International Journal of Emerging Technology in Computer Science & Electronics (IJETCSE)
ISSN: 0976-1353 Volume 24 Issue 2 – FEBRUARY 2017.

AMELIORATED BACTERIAL FORAGING ALGORITHM FOR CONGESTION MANAGEMENT IN COMPETITIVE MARKET

V.P. Sakthivel

Assistant Professor, Department of Electrical Engineering, Faculty of Engineering and Technology, Chidambaram – 608002, Tamilnadu, India

***Abstract* — The restructuring in electric power industry has prompted serious use of transmission lattices. In liberated power market, the power system works close to its evaluated limit as every major part in the market is attempting to pick up however much as could be expected by full use of existing resources. Blockage or congestion in at least one transmission lines may happen because of the absence of coordination among generation of power and transmission utilities or because of unforeseen possibilities, for example, blackouts in power generation, abrupt increment of load demand, or disappointment of gear. Hence, congestion management (CM) is one of the key elements of any independent system operator (ISO) in the rebuilt power industry.**

In this research work an Ameliorated Bacterial Foraging (ABF) optimization-based CM by optimal rearranging of power generation dependent on the generator sensitivity to the congested line. In ABF algorithm, the step size of each bacterium is made adaptive on the basis of objective functions of the current and best solutions. To attest the robustness and effectiveness of CM, the ABF algorithm is examined on IEEE 30-bus system. The results prove the latent and efficiency of the suggested ABF algorithm compared to the particle swarm optimization (PSO) and bacterial foraging (BF) approaches. The results obtained are very promising and confirm that the ABF algorithm is a very effective optimization technique for solving the CM problems.

Index Terms— Bacterial foraging algorithm, Congestion management, electricity market, generator rescheduling, sensitivity factor.

NOMENCLATURE

GS	Generator sensitivity to congested line
P_{ij}	Real power flow on the congested line k
P_g	Real power generated by generator k
ΔP_g	Real power adjustment at bus-g
$Cg(\Delta P_g)$	Incremental and decremental price bids
PF_k^0	Power flow caused by all contracts requesting transmission service
PF_k^{max}	Line flow limit of the line connecting bus-i and bus-j
N_G	Number of online generating units
N_g	Number of participating generators
N_l	Number of transmission lines in the system
P_g^{min} and P_g^{max}	Minimum and maximum limits of generator outputs
a_i, b_i, c_i	Cost coefficients
P_i	Real power output (MW) of ith generator
P_{Gi}	Real power injections at ith bus
Q_{Gi}	Reactive power injections at ith bus
P_{Di} & Q_{Di}	Load demands
$\lvert Y_{ij}\rvert$ & θ_{ij}	Magnitude and angle of bus admittance matrix
K	Line connected between buses i and j
G_k	Conductance
P_{Gi}^{min} and P_{Gi}^{max}	Lower and upper bounds for real power outputs of the ith generator unit
Q_{Gi}^{min} and Q_{Gi}^{max}	Lower and upper bounds for reactive power outputs of the ith generator unit
V_i^{min} and V_i^{max}	Lower and upper bounds of the voltages
NB	Number of buses
NV	Number of PV buses
NL	Number of lines
S_L^{max}	Line flow capacity of Lth transmission line
NC	Number of constraints
F(i, j, k, l)	Cost at the location of ith bacterium
Xi (j, k, l)	Location of the ith bacterium at jth chemotactic step, kth reproduction step and lth elimination-dispersal step
Xg	Global minimum bacteria from all the cost functions evaluated till that point

I. INTRODUCTION

A system is supposed to be congested when makers and customers of electric energy want to deliver and consume in sums that would make the transmission framework to work at or past at least one exchange limits. The primary assessment looked by the independent system operator (ISO) in a deregulated environment is to keep up the security and unwavering quality of the power system by boosting the market proficiency when the framework is clogged. The ISO, hence, needs to make a lot of straightforward and vigorous principles that ought not urge forceful entities to abuse clog to make market control and boost benefits at the expense of the market. Congestion in a transmission framework may not be permitted past a brief length since this could prompt falling blackouts with uncontrolled loss of burden.

There are a few techniques to ease congestion, for example, utilizing Flexible AC Transmission Systems (FACTS), tapping transformers, re-dispatching the generation, and abridging pool loads or potentially reciprocal agreements. In a deregulated environment, all the Generating Companies (GENCOs) and Distribution Companies (DISCOs) prepare their transactions in time. In any case, when of execution of exchanges, blockage may as of now be available in a portion of the transmission lines. Henceforth, ISO needs to ease the congestion with the goal that the system stays in a protected state.

