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A Novel Algorithm For Generation Rescheduling Based Congestion Management

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ABSTRACT

The practitioners and researchers has received considerable attention solving complex optimization problems with metaheuristic algorithms during the past decade. Many of these algorithms are inspired by various phenomena of nature. One of the promising solutions for secure and continuous power flow in the transmission line is rescheduling based congestion management approach but the base problem is rescheduling cost.. To solve the congestion with minimized rescheduling cost , a new population based algorithm, the Lion Algorithm (LA), is introduced in this paper . The basic motivation for development of this optimization algorithm is based on special lifestyle of lions and their cooperation characteristics. Based on some benchmark Lion Algorithm (LA) is compared with the existing conventional algorithms such as Particle Swarm Optimization (PSO), Genetic Algorithm (GA), Artificial Bee Colony (ABC), and Firefly (FF) by analyzing the convergence, cost, and congestion. In IEEE 30 bus system experimental investigation is carried out and the obtained results by the proposed algorithm LA (Lion Algorithm) in comparison to the other algorithms used in this paper.

Keywords: Rescheduling; congestion management; Optimization algorithm; LA

I. INTRODUCTION

To solve complex problems[2] in research field nature-inspired computing [1] intends with uncertainty, only based on natural inspiration[3], imprecise and high conflicts, partially true. A nature-inspired computing [4] is bio-inspired computing, starts emerging from the day of nature's behavior is be executed for solving real life problems [5].

In all the emerging fields[8],[9] the application of the bio-inspired optimization algorithm are going to used. 1970 [6], [7] . Evolutionary algorithms and Swarm intelligence is two category of the bio-inspired optimization algorithm[10],[11]. A new search algorithm called as Lion's Algorithm(LA) is proposed based on social behavior in this paper . Strongest mammal in the world is Lion due to its unique social behavior. On the basis of the behavior the Lion's algorithm is formulated to search for optimal solution in a huge search space.

Based on lion's unique social behavior a novel optimization algorithm Lion Algorithm (LA) is introduce in this paper.. to solve a minimization problem a simple LA model was proposed [12] in this paper. Hence, the main contributions of the paper is as follows:

- Based on lion's social behavior introduce a new optimization algorithm.
- Expands the system problem as a Large scale global optimization problem.

- To solve large scale system problem we studies the performance competency o the algorithm.
- solve the objective model in such a way that, the congestion management is accomplished.
- *To* accomplish congestion management, adaptive searching behaviour and swarm intelligence are incorporated with LA.

The rest of the paper is organized as follows Section II gives literature review, Section III Inspiration, Section IV gives the model of rescheduling based congestion management, Section V gives the steps of the lion algorithm , Section VI gives the results and discussion and Section VII gives the references.

II. LITERATURE REVIEW

The features and challenges of the literature review are analysed. It reveals the significance of adopted stochastic search methodologies for congestion management in a deregulated electrical market. Those meta-heuristic methods include Firefly algorithm [13],[14], PSO[15],[16] , and ALO [17] algorithm. Although these aforementioned algorithms are applied for congestion management, it needs to adopt significant improvements to meet the challenges yet. Firefly algorithm is a reliable, secure and inexpensive algorithm, however, in some cases; it gets struck into local minima. Moreover, the parameters of the algorithm are independent of time and memory power is very low. Subsequently, PSO algorithm is highly utilized for reducing the cost of rescheduling of generators and it has the ability to handle the congestion management under small and large networks with less computational time, but the premature convergence is a leading issue under this algorithm. On the other hand, ALO requires only less number of fitness evaluations which provides effective convergence; however, it may cause complexity in solving discrete problems. Therefore, it is essential to maintain the congestion management in a deregulated electrical environment through the implementation of an effective optimization algorithm.

III. INSPIRATION

Lions are the most socially inclined species which display high levels of cooperation and antagonism [18] and strong sexual dimorphism in both social behavior and appearance. The lion has two types of social organization: residents and nomads. Pride [19] is a group of residents lion. Group of about five females, their cubs of both sexes, and one or more than one adult males is called Pride. Due to sexual maturity the young males are excluded from their birth pride. Nomads is the second types of organizational, who move either in pairs or singularly. A lion may switch their lifestyles; residents may become nomads and vice versa.[19].

