{formation}\right)}{sum\ of\ fitness\ value\ in\ a\ week}; \quad (28)$$

$$sum\ of\ fitness\ value\ in\ a\ week = = \textstyle\sum_{i=1}^{n} f\left(y_i^{formation}\right). \quad (29)$$

When two teams j and l are playing a match with formations $y_i^{ацкьфешщт}$ and $y_l^{formation}$ then the power or strength index value of the teams will be calculated by

$$\varphi(j) = \frac{f\left(y_j^{formation}\right)}{sum\ of\ fitness\ value\ in\ a\ week}; \quad (30)$$

$$\varphi(l) = \frac{f\left(y_l^{formation}\right)}{sum\ of\ fitness\ value\ in\ a\ week}. \quad (31)$$

Probability for the team j winning the match:

$$probability(j, l) = \frac{\varphi(j)}{\varphi(j)+\varphi(l)}. \quad (32)$$

Probability of the Match between the teams l and j:

$$probability(j, l) + probability(l, j) = 1; \quad (33)$$

$$probability(l, j) = 1 - \frac{\varphi(j)}{\varphi(j)+\varphi(l)}. \quad (34)$$

Match between team i and l is given by:

```
Function match (i ,l)
Compute $\varphi(j)$ and
$sum\ of\ fitness\ value\ in\ a\ week$ by
$\varphi(i) = \frac{f\left(y_i^{formation}\right)}{sum\ of\ fitness\ value\ in\ a\ week}$
$sum\ of\ fitness\ value\ in\ a\ week =$
$\sum_{i=1}^{n} f\left(y_i^{formation}\right)$
If $probability(j, l) < r$
Then team "j" will be the winner and team "l" will
be loser
Otherwise
Team "l" will be the winner and team "j" will be
loser
End if
Apply the winning tactic for the winner
Apply the losing stratagem for the loser
End
```

Coaches are playing a lead role in giving effective input to the team. They share the knowledge and experience with players whenever needed. Also, coaches modify the tactics during the match towards the goal of winning, and it has been mathematically defined as

$$y_j^{formation}(t+1) = y_j^{formation}(t) + +random_1 \lambda^{formation}(upper\ bound_j - lower\ bound_j); \tag{35}$$

$$y_j^{substitute}(t+1) = y_j^{substitute}(t) + +random_1 \lambda^{substitute}(upper\ bound_j - lower\ bound_j). \tag{36}$$

How many numbers of ideas, game tactics are shared with the team is given by

$$Number_{idea\ sharing} = [Total\ positions(J)\delta_{idea\ sharing}]. \tag{37}$$

Ideas and tactics sharing procedure:

```
For k=1: $Number_{idea\ sharing}$
Choose arbitrarily a position
For J=1 ; j
Formation possessions of Position "j" modernization
is done through,
$y_j^{formation}(t+1) = y_j^{formation}(t) + random_1 \lambda^{formation}(upper\ bound_j - lower\ bound_j)$
Substitute possessions of Position "j" modernization
is done by,
$y_j^{substitute}(t+1) = y_j^{substitute}(t) + random_1 \lambda^{substitute}(upper\ bound_j - lower\ bound_j)$
End for
```

In team repositioning of the players in the game is a natural aspect. It will modify and consecutively elevate the procedure of the game in a specific match, and this process is mathematically defined by

$$Number_{repositioning} = [Total\ positions(J)\delta_{repositioning}]. \tag{38}$$

Sequentially after choosing two probable position *i* and *j* then two variables *C* and *D* with "2" modes of formation and substitute is given by:

$$C^{formation} = y_i^{formation}; \tag{39}$$

$$C^{substitute} = y_i^{substitute}; \tag{40}$$

$$D^{formation} = y_j^{formation}; \tag{41}$$

$$C^{substitute} = y_j^{substitute}. \tag{42}$$

Then

$$y_i^{formation} = D^{formation}; \tag{43}$$

$$y_i^{substitute} = D^{substitute}; \tag{44}$$

$$y_j^{formation} = C^{formation}; \tag{45}$$

$$y_j^{substitute} = C^{substitute}. \tag{46}$$

Repositioning procedure:

```
For k=1 to $Number_{repositioning}$
Positions i and j are arbitrarily chosen by
$C^{formation} = y_i^{formation}$ ; $C^{substitute} = y_i^{substitute}$
$D^{formation} = y_j^{formation}$ ; $C^{substitute} = y_j^{substitute}$
Position i and j are reversed by
$y_i^{formation} = D^{formation}$ ; $y_i^{substitute} = D^{substitute}$
$y_j^{formation} = C^{formation}$ ; $y_j^{substitute} = C^{substitute}$
End
```

During the game, there will be substitution in teams, and the number of substitutions is mathematically defined by

$$Number_{substitution} = = [random\ number\ .\ position\ (J)]. \tag{47}$$

Substitution procedure:

```
Compute the sum of substitution number by
$Number_{substitution} = [random\ number\ .\ position\ (J)]$
Describe the sets
For k=1 to $Number_{substitution}$
$y_{h(idea)}^{formation} = substitute(idea)$
$y_{h(idea)}^{substitute} = formation(idea)$
End
```

The winning team will determine the position within the exploration space, and it defined mathematically by including inertia weight *Ψ*:

$$y^{formation}(t+1) = y^{formation}(t) + +random_1.(\Psi^{formation})x \; x\left(y^{formation}(t)^* - y^{formation}(t)\right); \tag{48}$$

$$y^{\ substitute}(t+1) = y^{substitute}(t) + +random_1.(\Psi^{substitute})x \; x\left(y^{substitute}(t)^* - y^{substitute}(t)\right). \tag{49}$$

In any football team, the learning phase is significant, and it substantively progresses the performance of the game

$$\theta = d.b.random_1 - b; \tag{50}$$

$$v = d \cdot random_2; \tag{51}$$

$$b = \beta - current\ iteration\left(\frac{\beta}{\beta/maximum\ number\ of\ iteration}\right). \tag{52}$$

Then

$$y_j^m(t+1)_\Phi = \left(y_j^m(t)\right)_\Phi - \theta\left(\left|v\left(y_j^m(t)\right)_\Phi - \left(y_j^m(t)\right)\right|\right). \tag{53}$$

After few games, top teams in the rank table after few games, for example first “3” in the points table, will possess a good quality of learning. Since those three teams have virtuous strategy and amalgamation of players:

$$y_j^{formation}(t+1)_1 = \left(y_j^{formation}(t)\right)_1 - \\ -\theta\left(\left|v\left(y_j^{formation}(t)\right)_1 - \left(y_j^{formation}(t)\right)\right|\right); \tag{54}$$

$$y_j^{formation}(t+1)_2 = \left(y_j^{formation}(t)\right)_2 - \\ -\theta\left(\left|v\left(y_j^{formation}(t)\right)_2 - \left(y_j^{formation}(t)\right)\right|\right); \tag{55}$$

$$y_j^{formation}(t+1)_3 = \left(y_j^{formation}(t)\right)_3 - \\ -\theta\left(\left|v\left(y_j^{formation}(t)\right)_3 - \left(y_j^{formation}(t)\right)\right|\right). \tag{56}$$

With orientation to the most excellent team properties, the current solution modernization is done:

$$y_j^{substitute}(t+1)_1 = \left(y_j^{substitute}(t)\right)_1 - \\ -\theta\left(\left|v\left(y_j^{substitute}(t)\right)_1 - \left(y_j^{substitute}(t)\right)\right|\right); \tag{57}$$

$$y_j^{substitute}(t+1)_2 = \left(y_j^{substitute}(t)\right)_2 - \\ -\theta\left(\left|v\left(y_j^{substitute}(t)\right)_2 - \left(y_j^{substitute}(t)\right)\right|\right); \tag{58}$$

$$y_j^{substitute}(t+1)_3 = \left(y_j^{substitute}(t)\right)_3 - \\ -\theta\left(\left|v\left(y_j^{substitute}(t)\right)_3 - \left(y_j^{substitute}(t)\right)\right|\right); \tag{59}$$

$$y_j^{substitute}(t+1) = \\ = \frac{y_j^{substitute}(t+1)_1 + y_j^{substitute}(t+1)_2 + y_j^{substitute}(t+1)_3}{3}. \tag{60}$$