A. *Power Market Transactions*

The different transactions in power market are as follows:

Pool transaction: Here the sellers (competitive generators) present their steady and decremental bidding costs in a constant adjusting market. These are then consolidated in the power flow problem to yield the incremental/decremental change in the generator outputs.

Bilateral transaction: Here every transaction contract includes a compensation price that the buyer-seller pair is willing to accept if its transaction is curtailed, without third party intervention.

Multilateral transaction: Here the buys and deals understanding between GENCOs and DISCOs are enhanced by outsiders, for example, representative or forward contractual workers.

B. *Market Entities in Deregulated Environment*

The restructuring of electricity market has changed the role of traditional entities of the vertically integrated utility and created new entities that can function independently. The market entities can be broadly classified into market participants and ISO.

C. *Market Participants*

GENCOs: GENCOs generate electricity and have the opportunity to sell the electricity to entities with which they have negotiated sales contracts. Generally, GENCOs consist of a group of generating units within a single company ownership structure with the sole objective of producing electrical power. In addition to active power, they may sell reactive power (ancillary services) and operating reserves.

Transmission Companies (TRANSCOs): It transports power utilizing a high voltage, mass transmission system from GENCOs to DISCOs/retailers for conveying power to shoppers. A TRANSCO has part of building, claiming, keeping up and working the transmission system in a specific geological locale to offer types of assistance for keeping up the general unwavering quality of the electrical power systems and gives open access of transmission wires to all market agencies in the system. The venture and working expenses of transmission offices are recouped utilizing access charges, which are normally paid by each client inside the region and transmission utilization charges dependent on line streams contributed by every client.

DISCOs: A DISCO disseminates the power, through its offices, to clients in a specific geological district. They purchase discount power either through the spot markets or through direct agreements with GENCOs and provide power to the end client. A DISCO is a directed utility that builds and keeps up conveyance wires associating the transmission lattice to the end client. A DISCO is liable for building and working its electric framework to keep up an ideal level of unwavering quality and accessibility.

ISO: The part of an ISO in a serious market is to encourage the total dispatch of the power which becomes contracted among the market players. Consequently, expanding market proficiency with prime significance towards keep up the security and dependability of line or network.

D. *CM Techniques*

ISO essentially utilizes two sorts of strategies to remove congestion. These are recorded underneath.

Cost free methods are classified as:

- Out-maturing of blocked lines,
- Functioning of transformer taps/ shifters, and
- Functioning of FACTS

Non-cost-free methods are classified as:

- Re-dispatching of generation in a way not quite the same as the regular settling purpose of the market. A few generators down, while others increment their output. Thus, generators at this point do not work at equivalent incremental expenses.
- Curtailment of burdens and the activity of (non-cost free) load interference choices.

E. *Literature Survey*

In a deregulated power system TRANSCOs, GENCOs and DISCOs are under differential organizations. A few utilities combine to shape a pool, with a focal representative set up, to co-ordinate the procedure on hour premise. In a pool market, GENCOs and DISCOs present the sell and buy choices as sell and purchase offers to the market administrator, who, thus, clears the market utilizing a suitable market-clearing methodology.

Vinod kumar et al. [1] clarified in detail the CM and felt that regulating the transmission framework so the move limits are watched. In a liberated environment, all the GENCOs and DISCOs prepare of time. However, when of execution of exchanges there might be congestion in a portion of the transmission lines. Thus, ISO needs to ease the clog so the system stays in secure state. Meena and Selvi [2] introduced an open transmission dispatch in which pool and respective/multi horizontal dispatches exist together and continued to build up a CM approach for this situation. Dutta et al. [3] introduced CM methods applied to different sorts of power markets. Kennady and Eberhart [4] explored widely the procedures of CM and concluded that the CM is one of the significant errands performed by ISOs to guarantee the activity of transmission framework within the limits. In the rising electric markets, the CM turns out to be critical and it can force a boundary to the power exchanging. Tooth and David [5] proposed an effective zonal CM approach utilizing real and reactive power rescheduling dependent on AC transmission congestion distribution factors addressing about the ideal distribution of reactive power. The effect of ideal rescheduling of generators and capacitors has been shown in CM.

