Optimal Control Scheme for Non-Quadratic Performance Based on DHP Algorithm in Neural Networks

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Abstract

In this paper, an efficient method has been proposed for transmission line over load alleviation in deregulated power system.Here the generators are selected based on their sensitivity to the congested line and the active power of the participating generators are rescheduled using the bacterial foraging algorithm along with fuzzy for relieving congestion. The algorithm is tested in IEEE 30-bus system and compared with the simple bacterial foraging and particle swarm optimization for its effectiveness and robustness in congestion management. It is observed that the bacterial foraging algorithm (BFA) with fuzzy minimizes the cost effectively when compared to the simple bacterial foraging (SBF) and particle swarm optimization (PSO).

Keywords—*Congestion management, Deregulated market, SBF, PSO, Generator Sensitivity,Constraints*

I. INTRODUCTION

Bacteria Foraging Optimization Algorithm (BFOA), proposed by Passino [16], is a new comer to thefamily of nature-inspired optimization algorithms.Incompetitive markets, electricity price is regulated based on proposals offered by all market participant,thesemarkets provide the possibility of exchanging energy between various participants. Electricity is a commodity withspecial features which should be considered when making laws. For example, it is difficult to save, in any case ithas losses when transmitting and controlling the electricity flow requires using expensive equipment. Congestion is defined as the overloading of one or more transmission lines and/or transformers in the powersystem. In the deregulated electricity market, congestionoccurs when the transmission system is unable toaccommodate all of their desired transactions due to violationof MVA limits of transmission lines. In such market, most ofthe time, the transmission lines operate near to their stabilitylimits as all market players try to maximize their profits fromvarious transactions by fully utilizing transmission systems.

R.D. Christie et al. [1] explained in detail the congestion managementand felt that controlling the transmission system so thattransfer limits are observed is perhaps the fundamental transmissionmanagement problem. In order to relieve congestion, one caneither use FACTS devices [2], operate taps of a transformer, redispatchof generation [3] and curtailment of pool loads and/orbilateral contracts. In a deregulated environment, all the GENCOsand DISCOs plan their transactions ahead of time. But by the time ofimplementation of transactions there may be congestion in some ofthe transmission lines. Hence, ISO has to relieve the congestion sothat the system remains in secure state. ISO use mainly two typesof techniques to relieve congestion and they are as follows:

i) Cost free means:

a. Out-aging of congested lines.

b. Operation of transformer taps/phase shifters.

c. Operation of FACTS [2] devices particularly series devices.

ii) Non-cost free means:

a. Re-dispatch of generation [3] in a manner different from the natural settling point of the market. Some generators backdown while others increase their output. The effect of this isthat generators no longer operate at equal incremental costs.

b. Curtailment of loads and the exercise of (non-cost-free) loadinterruption options.

R.S. Fang et al. [4] considered an open transmission dispatchenvironment in which pool and bilateral/multilateral dispatchescoexist and proceeded to develop a congestion management strategyfor this scenario. K.L. Lo et al. [5] presented congestionmanagement techniques applied to various kinds of electricity markets.Ashwani Kumar et al. [6] reviewed extensively the literaturefor reporting several techniques of congestion management andinformed that the congestion management is one of the majortasks performed by Independent System Operators (ISOs) to ensurethe operation of transmission system within operating limits. Inthe emerging electric power markets, the congestion managementbecomes extremely important and it can impose a barrier to theelectricity trading. Ashwani Kumar et al. [7] proposed an efficientzonal congestion management approach using real and reactivepower rescheduling based on AC Transmission Congestion Distributionfactors considering optimal allocation of reactive powerresources. The impact ofoptimal rescheduling of generators andcapacitors has been demonstrated in congestion management. H.Y.Yamina and Shahidehpour [8] described a coordinating mechanismbetween generating companies and system operator for congestionmanagement using Benders cuts. F. Capitanescu and Van Cutsem [9]proposed two approaches for a unified management of congestionsdue to voltage instability and thermal overload in a deregulatedenvironment. J. Fu and Lamont [10] discussed a combined framework for service identification and congestion management while anew approach were applied to identify the services of reactive supportand real power loss for managing congestion using the upperbound cost minimization.