Usually, many players are getting transformed before the commencing of a particular season. This procedure is mathematically defined as follows:

$$number_{seasonal\ transfer} = [number\ \cdot percentage\ of\ teams \\ = partcipating\ in\ seasonal\ transfer]. \tag{61}$$

Seasonal transmit procedure:

```
For k=1 to $number_{seasonal\ transfer}$
$G = \{chose\ arbitrary\ index\ i\ from|i \neq h\}$
End for
For k=1 to $number_{seasonal\ transfer}$
For j=1 to J
r = random ()
if $r > 0.5$
$G_j^{formation}(idea) = o_j^{formation}$
$G_j^{substitute}(idea) = o_j^{subtitute}$
$o = chose\ randomly\ for\ the\ present\ teams$
End if
End for
$cost\ function\ (idea) = f(y^{formation}(idea))$
End for
```

With orientation to the performance in the matches, promotion and demotion of the teams will be there. Most excellently performed teams will be promoted to a senior division championship, and most poor performed teams will be demoted to top lower division league:

$$number_{teams\ movement} = \\ = total\ number\ of\ teams\ x \\ x\ \delta_{teams\ moved\ to\ another\ confederation}\ . \tag{62}$$

Promotion and demotion procedure:

```
Eliminate worst teams $number_{teams\ movement}$
Describe with formation and substitute
For k= 1 to $number_{teams\ movement}$
For j=1 to J
$number\ of\ team_j^{formation}(idea) = E_j^{formation}$
$number\ of\ team_j^{substitute}(idea) = E_j^{substitute}$
End for
$cost\ function\ (idea) =$
$f(number\ of\ teams^{formation}(idea))$
End for
Add number of teams to the confederation
```

Every football team has its private strategy; the formations of the team members are rendering to their prearranged tactics. Each Football team will analyze the conclusion of the Football match. The analysis will be based on strength, blemish, fortuitous, and stress, which unambiguously allies with inner strength and blemish with exterior aspects of fortuitous and stress. This investigation will be the basement for the progress of Football team performance in the play.

a. Begin.
b. Parameters are initialized.
c. Spot the most excellent team.
d. $number\ of\ season =$
   $= number\ of\ season + 1, i = 1$
e. Engender the Confederation timetable.
f. Match between team *C* and *D*.
g. Strength or power index computed for teams *C* and *D*.
h. The winner and loser are determined.
i. Applying different tactics.
j. Modernization of most excellent team.
k. The learning phase will be applied.
l. When the maximum number of weeks =
   = number of the week.
m. If yes, remove the top worst teams.
n. If no, go to step “e”.
o. Add a new team to the confederation.
p. Applying the transfer process.
q. Modernization of the best team.
r. The maximum number of seasons =
   = number of seasons.
s. If yes, determine the most excellent solution.
t. Otherwise, go to step “d”.
u. End.

3 Results and Discussion

In this work, the FCC algorithm has been applied to solve the problem. Real power loss reduction has been achieved. Competition and communication among the football teams have been imitated to design the algorithm. Previously many types of conventional algorithms have been applied to solve the problem. But many difficulties have occurred while handling the constraints. Then evolutionary algorithms are sequentially applied to the problem, and the primary point is that balancing the exploration and exploitation in the algorithm is the key to reach the nearby global optimal solution. But unfortunately, many evolutionary algorithms have been failed. In work, exploration and exploitation have been balanced. At first, the FCC algorithm is tested in the IEEE 30 bus system at Illinois Center for a Smarter Electric Grid, considering voltage stability index. Tables 1–4 show the comparisons with other standard algorithms. Figures 1–4 give a graphical comparison between the methodologies.