Ashwani kumar et al. [6] depicted a planning procedure between power producing organizations and system administrator for CM utilizing Benders cuts. Lamont et al. [7] presented two methodologies for CMs because of voltage unsteadiness and thermal over-burden in a liberated environment. Hazra and Sinha [8] examined a consolidated casing work for service estimation and the CM while another methodology was employed to recognize the services of reactive help and real power misfortune for overseeing blockage utilizing the upper bound cost minimization.

Chen and Zhang [9] introduced the Particle Swarm Optimization (PSO) idea as far as its forerunners, quickly investigating the phases of its advancement from social reenactment to enhancer and examined the utilization of the approach to the neural network training. Shi et al. [10] introduced the PSO in five classifications viz. approaches, topology, parameters, modified PSO approaches and applications.

The hunt process of a PSO approach ought to be a cycle comprised of both constriction and extension so it could be able to escape from nearby minima, and inevitably discover adequate arrangements. Yamina and Shahidehpour [11] surveyed the PSO strategies and their applications to power system optimization issues. Snider et al. [12] developed the PSO for settling Optimal Power Flow (OPF) with which CM in pool market is basically executed on IEEE 30 Bus framework. Kumar and Srivastava [13] proposed cost proficient rescheduling of generation and additionally load shedding approach for CM in transmission lattices utilizing Chaotic PSO (CPSO) technique.

Fattahi and Ehsan [14] proposed a procedure for decreasing the quantity of partaking generators and ideal rescheduling of their yields while overseeing blockage in a pool at least rescheduling cost and investigated the capacity of PSO method in tackling the CM issue. An ideal solution for static CM utilizing PSO based OPF technique. Here, the blockage has been made in the transmission line by stacking the lines and it is soothed by putting a static synchronous series compensator in an ideal place in the transmission line. Masoud Esmaili et al. [15] developed an adjusted blenders strategy for understanding the CM in power markets. Dutta and Singh [16] exhibited the transformation of the PSO approach to tackle different kinds of economic dispatch (ED) issues in power systems viz. multi-region ED with tie line limits, ED with various fuel choices, consolidated economic and emission dispatch of generators with precluded working zones. The effectiveness of the PSO technique proved that it tends to be implemented to a wide range of optimization problems.

As of late, another evolutionary procedure, called bacterial searching (BF) has been developed [17]. In this algorithm, the scavenging (techniques for finding and ingesting food) conduct of E.Coli microbes present in human digestion tracts is emulated. They go through various stages, for example, chemotaxis, amassing, proliferation and end dispersal. At present, BF calculation has been effectively applied in different power system optimization problems. Sakthivel et al proposed a new ameliorated bacterial foraging (ABF) based approach to improve the convergences speed and the global searching ability of the BF algorithm [18].

F. *Contributions and Organization of the Paper*

The main contribution of research paper is to tackle the CM issue by ideal rescheduling of active power of the generators dependent on their sensitivities to the clogged line utilizing ABF approach and the results are compared with the PSO and BF approaches. The merit of this methodology of easing the clog in the blocked line is very proficient as it is a non-cost-free procedure. The suggested approach exhibits the adequacy of the proposed technique on the CM issue considering IEEE 30-bus system.

This paper is organized as follows: Section 2 details the problem formulation of optimal power flow (OPF) and congestion management by rescheduling the active power in participating generators. An insight into the ABF algorithm is explained in Section 3. Section 4 deals the methodology of implementation of the ABF algorithm for CM problems. The effectiveness of the proposed ABF algorithm on the IEEE 30 is illustrated in Section 5. Section 6 concludes the findings of the paper and provides suggestions for further research work in this area.

II. PROBLEM FORMULATION

A. *OPF Problem Formulation*

The economic activity of generating utilities is constantly liked in a power system. In the liberated market, the initial segment of the power dispatch issue is to discover the favored schedule utilizing OPF and the subsequent part is rescheduling the generation for eliminating the clog. The OPF issue is tied in with limiting the fuel cost of producing units for a particular time of operation in order to achieve ideal generation dispatch among the committed units and consequently fulfilling the load demand, generator activity imperatives and line stream limits.

The objective function is corresponding to the production cost can be approximated to be a quadratic function of the active power outputs from the generating units. Symbolically, it is represented as

$$\text{Minimize } F_t^{\cos t} = \sum_{i=1}^{N_G} f_i(P_i) \qquad (1)$$

where $f_i(P_i) = a_i p_i^2 + b_i p_i + c_i$

$i = 1,2,\ldots\ldots,N_G$ is the expression for cost function corresponding to ith generating unit and a_i, b_i and c_i are its cost coefficients. P_i is the real power output (MW) of ith generator. N_G is the number of online generating units. This obliged OPF issue is exposed to an assortment of limitations relying on reality ramifications. These incorporate power balance limitations to consider the energy balance; attainability of real and reactive power generation, voltage limits at load buses and line stream limits.

