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Modified Bacterial Foraging Algorithm for Economic Load Dispatch and Optimal Power Flow

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Abstract: In this paper proposes an efficient technique to solve Economic load dispatch with optimal power flow problem. The optimal power flow problem consists the real and reactive power flow problems. The real power problem is the traditional economic dispatch considering the minimum fuel cost. Modified bacterial foraging algorithm (MBFA) method is used for solving the non- linear optimization problems. The optimization technique inspired by the foraging behavior of the E.Coli bacteria. Simulation results for IEEE-30 bus network are presented to show the effectiveness of the proposed method. Our proposed approach satisfactorily finds global optimal solution within a smaller number of iteration. In this proposed MBFA-OPF, Newton-Raphson method and MBFA algorithm have been used for power flow and economic dispatch respectively. The solutions obtained are quite encouraging and useful in the present de-regulated environment.

Keywords: Economic Dispatch, Optimal Power Flow, Modified Bacterial Foraging Algorithm (MBFA).

I. Introduction

Optimal power flow was introduced in the early 1960s by carpentier [1] as an extension of conventional economic dispatch. OPF problem solution aims to optimize objective function via optimal adjustment of the power system control variables while at the same time satisfying various equality and in-equality constraints. A wide variety of optimization techniques have been applied in solving the OPF problem such as nonlinear programming [2- 7] Newton based techniques, genetic algorithm [8], particle swarm optimization. Recently a new evolutionary computation technique, called Modified bacterial foraging Algorithm (MBFA) has been proposed. MBFA Technique is a high dimensionality of the search space based optimization technique. Bacterial foraging algorithm (BFA) is a recently introduced optimization technique inspired by the foraging behavior of the E.coli bacteria. BFA has been applied to solve various optimization problems such as economic load dispatch and optimal power flow. BFA gives the poor convergence properties and high timing requirements. The poor behavior of BFA to be modified for the complex problem of economic load dispatch. The MBFA is used to solve the load flow problems with the help of high dimension search spaces and convergence properties. Power factor correction has been simulated in [11], to recycle the inductor leakage energy.

The objective of the economic load dispatch problem is minimizing the fuel cost function of thermal generators by optimally allocating the total load among these generating units. The cost function to be minimized is subject to various operational constraints such as equality and inequality constraints. Under de-regulation the generation patterns resulting from market activities can be quite different from the traditional one [9]. Further since any non-utility generator (NUG) in the system can sell all part of its output to single or multiple buyers located anywhere within the network, have made the problem very much complicated. NUG includes both independent power producers (IPPs) and co-generators. There is a need for an optimal system, which may balance the needs of energy providers, the resellers, the large industrial customers and residential consumers. Some methods and mathematical models have been reported in literature for solving above-mentioned problems.

The MBFA is tested under five constraints like voltage constraints, generator constraints, transformer tap-set and

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transmission line constraints. Optimal operation of power system operation can be divided into two sub- problems.

Energy harvesting is one of the features to be considered in MEMS using cantilever sensor [12].

II. OPTIMAL POWER FLOW PROBLEM FORMULATION

A. Mathematical Formulation

The optimization of production cost function F of generation has been formulated based on classical OPF problem without violating system constraints. For a given power system network, the optimization of production cost of generation is given by the following equation.

a. Base case (optimal generation without any wheeling transition).

For a given power system network, the optimization cost of generation is given by the following equation.

$$C = \min \sum_{L=1}^{Ng} fi(PG_i)\$/hr$$

(1)

Where

C = Optimal cost of generation when the utility supplying its own load.

$Fi(PG_i)$ = Generation cost function of the i^{th} generator for PG_i generation.

PG_i = Power generation by the i^{th} generator.