Table 1 – Comparison of real power loss with different metaheuristic algorithms

Parameter	DE [42]	GSA [41]	APOPSO [40]	FCC
Real Power Loss in MW	4.56	4.51	4.40	4.23
Voltage deviation in PU	1.96	0.88	1.05	1.04
L stability index	0.55	0.14	0.13	0.120

Table 2 – Comparison of different algorithms with reference to voltage stability improvement

Parameter	DE [42]	GSA [41]	APOPSO [40]	FCC
Real Power Loss in MW	6.48	6.91	5.70	5.42
Voltage deviation in PU	0.09	0.07	0.09	0.08
L stability index	0.14	0.13	0.14	0.13

Table 3 – Comparison with the reference to voltage deviation minimization

Parameter	DE [42]	GSA [41]	APOPSO [40]	FCC
Real Power Loss in MW	7.07	4.98	4.48	4.23
Voltage deviation in PU	1.42	0.22	1.86	1.82
L stability index	0.12	0.14	0.12	0.12

Table 4 – Comparison of values with reference to multi-objective formulation

Parameter	APOPSO [40]	FCC
Real Power Loss in MW	4.84	4.73
Voltage deviation in PU	1.01	1.00
L stability index	0.12	0.12

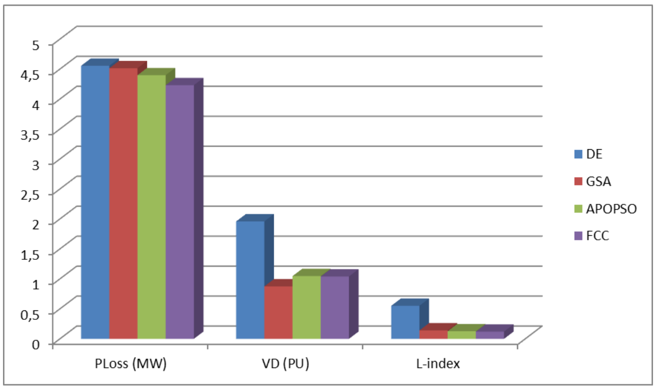

Figure 1 – Comparison of real power loss

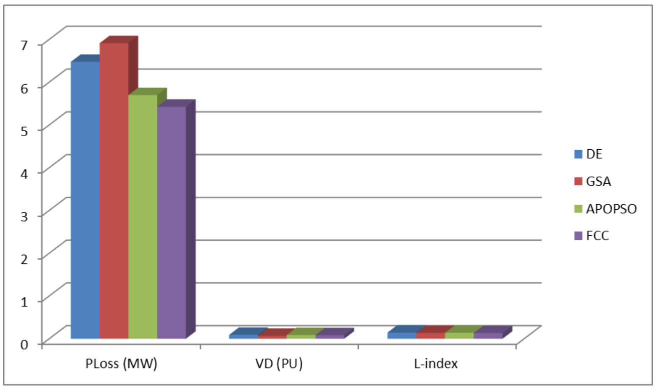

Figure 2 – Comparison with reference to voltage stability improvement

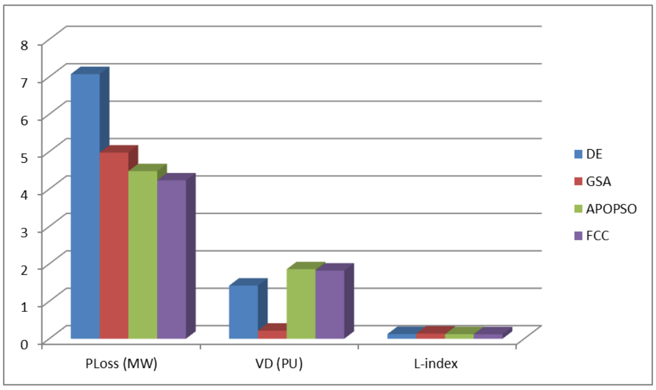

Figure 3 – Comparison with the reference to voltage deviation minimization

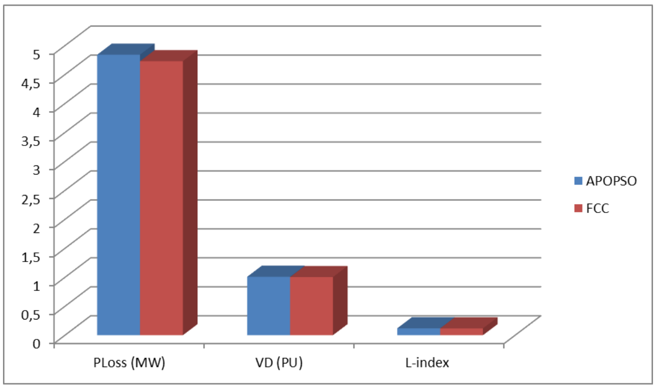

Figure 4 – Comparison with the reference to multi-objective formulation

Validity of the projected FCC algorithm has been tested without considering voltage stability index in standard IEEE 14, 30, 57, 118, and 300 bus systems. Tables 5–9 show the comparison of power loss. Figures 5–9 gives graphical comparison between the methodologies.