B. Power Balance Constraints

This limitation depends on the balance between all out generation and complete loads. That is given by set of non-straight power stream conditions as follows:

$$P_{G_i} - P_{D_i} - \sum_{j=0}^{n} |V_i||V_j||Y_{ij}|\cos(\theta_{ij} - \delta_i - \delta_j) = 0 \qquad (2)$$

$$Q_{G_i} - Q_{D_i} - \sum_{j=0}^{n} |V_i||V_j||Y_{ij}|\sin(\theta_{ij} - \delta_i - \delta_j) = 0 \qquad (3)$$

The real power loss in the system can be modeled a

$$P_{loss} = \sum_{k=1}^{N_l} g_k |V_i|^2 + |V_j|^2 - 2|V_i||V_j|\cos(\delta_i - \delta_j) \qquad (4)$$

C. Generator Constraints

The power output of each producing unit has a lower and upper bound with the goal that it lies in the middle of these limits. This imperative is indicated by a couple of imbalance requirements as follows:

$$P_{Gi}^{\min} \le P_{Gi} \le P_{Gi}^{\max} \qquad (5)$$

$$Q_{Gi}^{\min} \le Q_{Gi} \le Q_{Gi}^{\max} \qquad (6)$$

D. Voltage Limits

The voltage extents of every burden bus in the wake of leading the load stream reenactment ought to be checked between its limits. This voltage greatness is having its own lower and upper bound and numerically indicated by:

$$V_i^{\min} \le V_i \le V_i^{\max} \qquad (7)$$

E. Transmission Line Loadings

The line streams of all the transmission lines ought to be inside its line limit given by MVA ratings. This can be given as:

$$S_L \le S_L^{\max} \qquad (8)$$

F. OPF Constraints Handling

The equity and imbalance requirements of the power dispatch issue are considered in the objective work (J_{error}) itself by incorporating a penalty function.

$$PF_i = \begin{cases} K_i (U_i - U_i^{\lim})^2 & \text{If violated} \\ 0 \end{cases} \qquad (9)$$

Presently the last solution ought not contain any penalty for the imperative violation. In this way, the objective of the issue is the minimization of generation cost and penalty function because of any constraint violation as characterized by the accompanying condition.

$$J_{error} = F_t^{\cos t} + \sum_{l=0}^{nc} PF_i \qquad (10)$$

G. Determination of Generator Sensitivity Factor

The generators in the framework have various sensitivities to the power stream on the clogged line. A change in real power stream in a transmission line k related between ith bus and jth bus in view of progress in power generation by generator g can be named as generator sensitivity (GS) to obstructed line. Numerically, GS for line k can be composed as:

$$GS_g = \frac{\Delta P_{ij}}{\Delta P_g} \qquad (11)$$

H. Congestion Management Problem

It is prudent to choose the generators having non uniform and enormous extents of sensitivity esteems as the ones most sensitive to the power stream on the clogged line and to take an interest in CM by rescheduling their capacity yields. In light of the offers got from the generators, the amount of rescheduling required is figured to solve the accompanying streamlining problem.

$$C_c = \min \sum_{g}^{N_g} C_g(\Delta P_g)\Delta P_g \qquad (12)$$

Subject to

$$\sum_{g}^{N_g} ((GS_g \Delta P_g) + PF_k^0 \le PF_k^{\max} \qquad (13)$$

$$\Delta P_g^{\min} \le \Delta P_g \le \Delta P_g^{\max} \qquad (14)$$

$$\Delta P_g^{\min} = P_g - P_g^{\min} \qquad (15)$$

$$\Delta P_g^{\max} = P_g^{\max} - P_g \qquad (16)$$

$$\sum_{g=1}^{N_g} \Delta P_g = 0 \qquad (17)$$

Where ΔPg is the real power adjustment at bus-g and Cg (ΔPg) are the incremental and decremented price bids submitted by generators and these generators are willing to adjust their real power outputs. PF_k^0 is the power flow brought about by all agreements mentioning the transmission administration. $PF_k^{\max}$ is the line flow limit of the line joining the ith bus and jth bus. Ng is the number of participating generators, N_l is the number of transmission lines in the system, $P_g^{\min}$ and $P_g^{\max}$ denotes respectively the minimum and maximum limits of generator outputs. It can be seen that the power flow solutions are not required during the process of optimization.