J. Kennedy and Eberhart [11] described the Particle Swarm Optimization(PSO) concept in terms of its precursors, briefly reviewingthe stages of its development from social simulation to optimizerand discussed application of the algorithm to the training of artificialneural network weights. Y. Shi [12] surveyed the research and development of PSO in five categories viz. algorithms, topology,parameters, hybrid PSO algorithms and applications. In general, thesearch process of a PSO algorithm should be a process consisted ofboth contraction and expansion so that it could have the ability toescape from local minima, and eventually find good enough solutions.

Y. Del Valle et al. [13] presented a detailed review of the PSO technique, the basic concepts and different structures and variants,as well as its applications to power system optimization problems.Z.X. Chen et al. [14] introduced PSO for solving Optimal PowerFlow (OPF) with which congestion management in pool market ispractically implemented on IEEE 30 Bus system and proved thatcongestion relief using PSO is effective in comparison with InteriorPoint Method and Genetic Algorithm approach. J. Hazra and Sinha[15] proposed cost efficient generation rescheduling and/or loadshedding approach for congestion management in transmissiongrids using Multi Objective Particle Swarm Optimization (MOPSO)method. K.M. Passino [16] explained in detail the biology and physics underlying the chemotactic (foraging) behaviour of Escherichia colibacteria that formulated Simple Bacterial Foraging (SBF) OptimizationAlgorithm for optimization process represented by the activityof social bacterial foraging. The algorithm presented in [16] hasbeen utilized in this paper for optimal generation of active power of the participating generator.

Fuzzy logic rules is created using fuzzy toolbox of MATLAB to fuzzify the run length vector C(i) for optimal value which is incorporated in the SBF algorithm.Janardan Nanda et al. [17] made a maiden attempt to examine andhighlight the effective application of Bacterial Foraging algorithmto optimize several important parameters in Multiarea AutomaticGeneration Control (AGC) of a thermal system and compared itsperformance to establish its superiority over Genetic Algorithm(GA) & classical methods.H. Vahedi et al. [18] proposed a novel Mixed Integer SBF algorithm for solving constrainedOPF problem for practical applications. Results show thatthe Mixed Integer SBF algorithm is superior to PSO based algorithmin terms of solution quality, convergence rate and evolutionarycomputing time.

It isobserved that researchers have not attempted so far to dynamicallyadjust the run length vector of the SBF algorithm for optimalrescheduling of the active powers of the participating generators byapplying fuzzy criterion to relieve congestion in the congested line.Further, no attempt has been made so far to employ SBF for optimalrescheduling of active power of the select participating generators to relieve congestion in the congested line. To incorporate the innovativenessinto congestion management, a new method of BFA with fuzzy is attempted for the first time to relieve congestion in the congestedline by optimal rescheduling of active powers of the selectparticipating generators.Instead of selecting all the generators to relieve congestion, inthis paper it is proposed to select only those generators which arevery sensitive for relieving congestion in transmission lines. Thisis done by the selection of participating generators using generatorsensitivities to the power flow on congested lines. Further, itis proposed to solve congestion management problem by optimalrescheduling of active power of participating generators employing the BFA with fuzzy. Subsequently, the BFA with fuzzy is compared with SBF and conventional PSO algorithmsto determine the best optimal solution for rescheduling the activepower of participating generators to relieve the congestion.

In this paper static congestion management by optimal reschedulingof active power of the generators selected based ontheir sensitivities to the congested line is attempted by BFA with fuzzy for thefirst time and compared the test results with SBF and conventionalPSO. The main advantage of this approach of relieving congestionin the congested line is quite efficient as it is a non-cost free meanstechnique. This paper illustrates the effectiveness of the proposedmethod on the congestion management problem considering IEEE30-bus system.