Lions typically hunt together with other members of their pride. Coordinated group hunting brings a greater probability of success in lion hunts. The male lions and some of lionesses usually stay and rest while waiting for the hunter lionesses to return from the hunt. Lions do mate at any time of the year, and the females . A lioness may mate with multiple partners when she is in heat [20] . In nature, male and female lions mark their territory and else-where, which seems a good place with urine.

In this work in order to an optimization algorithm, some characters of lions are mathematically modeled. In this algorithm initial population, referring to as a specified size is formed by the lions. There are few lions other than the resident lion in this population which are turned as no made lions. Percentage of the prides members consist of the female and the rest are males while this male is nomade lion is vice versa.

A territory of the pride is define the best visited position of each member of pride in a pride the female are the once which go hunting and the males roams in the territories. The mating process happen between the females and the resident males of the pride. There are some young male which are excluded from the pride when on maturity becomes nomade and share lesser power than the resident males.

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The Nomade lion also has to move around in search of space randomly to find a better plane for themselves. Sometimes, there can be a case where overpowered by the nomad lions, the resident males are driven out of the pride, turning the nomad lions into resident lions. There are a few females lions who tend to immigrate from one pride to another, and also change their lifestyles to turn to be Nomads and vice versa in the course of evolution. The weak way die or be killed by another lion due to many other factors and rules of the nature.

IV. MODEL OF RESCHEDULING BASED CONGESTION MANAGEMENT

A. *Congestion Cost*

The cost of rescheduling is defined here as congestion cost as mentioned in eq. (1)

$$C_{total} = \sum_{j \in N_g} (C_j \Delta P_G^+(j) + D_j \Delta P_G^-(j))\$/n \quad (1)$$

where, C_{total} refers to the cumulative cost of modifying the active power output (\$/n), $C_j : j = 1,2,\ldots,N_g$ and D_j refer to price bids for incremental power and decremental power in \$/MWn by j^{th} GENCO, $\Delta P_G^+(j)$ and $\Delta P_G^-(j)$ are the active power increment of the generator(MW) and active power decrement of the generator(MW) respectively.

B. *Constraints:*

The minimization of rescheduling cost has to be formulated as constrained minimization function.

Consider $\Delta P_G : 0 \le j \le N_g$ (MW), where ΔP_G denotes the change in power generated by MW for a cost of $f(\Delta P_G)$ in \$ for G^{th} generation unit. The minimization function can be defined as

$$S^* = \underset{\Delta P_G \forall G}{\arg} \min \sum_{j=1}^{N_g} f\left(\Delta P_G(j)\right) \quad (3)$$

The constraints given below.

(i) Generation capacity constraint:

$$P_G^{\min} \le P_G \le P_G^{\max} \quad (4)$$

where, P_G refers to the quantity of active power that is generated in MW, $P_G^{\min}$ and $P_G^{\max}$ denotes the minimum and maximum quantity generated in MW.

(ii) Real power balance constraints:

$$\sum_{j=1}^{N_g} P_G - \left(P_{PD} + P_{TL}\right) = 0 \quad (5)$$

Where, P_{PD} and P_{TL} denote the power demand and transmission losses in MW.

(iii) Stability Limits:

The given sequential stability limits are the important criteria to define and ensure congestion mitigation.

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$$V_G^{\min} \le V_G \le V_G^{\max} \quad (6)$$

$$\partial_G^{\min} \le \partial_G \le \partial_G^{\max} \quad (7)$$

$$P_G^2 + Q_G^2 \le (S_G^{\max})^2 \quad (8)$$

In eq. (6) and (7), $\left(V_G^{\min}, V_G^{\max}\right)$ and $\left(\partial_G^{\min}, \partial_G^{\max}\right)$ are voltage and angle limits that define voltage stability from the generator. P_G^2, Q_G^2 denotes the power flow in MVA and $S_G^{\max}$ represents maximum power flow limit.

(iv) Ramp up limits:

For equal up and down rescheduling costs, the ramp limits can be defined as

$$\Delta P_G^{\min} \le \Delta P_G \le \Delta P_G^{\max} \quad (10)$$

where, $\Delta P_G^{\min}$ and $\Delta P_G^{\max}$ are changes in minimum and maximum quantity generated in MW.

C. Objective Model:

The cost of $f\left(\Delta P_g\right)$ for j^{th} generation unit is defined as the sum of cumulative cost for rescheduling and the violation level on the voltage of the respective transmission line. The cost function to define the rescheduling strategy is given below.

$$f\left(\Delta P_g\right) = C_{total} + P_{profile} C_{profile} + P_{constraints} C_{constraints} \quad (11)$$

Where, $P_{constraints}$ and $P_{profile}$ denote the penalty cost imposed on violating the constraints and voltage profile, respectively.