III. ABF ALGORITHM

BFO is a newly introduced evolutionary optimization algorithm that mimics the foraging behavior of Escherichia coli (commonly referred to as *E. coli*) bacteria. BFO was first introduced by Passino [17]. There are successful applications of BFA in optimization problems, such as power system problems and electrical machine design problems [18].

BFO models the development of *E. coli* bacterium moves utilizing an example of two kinds of developments: tumbling and swimming. Tumbling alludes to an arbitrary alter in the path of drive, and swimming alludes to moving in an orderly fashion in a provided guidance. A bacterium in a nonpartisan medium shift back and forth among tumbling and swimming drives.

Assume it is wanted to look for the position X in a N-dimensional space. Assume X_i is the underlying situation of bacterium i in the exploration area, i = 1, 2, . . . S, where S is the quantity of microscopic organisms. Let F (X_i) speak to a goal work. Let F (X_i) < 0, F (X_i) = 0, and F (X_i) > 0 indicate to the bacterium at area X_i in supplement rich, impartial, and harmful conditions. Chemotaxis is a searching conduct that catches the cycle of enhancement, where microscopic organisms to move up the supplement focus slope. A chemotactic step size varying as the function of the current objective value provides better convergence behavior and solution quality as compared to a fixed step size. Hence, an adaptive approach for the step size for ith bacterium is used as:

$$C(i) = \frac{\left|F\left(X_i\right)\right|}{\left|F\left(X_i\right)\right| + \alpha} = \frac{1}{1 + \frac{\alpha}{\left|F\left(X_i\right)\right|}}$$

The bacterium i at location X_i makes a chemotactic stride j with the progression size C(i) and assesses alone for target work F (X_i) at every progression. On the off chance that at position X_i (j + 1), the target esteem F is in a way that is better than at location X_i (j), at that point another progression of same size C(i) in a similar course will be taken once more, if that progression brought about a situation with a superior incentive than at the past advance. This is alluded to as a swimming advance. Swimming is proceeded until for a most extreme number of steps N_s.

Algorithm 1 Pseudocode for ABF algorithm

```
Initialize S, N, Nc, Ns, Nre, Ned, ρed, dattract, hrepellant, ωattract, ωrepellant, Xmin and Xmax
Initialize Xi randomly for i = 1, 2, . . . , S
Initialize C(i) for i = 1, 2, . . . , S
Set the loops counters j, k and l to 0
//Elimination-Dispersal loop:
while l ≤ Ned do
  l = l + 1
  //Reproduction loop:
  while k ≤ Nre do
    k = k + 1
    //Chemotaxis loop:
    while j ≤ Nc do
      j = j + 1
      for each bacterium i = 1, 2, . . . S do
        Compute F(i, j, k, l)
        Let F (i, j, k, l) = F (i, j, k, l) + Fcc (Xg, Xi)
        Let Flast = F (i, j, k, l)
        //Tumble:
        Generate a N-dimensional random vector Δm (i), i = 1, 2, . . ., N on [-1, 1]
        //Move:
        Let Xi (j + 1, k, l) = Xi (j, k, l) + C(i) Δ(i) / sqrt(Δ^T(i) Δ(i))
        Compute F (i, j + 1, k, l) with Xi (j +1, k, l)
        //Swim:
        Let m = 0
        while m < Ns do
          Let m = m + 1
          if F (i, j + 1, k, l) < Flast then
            Let Flast = F (i, j + 1, k, l)
            Let Xi (j + 1, k, l) = Xi (j + 1, k, l) + C(i) Δ(i) / sqrt(Δ^T(i) Δ(i))
            Use this Xi (j +1, k, l) to compute new F (i, j + 1, k, l)
          else
            m = Ns
          end if
        end while
      end for
    end while
    Compute for each bacterium i, for given k and l
      F^i_health = Σ_{j=1}^{Nc+1} F(i, j, k, l)
    Eliminate Sr fraction of bacteria with highest Fhealth and split the other bacteria into two at their locations.
  end while
  For each bacterium, with probability ρed eliminate the bacterium and create a new one at a random
  position.
end while
```

After N_c chemotactic steps, a propagation step is taken in which the populace is arranged in climbing request of the target esteem F and least sound microscopic organisms are supplanted by the duplicates of the more beneficial microbes. After N_{re} generation steps, an end dispersal step is occupied. Here, a bacterium is wiped out and another bacterium is made at an irregular area in the hunt space with likelihood ρ_{ed}. The algorithm terminates after N_{ed} disposal dispersal steps.