II. CONGESTION MANAGEMENT METHOD

Congestion is defined as the overloading of one ormore transmission lines and/or transformers in the powersystem. In the deregulated electricity market, congestionoccurs when the transmission system is unable toaccommodate all of their desired transactions due to violationof MVA limits of transmission lines.

Congestion may lead to rise in cost of electricity, tripping of overloaded lines andconsequential tripping of other healthy lines. It may alsocreate voltage stability related problems. It should be relievedto maintain power system stability and security, failing whichresults into system blackout with heavy loss of revenue.Various factors and phenomena cause congestion on transmission lines that inherent limitations of transmission network can be pointed as one of them which are divided into two major categories:

1. Physical limitations
2. System limitations

Thermal limitation of a transmission line or a transformer is among physical limitations of transmissionnetwork. Voltage limitation in a node, transient stability, dynamic stability, reliability and similar cases are alsoexamples of system limitations of transmission network. Given the above limitations, many factors can be effectivein the occurrence of congestion on transmission lines, such as energy consumption increase in point in thenetwork, concurrent use of electrical appliances during peak hours and non-coordinated exchanges. Also thedeparture of a number of transmission lines or power generation units in a point in the network due to error orrepairs makes more loading of network healthy lines and congestion on these lines.Hence, ISO has to relieve the congestion so that the system remains in a secure state. ISO mainly uses two types of techniques to relieve congestion. These are listed below.

i) Cost free means

a. Out-aging of congested lines

b. Operation of transformer taps/phase shifters

c. Operation of FACTS [2] devices, particularly series devices

ii) Non-Cost free means

a. Re-dispatching power generation [3] in a manner different from the natural settling point of the market. Some generators back down, while others increase their output. Consequently, generators no longer operate at equal incremental costs.

b. Curtailment of loads and the exercise of (non-cost free) load interruption options.

III. BACTERIAL FORAGING WITH FUZZY METHOD

Bacterial foraging algorithm for optimization has been widely accepted as a global optimizationalgorithm of current interest for distributed optimization and control. Bacterial Foraging Algorithm is inspired by the social foragingbehaviour of Escherichia coli. This algorithm has already drawn the attention of researchers because of its efficiency insolving real-world optimization problems arising in several application domains.

In a natural evolutionary process the survival of the species depends upon the fitness criteria that is based on the food searching ability and the motile behaviour. The species with better food searching ability tends to move on to the next generation and the species with the poor search ability gets eliminated or gets reshaped to transform into a strong species. The E. coli bacteria is generally present in human intestine tends to perform four processes, they are Chemotaxis, Swarming, Reproduction and Elimination-Dispersal event.

Chemotaxis:The characteristics of movement of bacteria in search of food can be defined in two ways, i.e. swimming and tumblingtogether known as chemotaxis. A bacterium is said to beswimming if it moves in a predefined direction, and tumbling ifmoving in an altogether different direction. Mathematically, tumbleof any bacterium can be represented by a unit length of randomdirection Δ (i) multiplied by a step length of that bacterium C(i). Incase of swimming this random length is predefined.

There is a scope to fuzzify the variable C(i) for arriving at the optimum value of the step size for the given problem in less time.Initially the run length vector C(i) value is selected by random selectionand it plays an important role in the convergence of SBF algorithm. A small value of C(i) causes slow convergence, whereasa large value may fail to locate the minima by swimming throughthem without stopping. The selection of C(i) is tedious and timeconsuming in SBF. Hence, fuzzy adaptive scheme is utilized to C(i)for ensuring the convergence of SBF algorithm. Here, the fuzzyinput variables are taken as C(i) and the error from the objectivefunction to obtain the fuzzy output as ΔC(i) for optimal value. The fuzzy toolbox of MATLAB package on Windows environmentis employed to fuzzify the run length vector C(i) and the procedureto create fuzzy logic rules using fuzzy logic toolbox is detailed inAppendix A.