V. STEPS OF THE PROPOSED LION ALGORIHTM

In recent days, LA-based rescheduling strategy is a advanced optimization algorithm, which is based on social behaviour of lions, has become popular. Hence, this paper adopts LA to solve the objective model, as given in eq. (11) and so the congestion can be minimized.

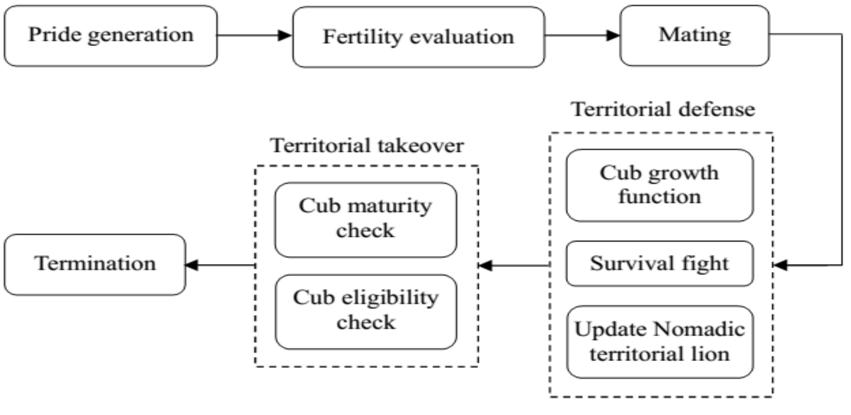

Fig 1. Steps of the Proposed LA for Rescheduling based Congestion Management

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The description of the steps of LA algorithm as illustrated in fig.2 is explained below.

1. Pride Generation
2. Fitness Evaluation
3. Fertility Evaluation
4. Mating
5. Territorial Defence

5a.Cub growth function

5b Survival fight

5c. Update Nomadic territorial lion

6. Territorial Take over

6a Cub maturity check

6b Cub eligibility Check

7. Termination

Step 1: Pride Generation: From existing ssolutions, some solution is derived which are known as Cubs and a solution to be determined is known as Lion.. There are two arbitrary solutions which are initiated from Pride one is male and other is female. For generating a unique solution pride generation is responsible.

Step 3: Evaluation of Fertility: First, the fitness of male lion, female lion and nomad lion are determined. The algorithm 1 shows the pseudo code of fertility evaluation. By inspecting the fertility of both lion and lioness, the convergence problem that arrived at the local optima is evaluated.

Step 4: Mating: Mating is generally process in which new best solutions is derived from the existing solutions. It includes crossover and mutation for deriving new solutions.

Step 5: Territorial Defence :

(a) Cub growth function: In this step, the generated cubs are allowed to random mutation with the mutation level. If the old cubs are lesser than the newly muted cub, then the old cubs are replaced by newly muted cubs.

(b) Territorial Defence: Territorial defence is the process in which we evaluating the existing solution and newly generated solution . Also in this process if new solution is better than existing solution we replacing existing solution by new solution The pseudo code of territorial defence is illustrated in algorithm 2.

Step 6: Territorial Takeover: The best male and female solutions which derived is known as territorial takeover.. The pseudo code of territorial takeover is shown in algorithm 3.

Step 7: Termination: Termination process is incurred only if the fitness evaluation count is beyond the limit. However, at the end of this process the optimal solution for the congestion management in rescheduling is provided by L^{male}

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ALGORITHM 1: PSEUDO CODE OF FERTILITY EVALUATION

Input: L^{male}, L^{female}, $f^{reference}$, S_t^{rate} and L_g^{rate}

Output: L^{male}, L^{female}, $f^{reference}$, S_t^{rate} and L_g^{rate}

// L^{male} Evaluation

If $f^{reference} \leq f\left(L^{male}\right)$

$L_g^{rate} \leftarrow L_g^{rate} + 1$

else

Reset L_g^{rate}

$f^{reference} \leftarrow f\left(L^{male}\right)$

End if

// L^{male} Evaluation

If S_t^{rate} is not adequate

Set u^{fc} and g^{fc} to zero

Do

Compute $L^{female+}$

$g^{fc} \leftarrow g^{fc} + 1$

If $f\left(L^{female+}\right) < f\left(L^{female}\right)$

$u^{fc} \leftarrow 1$

$L^{female} \leftarrow L^{female+}$

Reset S_t^{rate}

ALGORITHM 2: PSEUDO CODE OF TERRITORIAL DEFENCE

Obtain nomad coalition

Choose $L^{e-nomad}$

If $L^{e-nomad}$ wins

$L^{male} \leftarrow L^{e-nomad}$

Eliminate $L^{e-nomad}$ from the nomadic world

Kill L^{m-cub} and L^{f-cub}

Reset age(cubs)