Table 5 – Comparison of parameters (IEEE 14 system)

Parameters	Base case [45]	MPSO [45]	PSO [44]	EP [43]	SARGA [43]	FCC
Percentage of reduction in power loss	0.00	9.20	9.10	1.50	2.50	23.69
Total power loss	13.55	12.29	12.32	13.35	13.22	10.34

Table 6 – Comparison of parameters (IEEE 30 system)

Parameters	Base case [45]	MPSO [45]	PSO [44]	EP [43]	SARGA [43]	FCC
Percentage of reduction in power loss	0.00	8.40	7.40	6.60	8.30	19.03
Total power loss	17.55	16.07	16.25	16.38	16.09	14.21

Table 7 – Comparison of parameters (IEEE 57 system)

Parameters	Base case [45]	MPSO [45]	PSO [44]	EP [43]	SARGA [43]	FCC
Percentage of reduction in power loss	0.00	15.40	14.10	9.20	11.60	26.57
Total power loss	27.80	23.51	23.86	25.24	24.56	20.41

Table 8 – Comparison of parameters (IEEE −118 system)

Parameters	Base case [45]	MPSO [45]	PSO [44]	EP [43]	SARGA [43]	FCC
Percentage of reduction in power loss	0.00	11.70	10.10	0.60	1.30	14.39
Total power loss	132.8	117.19	119.3	131.9	130.96	113.6

Table 9 – Comparison of real power loss (IEEE – 300 system)

Parameter	EGA [47]	EEA [47]	CSA [46]	FCC
Power loss	646.30	650.60	635.89	610.20

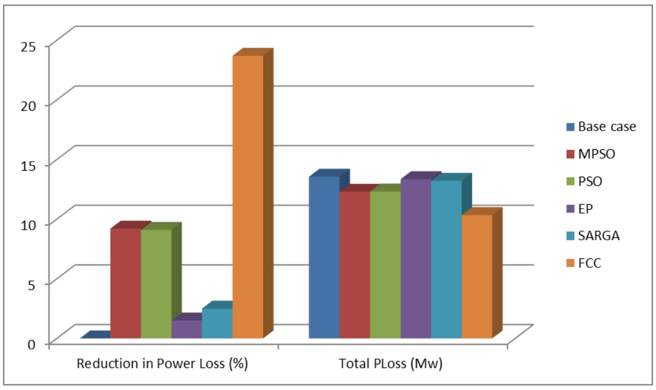

Figure 5 – Comparison of real power loss between methodologies (tested in IEEE 14 bus system)

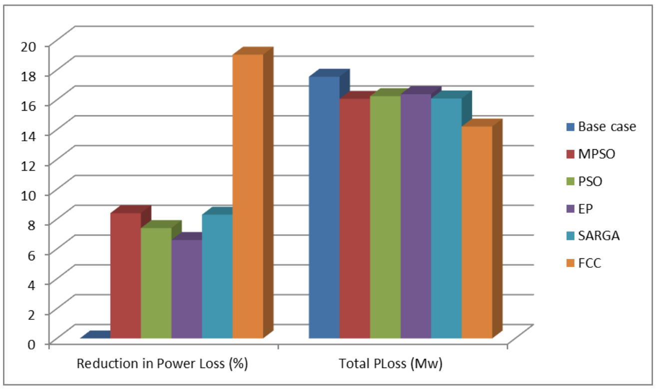

Figure 6 – Comparison of real power loss between methodologies (tested in IEEE 30 bus system)