Swarming: For the bacteria to reach at the richest food location(i.e. for the algorithm to converge at the solution point), it is desiredthat the optimum bacterium till a point of time in the search periodshould try to attract other bacteria so that together they convergeat the solution point more rapidly. To achieve this, a penalty functionbased upon the relative distances of each bacterium from thefittest bacterium till that search duration, is added to the originalcost function. Finally, when all the bacteria have merged into thesolution point this penalty function becomes zero. The effect ofswarming is to make the bacteria congregate into groups and moveas concentric patterns with high bacterial density.

Reproduction: The original set of bacteria, after getting evolvedthrough several chemotactic stages reach the reproduction stage.Here, the best set of bacteria (chosen out of all the chemotacticstages) gets divided into two groups. The healthier half replaces theother half of bacteria, which gets eliminated, owing to their poorerforaging abilities. This makes the population of bacteria constantin the evolution process. The survival and elimination behaviour ofany bacterium is better known as its motile behaviour.

Elimination and dispersal: In the evolution process a suddenunforeseen event can occur, which may drastically alter the smoothprocess of evolution and cause the elimination of the set of bacteriaand/or disperse them to a new environment. Most ironically,instead of disturbing the usual chemotactic growth of the set ofbacteria, this unknown event may place a newer set of bacterianearer to the food location. From a broad perspective, eliminationand dispersal are parts of the population level long distance motilebehaviour. In its application to optimization it helps in reducing the behaviour of stagnation (i.e. being trapped in a premature solutionpoint or local optima) often seen in such parallel search algorithms.

Bacterial Foraging Algorithmwith Fuzzy for congestion management by optimal rescheduling of generators is as described below:

STEP 1: Initialize parameters $S, N_S, N_C, N_{re}, N_{ed}, P_{ed}, C(i)(i=1,2,\ldots,S), \theta^i$.

STEP 2: Elimination-dispersal loop: l = l + 1.

STEP 3: Reproduction loop: k = k + 1.

STEP 4: Chemotaxis loop: j = j + 1.

a) For i=1,2,..,S to take a chemotactic step for bacterium i

b) Compute fitness function J_{error} (i,j,k,l)

J_{error} (i,j,k,l)=J_{error} (i,j,k,l)+J_{cc} (θ^i(j, k, l),P(i,j,l))

c) J_{last} = J_{error} (i,j,k,l) to save this to find a better cost.

d) Tumble:

Generate a random vector $\Delta(i) \in R^p$ with each element Δ_m(i), where

m = 1,2, . . ., p, a random number on [−1,1].

e)move:θ^i(j+1,k,l)=θ^i(j, k, l)+C(i)($\Delta(i)/\sqrt{\Delta^T(i)\Delta(i)}$) ,step size C(i) for bacterium i.. Fuzzify the variable C(i) using MATLAB Fuzzy toolbox .

f) Compute J_{error} (i,j+1,k,l)

J_{error}(i,j+1,k,l)=J_{error}(i,j+1,k,l)+J_{cc}(θ^i(j + 1, k, l),P(j+1,k,l))

g) Swim

1. m=0 represents counter for swim length

2. While m<Ns , m=m+1,If J_{error} (i,j+1,k,l) < J_{last}, if doing better

Let J_{last} = J_{error}(i,j+1,k,l) and

Let θ^i(j+1,k,l)=θ^i(j+1,k,l)+C(i)$\frac{\Delta(i)}{\sqrt{\Delta^T(i)\Delta(i)}}$

J_{error}(i,j+1,k,l)J_{error}(i,j+1,k,l)=J_{error}(i,j+1,k,l)+J_{CC}(θ^i(j + 1,k,l,P(j+1,k,l))

Else, m=N_s and End of while statement

h) Go to next bacterium (i + 1), if i ≠S Go to [b] to process the next bacterium

STEP 5: If j<N_c, Go to 4 to continue chemotaxis, since the life of the bacteria is not over.

STEP 6: Reproduction: For the given k and l, and for each i = 1, 2, .. , S,

$$J^i_{health} = \sum_{j=1}^{Nc} Jerror(i,j,k,l)$$

STEP 7: If k < N_{re}, Go to 3 to perform reproduction

STEP 8: Elimination-dispersal: For i = 1,2. . .S, with probability P_{ed}, Perform elimination dispersal to eliminate and disperse one to a random location. If l < N_{ed}, Go to 2 Otherwise end.