Defence result $\leftarrow 1$

Else

Update nomad coalition

Defence result $\leftarrow 0$

End if

Till g^{fc} reaches $g_{\max}^{fc}$

End if

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ALGORITHM 3: PSEUDO CODE OF TERRITORIAL TAKEOVER.

Input: L^{male} L^{m-cub} L^{female} L^{f-cub} S_t^{rate}

If $f\left(L^{male}\right) > f\left(L^{m-cub}\right)$

$L^{male} = L^{m-cub}$

End if

$L^{old} = L^{female}$

If $f\left(L^{female}\right) > L^{f-cub}$

$L^{female} = L^{f-cub}$

If $L^{female} \neq L^{old}$

Clear S_t^{rate}

End if

TABLE –I Generation Limits And Cost Coefficents Of IEEE 14 Bus System

VII.RESULTS AND DISCUSSION

A. Experimental Setup

The implementation of proposed rescheduling based congestion management is developed in the working platform of MATLAB. The experimentation is carried out in IEEE benchmark test bus systems such as IEEE 14 bus system. The system consists of loads, capacitor banks, transmission lines, and generators. Here in IEEE 14 bus system, three GENCOs are connected. Accordingly, Table I show the generation limits and cost coefficients of the IEEE 14 bus system. Moreover, the performance of LA-based rescheduling strategy is compared with other conventional rescheduling techniques such as PSO-based rescheduling strategy, GA-based rescheduling strategy, ABC-based rescheduling strategy, and FF-based rescheduling strategy using convergence analysis, cost analysis, and congestion analysis.

B. Convergence Analysis

The convergence analysis of the proposed optimal congestion management technique and conventional techniques from various bus systems are shown in fig 2. The convergence of all the techniques is analysed by the ability to minimize the cost function in correspondence with the number of iterations. In the rescheduling process performed for IEEE 14 bus system, the rescheduling cost incurred by LA is extremely lesser than the conventional algorithms such as PSO, GA, ABC and FF. Initially, the cost function is found to be at peak level and as the number of iteration increases, the rescheduling cost incurred by LA gets minimized. Moreover, the rescheduling strategy with minimized cost is observed at the last iteration, i.e., 100th iteration. From the convergence analysis on IEEE Fourteen (IEEE-14) bus system, it is observed that the rescheduling cost minimization occurred by LA is 28% better than ABC and 35% better than the other conventional methods PSO, GA, and Firefly respectively.

As a result, it is concluded that the performance level of LA in rescheduling process is exceeding abundantly when compared with the existing congestion management techniques.

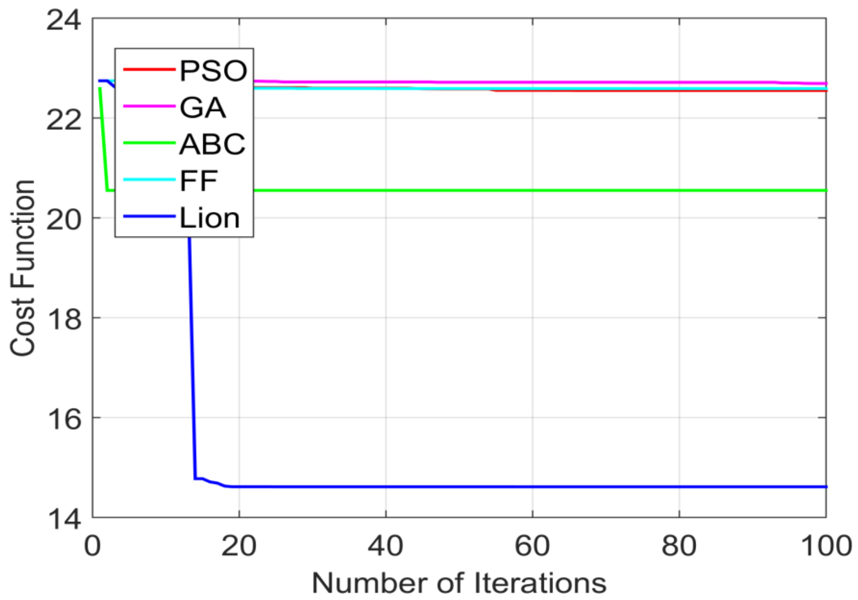

Fig 2 Demonstration of convergence analysis by PSO,GA,ABC,FF and Lion Algorithm LA from IEEE- 14 bus systems