Microorganisms make swarms by methods for cell-to-cell flagging by means of an attractant and a repellant. Cell-to-cell fascination for bacterium i is indicated to with F_{cc} (X_g, X_i), i = 1, 2, . . . S. This is characterized as:

$$F_{cc}(X_g, X_i) = \sum_{i=1}^{S}[d_{attract}\exp(-\omega_{attract}\sum_{n=1}^{N}(X_g - X_i)^2)] + \sum_{i=1}^{S}[h_{repellant}\exp(-\omega_{repellant}\sum_{n=1}^{N}(X_g - X_i)^2)]$$

The cell-to-cell signaling F_{cc} ( ) helps cells to move toward other cells, but not very close to them**.**

The detailed pseudocode for BFO algorithm is given in Algorithm 1.

IV. Application of Algorithm to CM Problem

The computational procedure for ABF algorithm-based CM problem is described hereunder:

Step 1: Read line parameters, upper and lower limits for active and reactive powers of the generators, voltage limits for the load buses and maximum line loading limits, active powers produced at the generator buses and active and reactive powers consumed at the load buses as determined by market clearing procedure.

Step 2: Input the ABF parameters, population size, and number of iterations and specify the lower and upper boundaries of the decision variables.

Step 3: Create congestion in the network intentionally. The line outages are occurred and load is incremented.

Step 4: Run load flow using Newton Raphson (NR) method where the generation, load and loss are satisfied according to the equality constraint Eqs. (2) and (3)

Step 5: Determine the excess power flow in line and bus voltage violation using the results of NR. And calculate the sensitivity of all the generators with respect to excess power flow in line and change in the output of the generators from the committed generator data that is already given.

Step 6: Determine the number of the generators participating in the process of rescheduling from the value of their sensitivity.

Step 7: Generate randomly the bacteria between the maximum and the minimum operating limits of the generators.

Step 8: Determine the minimum cost of rescheduling using the objective function Eq. (12) for each bacterium.

Step 9: Modify the positions of the generator values for all the bacteria using tumbling/swimming process.

Step 10: Perform reproduction and elimination-dispersal operation.

Step 11: The objective function values are calculated for the updated positions of the bacteria. If the stopping criteria are met, the position of bacterium corresponding to the minimal objective value is chosen as the optimal solution. Otherwise, the procedure is repeated from Step 9.

V. RESULTS AND DISCUSSIONS

The effectiveness of the ABF algorithm has been tested for IEEE-30 bus system as shown in Figure 1 and compared with PSO and BF approaches. The strategies are executed in MATLAB and the developed software code is executed on INTEL computer.

A. *Optimal Power Flow*

The favored generation schedule relating to the specific burden condition is offered by running the OPF to limit the fuel cost alone and is presented in Table 1. The generator yields aside from the slack bus generator are addressed as the variables for the OPF. The PSO, BF and ABF strategies are utilized to minimize the fuel cost. It is giving the least fuel cost esteems as 801.841 $/h by ABF strategy. The relating power generation is chosen as the favored schedule to satisfy the typical load demand.