IV. GENERATOR SENSITIVITY

A change in real power flow in a transmission line k connected between bus i and bus j due to change in power generation by generator ‘g’ can betermed as generator sensitivity to congested line (GS).

$$\mathbf{GS_g = \frac{\Delta P_{ij}}{\Delta P_g}} (1)$$

Where,

ΔP_{ij} = change in the real power flow of the congested line

ΔP_g = change in the real power generated by the generator

V. OBJECTIVE FUNCTION

The objective function of rescheduling real power generation using cost

Minimization is given by

$$C = \text{minimize} \sum_{g=1}^{Ng} C_g(\Delta P_g)\Delta P_g (2)$$

Where

$C_g(\Delta P_g)$ = incremental and decremental bids submitted by generators

ΔP_g= Unit change in real power adjustment at generator

N_g= Number of generators

Subject to

$$\sum_{g=1}^{Ng}((GS_g)\Delta P_g) + PF_k^0 \leq PF_k^{max} \quad (3)$$

Where k=1, 2, 3…N_l

$$\Delta P_g^{min} \leq \Delta Pg \leq \Delta P_g^{max} \quad (4)$$

$$\Delta P_g^{min} = P_g - P_g^{min} \quad (5)$$

$$\Delta P_g^{max} = P_g^{max} - P_g \quad (6)$$

$$\sum_{g=1}^{Ng} \Delta Pg = 0 \quad (7)$$

Where g = 1, 2… Ng

PF_k^0 = power flow caused by all contracts requesting the transmission services.

PF_k^{max} = line flow limit of the line connecting bus-i and bus j

N_l= number of transmission lines in the system.

GS_g= generator sensitivity of generator g.

V. PARAMETER SELECTION AND FUZZY RULES

FUZZY RULES:

1) If input is NB, then output is NB.

2) If input is NS, then output is NM.

3) If input is Z, then output is NS.