C. StatisticaReport

Table II show the statistical reports on the minimized rescheduling cost obtained from LA-based rescheduling strategy and other conventional rescheduling algorithms. The statistical parameters include best case, worst case, mean performance, median performance and the standard deviation (also referred as Std in the Tabulations) between the mean and the individual performances. Table II show comparison of rescheduling cost reduction in percentage by LA With Conventional methods From IEEE 14 Bus System.

Methods	Best	Worst	Mean	Median	Std
PSO	14.627	22.586	20.972	22.551	3.547
GA	22.684	22.725	22.697	22.691	0.016719
ABC	20.541	20.587	20.555	20.55	0.018705
Firefly	20.544	22.605	21.372	20.564	1.1184
Lion	14.614	20.548	18.166	20.521	3.2412

Generator number	P_i^{min} (MW)	P_i^{max} (MW)	a_i (\$/MWhr)	b_i (\$/MWhr)	c_i (\$/hr)
1	10	160	0.005	2.450	105.00
2	20	80	0.005	3.510	44.100
3	20	50	0.005	3.890	40.600

TABLE-II Stastical Report On Rescheduling Cost Reduction By La With Convetional Methods From IEEE 14 Bus System

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Case Scenario	PSO Algorithm	GA Algorithm	ABC Algorithm	FF Algorithm
Best	LA is 85% better.	LA is 35% better.	LA is 28% better.	LA 28% is better.
Worst	LA is 90% better	LA is 95% better	LA is 18% better	LA is 90% better
Mean	LA is 13% better	LA is 19% better	LA is 11% better	LA is 15% better
Median	LA is 9% better	LA is 9% better	LA is 14% as LA	LA is 2% better
Std. Deviation	LA is 8% better	LA is 99% better	LA is 99% better	LA is 65% better

TABLE III Comparison of Rescheduling Cost Reduction in Percentage By LA With Conventional Method From IEEE 14 BuS System

All together we can finalize that the rescheduling cost minimization by LA-based rescheduling strategy is more effective when compared to the other conventional methods.

D. Cost Analysis

Table IV and Table V summarizes the congestion cost, compensation cost and final cost incurred by LA-based rescheduling strategy and other existing algorithms from IEEE 14 bus systems. On the basis of comparison, it is found that LA is better than GA, PSO & ABC Algorithms.

Methods	Congestion cost ($)	Compensation cost ($)	Final cost ($)
PSO	14.495	805.59	22.551
GA	14.48	821.06	22.691
ABC	9.3972	1115.3	20.55
FF	14.495	809.47	22.589
LA	2.5485	1206.5	14.614

TABLE IV. Cost Analysis Of Rescheduling Cost Incurred By La With Conventional Methods From IEEE 14 Bus System

Name of Algorithm	GA Based Rescheduling Strategy	GA Based Rescheduling Strategy	PSO Based Rescheduling Strategy	ABC Based Rescheduling Strategy
LA Algorithm	LA is 35% Better.	LA is 35% Better.	LA is 28% Better.	LA is 35% Better.

TABLE V. Comparison In Percentage of LA With Other Algorithm From IEEE 14 Bus System

E. Congestion Analysis

The congestion analysis of the proposed optimal congestion management technique and conventional techniques from two bus systems IEEE 14 bus system are shown in fig.3.