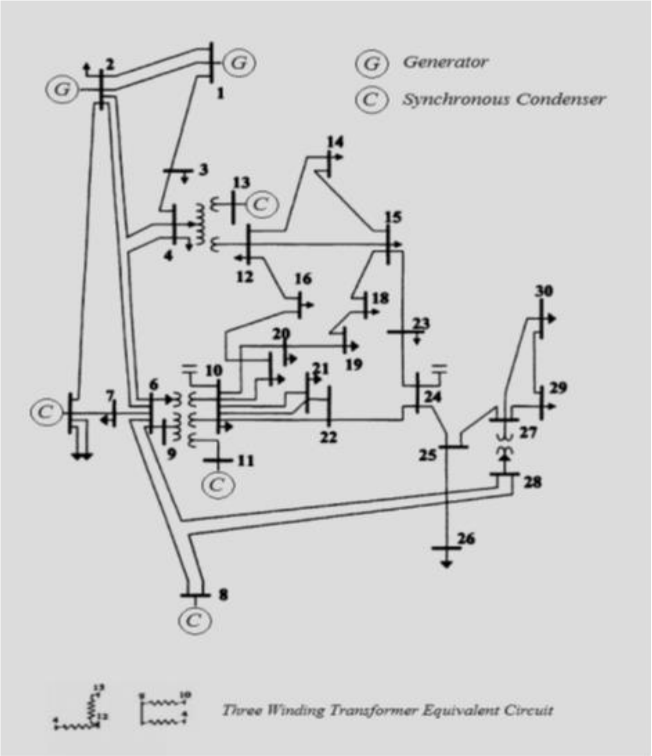

Fig. 1. One line diagram of standard IEEE-30 bus data

Table 1. Real power generation before CM

Generator Bus No.	Real power generation before CM (MW)		
	PSO	BF	ABF
1	176.93	176.46	176.48
2	48.72	48.96	48.98
5	21.44	21.94	21.62
8	21.60	21.72	21.69
11	12.10	12.10	12.10
13	12.0	12.0	12.0
Cost ($/h)	801.844	801.843	801.841

B. *Removal of Congestion*

The clog is made in the system by stacking at load Bus-14 and is happened in Line-26 associating Bus-10 and Bus-17. The real power stream of the Line-26 before and after the CM is given in Table 2 and appeared in Figure 2. The real power stream got in the clogged (line-26) is 7.01 MW. Nevertheless, the real power stream limit of the line is 6.99 MW.

Table 2. Line flow before and after CM

Branch power flow		Real power flow (MW) before CM	Real power flow (MW) after CM		
From bus	To bus		PSO	BF	ABF
10	17	7.01	6.93	6.94	6.76

Table 3. Real power generation after CM

Generator Bus No.	Real power generation after CM (MW)		
	PSO	BF	ABF
1	176.15	174.88	176.12
2	47.55	52.75	49.67
5	21.45	21.43	21.83
8	24.50	23.54	23.15
11	14.5	13.72	13.36
13	12.0	12.0	12.0
Best cost (Rs/MWh)	226.53	220.45	210.56

Worst cost (Rs/MWh)	290.11	255.23	218.64
Mean cost (Rs/MWh)	260.73	230.44	213.43

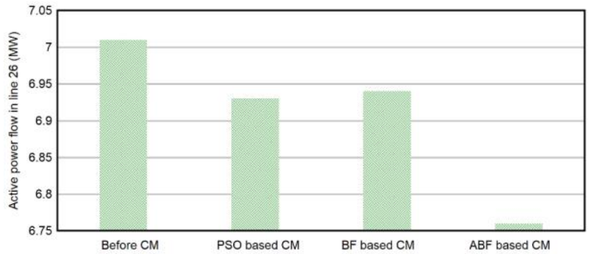

Fig. 2. Real power streams in Line 26

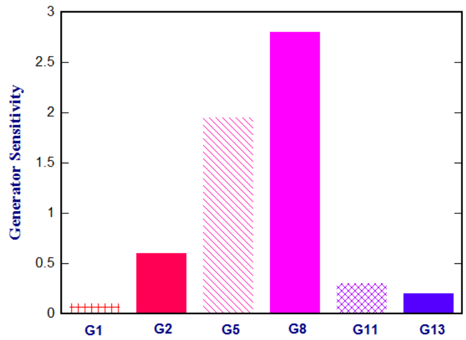

Fig. 3. GS factors of Line 26

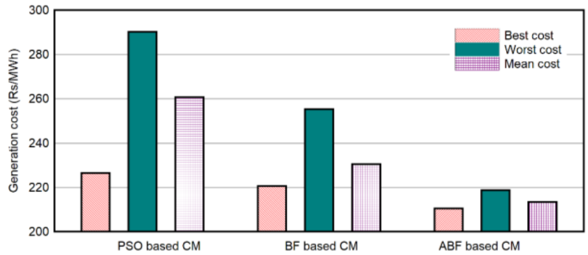

Fig. 4. Fuel cost acquired by different algorithms

The computed generator sensitivities for the congested Line-26 are shown in Figure 3. From the Figure it is noticed that all the generators are having strong influence on the congested line. The ABF strategy is utilized for finding the vital change in power generation to eliminate this clog on Line 26. The generation rescheduling by PSO, and ABF strategies are presented in Table 3. The 20 runs are made with both the strategies and the obtained fuel costs are introduced in a similar table.

Figure 4 shows the cost of congestion management obtained by PSO, BF and ABF algorithms. It is observed from Figure 4 that the ABF algorithm obtains minimum cost for rescheduling of active power of participating generators to alleviate congestion.