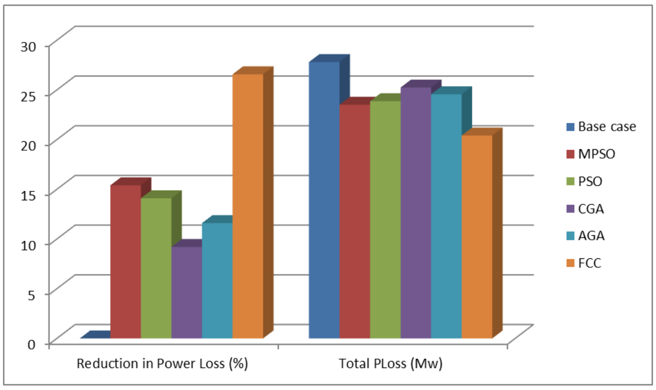

Figure 7 – Comparison of real power loss between methodologies (tested in IEEE 57 bus system)

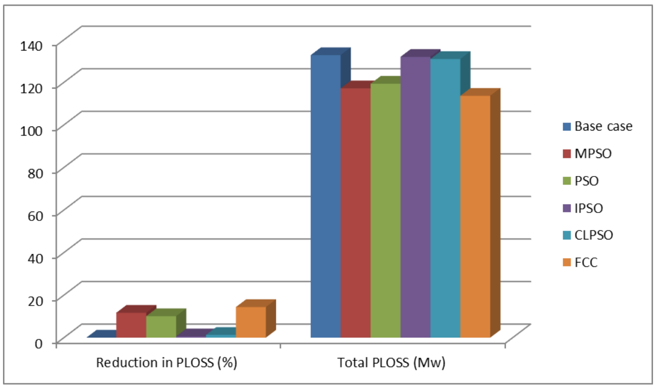

Figure 8 – Comparison of real power loss between methodologies (tested in IEEE 118 bus system)

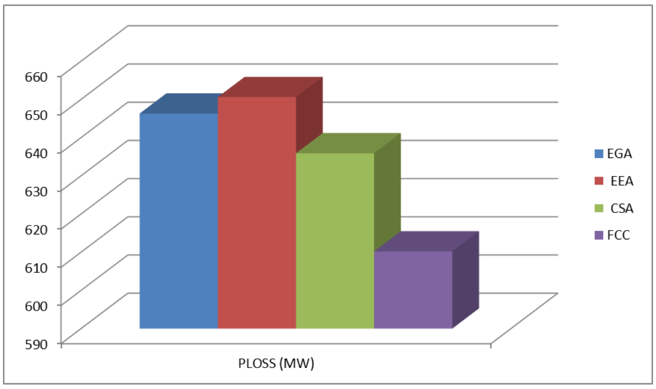

Figure 9 – Comparison of real power loss between methodologies (tested in IEEE 300 bus system)

4 Conclusions

In this work, the FCC algorithm successfully solved the optimal reactive power problem. Primary solution formation and initialization of the teams are based on the team's tactic. The winning team discovered the position through exploration space by including inertia weight Ψ. Primarily fitness function of the solution is computed to improve the process of finding the optimal solution. Key properties of the team have been successfully imitated to solve the problem. The transfer and modernization process improved the algorithm to find an excellent solution. The proposed FCC algorithm is tested in IEEE 30, bus system – real power loss minimization, voltage deviation minimization, and voltage stability index enhancement has been attained. Then with considering L-index alone Proposed FCC algorithm has been tested in standard IEEE 14, 57, 118, and 300 bus test systems. The percentage of power loss reduction has been enhanced when compared to other standard algorithms. Real power loss reduction has been attained effectively with voltage stability enhancement and minimization voltage deviation achieved.

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