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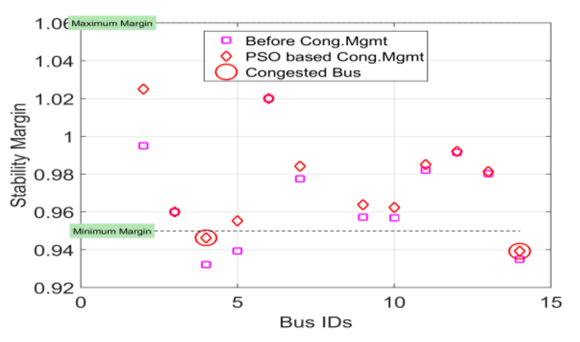
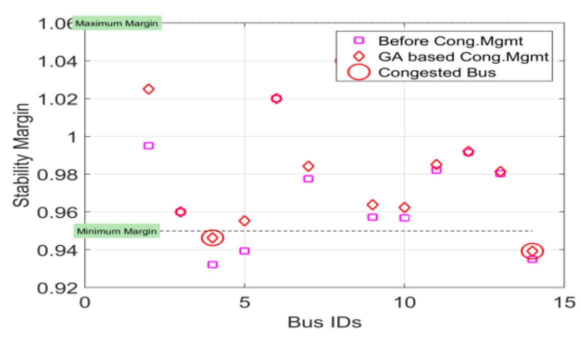
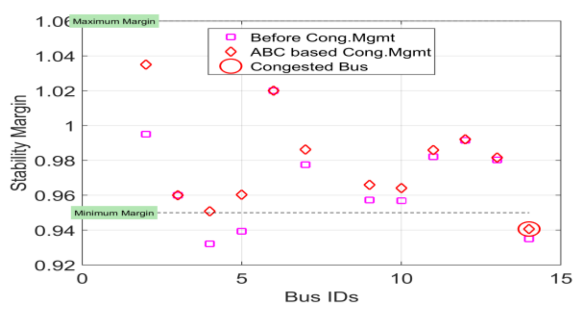
Fig. 3 Demonstration of congestion analysis by PSO,GA,ABC,FF and LA from IEEE bus systems (a),(b),(c),(d),(e) from



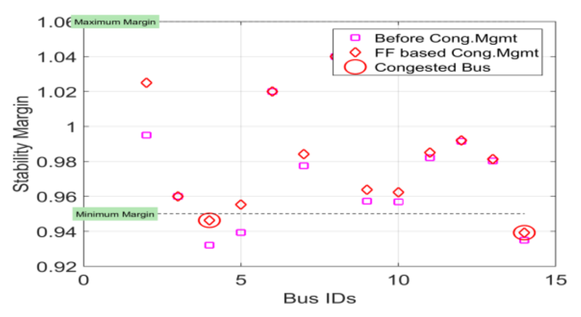
(a)



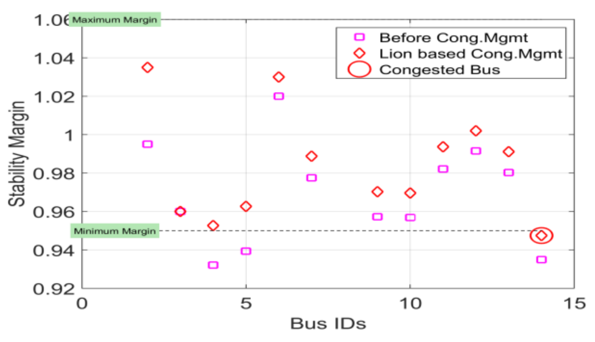
(b)



(c)



(d)



(e)

IEEE 14 bus system

Fig.3(a), fig.4(b), fig.4(c), fig.4(d) and fig.4(e) explains how the corresponding congestion management techniques performed from IEEE 14 bus system to minimize the congestion that occurred in buses. Initially, below the minimum margin, there are two congested buses and fig.(a), (b), (c), (d) represents the congestion management by PSO, GA, ABC, and FF, in such a way that congestion is recovered. However, it is not so effective when compared to congestion management technique LA as shown in fig. (e), LA makes a drastic change by which the congested buses are reduced from two to one. Here the efficiency of LA is higher than the other conventional methods. Thus we can say that LA leads the position in terms of performance while comparing with the other techniques.

VI. CONCLUSION

In recent years, generation rescheduling is the technique adopted to provide power system security and continuous power supply without congestion in the transmission line. However, rescheduling of the generator is

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one of the congestion management approaches, which also raises the challenge of minimizing the rescheduling cost. In the view of that, rescheduling cost was minimized in this paper by exploiting LA algorithm and, further the performance was compared with the conventional algorithms such as PSO, GA, ABC, and FF respectively. This comparison was substantiated by analysing the convergence, cost, and congestion mitigation of the entire algorithms. Thus, it is concluded that the performance of the LA-based rescheduling strategy is superior to the existing conventional methods by minimized rescheduling cost in computation.

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