VI. CONCLUSIONS

In this work, an efficient and comparatively new algorithm named ameliorated bacterial foraging algorithm (ABF) is proposed to solve the congestion management (CM) problem. The CM issue has additionally been settled through ideal rescheduling of real powers of generators using PSO and BF strategies. The generators have been picked dependent on the generator affectability to the clogged line. The rescheduling has been completed by minimizing the fuel cost with the fulfillment of line stream limits. The results acquired by ABF strategy has been examined on the IEEE 30-bus and contrasted with the PSO and BF approaches. Simulation results demonstrate that the ABF algorithm has unrivaled highlights, preferences over different approaches considering less computational endeavors, robustness, stays away from untimely convergence, basic relevance and stable convergence behavior. In spite of the fact that, the proposed ABF approach is applied to solve the CM problems in the current research work, it appears from its exceptional quality that ABF algorithm can possibly to solve other power system optimization problems.

REFERENCES

[1] D.M. Vinod Kumar, and Ch. Venkaiah, “Swarm intelligence-based security constrained congestion management using SSSC,” in: Proceedings of APPEEC 2 2009.

[2] T. Meena, and K. Selvi, “Cluster based congestion management in deregulated electricity market using PSO,” in: Proceeding of IEEE Indicon Conference, December 11_13, 2005.

[3] S. Dutta, and S.P. Singh, “Optimal rescheduling of generators for congestion management based on particle swarm optimization,” IEEE Transactions on Power Systems 23 (4) (2008) 1560–1569.

[4] A. Kennedy and R. Eberhart, “Particle Swarm Optimization,” in Proc. IEEE Int. Conf. Neural Networks, Nov. 29–Dec. 1 1995, vol. IV, pp. 1942–1948.

[5] R.S. Fang, and A.K. David,” Transmission congestion management in an electricity market,” IEEE Transactions on Power Systems 14 (3) (1999) 877–883.

[6] Ashwani Kumar, S.C. Srivastava, and S.N. Singh, “A zonal congestion management approach using real and reactive power rescheduling,” IEEE Transactions on Power Systems 19 (1) (2004) 554–562.

[7] J. Fu, and J.W. Lamont, “A combined framework for service identification and congestion management,” IEEE Transactions on Power Systems 6 (1) (2001) 56–61.

[8] J. Hazra, and A.K. Sinha, “Congestion management using multi objective particle swarm optimization,” IEEE Transactions on Power Systems 22 (4) (2007) 1726– 1734.

[9] Z.X. Chen, L.Z. Zhang, and J. Shu, “Congestion management based on particle swarm optimization,” in: Proceedings of IEEE The 7th International Power Engineering Conference 2005, 2, 2005, pp. 1019–1023.

[10] Y. Shi, “Particle swarm optimization,” in: IEEE Neural Networks Society, 2004, pp. 8–13.

[11] H.Y. Yamina, and S.M. Shahidehpour, “Congestion management coordination in the deregulated power market,” Electric Power Systems Research 65 (2003)119–127.

[12] K.L. Lo, Y.S. Yuen, and L.A. Snider, “Congestion management in deregulated electricity markets,” in: IEEE International Conference on Electric Utility Deregulation and Restructuring and Power Technologies 2000, 2000, pp. 47–52.

[13] A. Kumar, S.C. Srivastava, and SN. Singh, "A zonal congestion management approach using real and reactive power rescheduling," IEEE Trans Power System 2004; 19(1):554–62.
[14] A. Fattahi, and M. Ehsan, "Sensitivity based redispatching method for congestion management in a pool model," IJ Emerging Electr Power System 2005; 3(2):1–22 [Article no. 1077].
[15] Masoud Esmaili, Fatemeh Ebadi, Heidar Ali Shayanfar, and Shahram Jadid, Congestion management in hybrid power markets using modified Benders
[16] Decomposition," Applied Energy 102 (2013) 1004–1012. S.
[17] Dutta, and SP. Singh, "Optimal rescheduling of generators for congestion management based on particle swarm optimization," IEEE Trans Power System 2008; 23(4):1560–9.
[18] K.M. Passino, "Biomimicry of bacterial foraging for distributed optimization and control", IEEE Control Systems Magazine, Vol. 22 No. 3, pp. 52-67, 2002.
[19] V.P Sakthivel, R. Bhuvaneswari, and S. Subramanian, "Design optimization of three-phase energy efficient induction motor using adaptive bacterial foraging algorithm", COMPEL: International Journal of Computation and Mathematics in Electrical and Electronics Engineering, Vol. 29 No. 3, pp. 699-726, 2010.