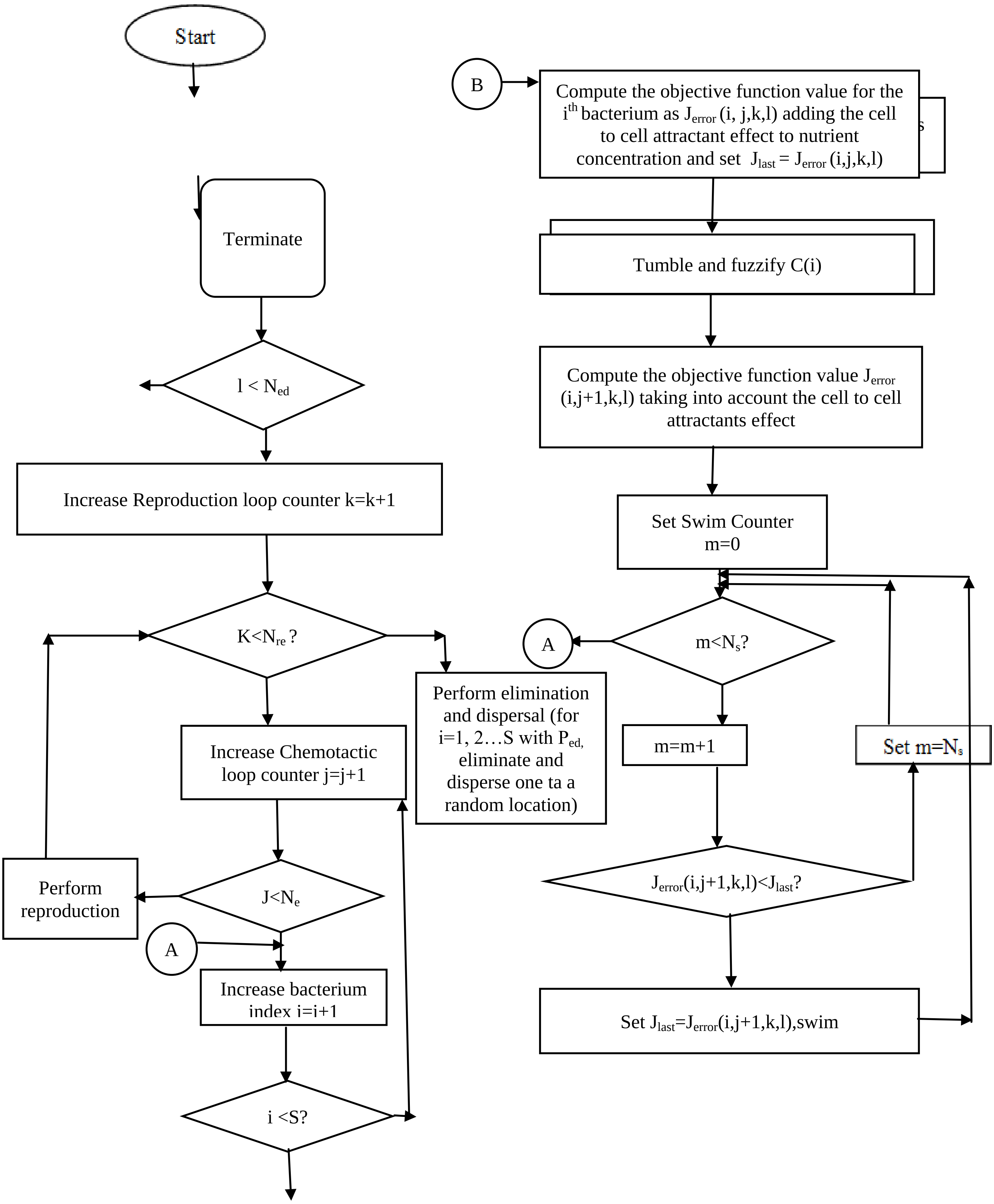
4) If input is PS, then output is Z.

5) If input is NM, then output is PS.

6) If input is PM, then output is PM.

7) If input is PB , then output is PB.

Fig.1.Flowchart of Bacterial Foraging Algorithm



The parameters selected for the proposed bacterial foraging algorithm with fuzzy is as follows:

Number of bacteria to be optimized, P = 2

Number of bacteria, S = 30

Number of chemotactic steps, Nc = 50

Swimming length, Ns = 4

Number of reproduction steps, Nre = 4

Number of elimination & dispersal events, Ned = 2

Run length vector initial value, C(i) = 0.05

Probability of elimination & dispersal, Ped = 0.25

Number of bacteria reproduction, Sr = S/2

VI. RESULT AND DISCUSSION

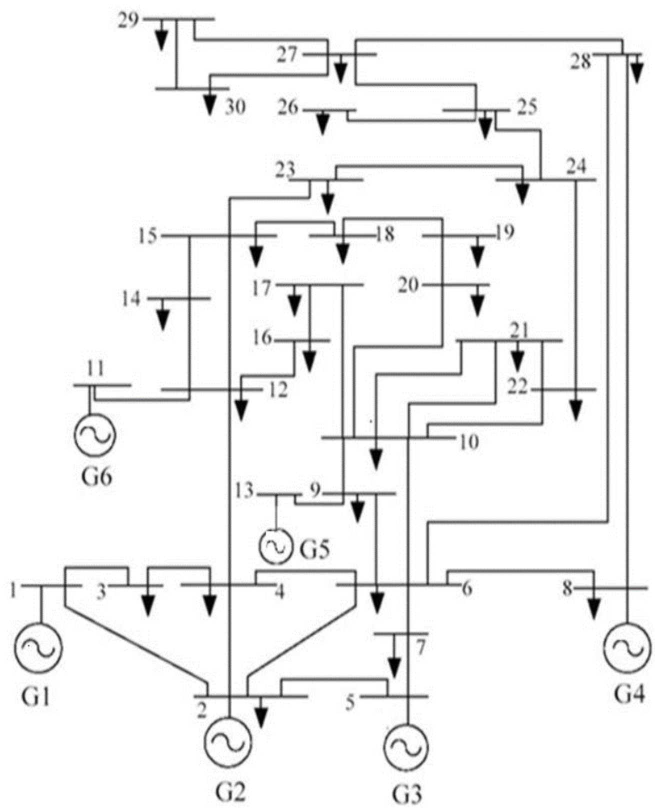


Fig.2. Single Line Diagram of IEEE 30 Bus System

The IEEE 30-bus system consists of six generator buses and 24 load buses. Accordingly, the Generator Sensitivities are computed for the congested Line-26 for the system. Generators which are to participate in congestion management are to be selected depending on their sensitivities to the congested line. In this test system, it is observed that all the generators show strong influence on the congested line. This is perhaps the system is very small and generally very tightly connected electrically. All the generators are participating in congestion management and the evolutionary algorithms are employed to optimally reschedule the active power of the generators for relieving congestion in Line-26.Mostly, congestion is due to exceeding power flow limit of one or more lines and outage of some important elements.

Table I : Active power flow in congested line after and before congestion management for IEEE 30-bus system

Branch power flow		Before Congestion management active power flow(MW)	After congestion management active power flow (MW)
From bus	To bus		
10	17	8.4200	8.1260

Table II : Comparisons of cost of congestion management for IEEE 30-bus system

Cost of CM(Rs/MWh)	FABF	SBF	PSO
Best	117.4467	177.12	160.23
Mean	134.5100	177.36	161.49
Worst	183.6439	177.38	161.61

Table III : Active power generation before and after congestion management for IEEE 30-bus system

Bus no.	Before Congestion management active power generation (MW)	After Congestion management active power generation (MW)
1	188.60	198.5
2	42.40	52.3
5	18.30	28.2
8	10.60	20.51
11	10.80	20.7
13	12.70	22.6

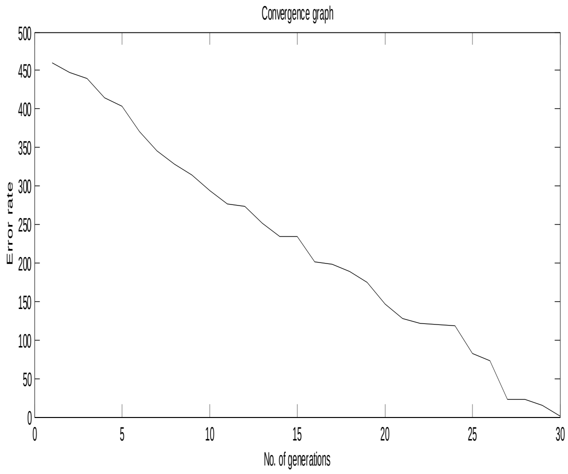


Fig.3. Plot of convergence graph

It has been observed from table I that the transmission line connecting bus 10 and bus 17 carries 8.42 MW power before congestion management. This congestion is created by increasing the load of bus 14.After solving the congestion management problem the power flow in the line 26 is reduced by 8.1260 MW.

From the comparison of the cost of congestion we can conclude that the bacterial foraging algorithm with fuzzy is lowest than the simple bacterial foraging and particle swarm optimization (table II).Fig.3.indicates that the bacterial foraging algorithm with fuzzy converges faster.

VII. CONCLUSION

Congestion management problem has been solved using optimal rescheduling of active powers of generators selected based on the generator sensitivity to the congested line, utilizing bacterial foraging algorithm with fuzzy. Here rescheduling is done taking into consideration the minimization of cost and satisfying line flow limits. The results obtained by the bacterial foraging with fuzzy are compared with Simple Bacterial Foraging (SBF) and conventional PSO algorithms. This method is tested on IEEE 30-bus. The results show that bacterial foraging algorithm with fuzzy is giving the best optimal solution in comparison with Simple Bacterial Foraging (SBF) and conventional PSO algorithms with respect to cost and runtime for relieving congestion in the congested line.

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