Ng = Number of generator connected network.

b. The operating cost function of the power producer is optimized with the following power system constraint.

$$\sum^{Ng} (PG_i) = Pd + Pl$$

(2)

Where,

P_d = total load of the system

P_l = Transmission losses of the system (when the utility supplying its own load)

c) The power flow equation of the power network,

$$g(|v|, \phi) = o$$

(3)

Where

$|v|$ an ϕ is a voltage magnitude and phase angle of different basis.

d) The in-equality constraint on real power generation PG_i of generation i

$$P\sum_{Gi}^{min} \le PG_i \le P_{Gi}^{max}$$

(4)

e) The in equality constraint on voltage of each PQ bus

$$V_i^{min} \le V_i \le V_i^{max}$$

(5)

Where

V_i^{min} and V_i^{max} are respectively minimum and maximum voltage at bus i.

f) Power Limit on transmission line

$$MVAf_{p.q} \le MVAf_{p,q}$$

(6)

Where

$MVAf_{p,q}$ is the maximum rating of transmission line connecting bus P and q.

III. FORAGING ALGORITHM

BFA is an optimization technique motivated by the foraging behaviour of the *E.coli* bacteria. The biological aspects of the bacterial foraging strategies and their motile behaviour as well as their decision making mechanisms can be found in [10]. BFA is designed to solve non gradient optimization problems and to handle complex and non-differentiable objective functions. Searching the hyperspace is performed through three main operations, namely;

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chemotaxis, reproduction and elimination dispersal activities [20]. The chemotaxis process is performed through swimming and tumbling. The bacterium spends its Life alternating between these two modes of motion. In the BFA, a tumble is represented by a unit length in a random direction ϕ(j), which specifies the direction of movement after a tumble. The size of the step taken in the random direction is represented by the constant run-length unit c(i) – For a Population of bacteria the location of the i^{th} bacterium at the j^{th} chemotactic step, k^{th} reproduction step and i^{th} elimination/dispersal event is represents by $\theta^i(j,k,l)\ \Sigma\ R^P$. At this location the cost function is denotes by J(i,j,k,l), which is also known as the nutrient function. After a tumble, the location of the i^{th} bacterium is represented by

$$\theta^{i}(j+1, k,l) = \theta^{i}(j,k,l) + c(i,j)\ \phi(j) \quad (7)$$

Where at θ^i (j+1,k,l) the cost function J(i, j+1, k, l) is better lower than J(i, j, k, l), another step of size (i, j) in the same direction is taken. This swimming operation is repeated as long as a lower cost is obtained until a maximum present number of steps, N_s is reached.

The cost function of each bacterium is the population is affected by a kind of swarming that is performed by the cell to cell signalling release by the bacteria groups to form swarm patterns. This swarming is expressed as follows:

$$J_x(\theta, P(j,k,L)) = \sum_{i=1}^{s} J_x^i(\theta, \theta^i(j,k,L))$$

$$= \sum_{i=1}^{s}\left[-d_{attract}\exp\left(-\omega_{attract}\sum_{m=i}^{P}(Qm - Q^{i}m)^2\right)\right]$$

$$+ \sum_{i=1}^{s}\left[-h_{repellant}\exp\left(-\omega_{exp\,llant}\sum_{m=i}^{P}(Qm - Q^{i}m)^2\right)\right]$$

Where

$d_{attract}$, $\omega_{attract}$, $h_{repellant}$ and $\omega_{attract}$, are co-efficient represent the characteristics of the attractant and repellent signals released by the cell and θ_m^j component of i^{th} bacterium position $\theta_{.}^{j}$ P(j, k, l) is the position of each member of the population of the S bacteria and define as.

$$P(j, k, l) = \{\ \theta i(j, k, l) \mid i = 1,2,\ldots,S\} \quad (9)$$

Where s is size of the bacteria population.

The function (a) which represents the cell to cell signaling effect is added to the cost function

$$J(i, j, k, l) + J_{\alpha}(\theta, P) \quad (10)$$

A production process is performed after taking a maximum number of chemotactic steps, N_c. The population is halved so that the least healthy half dies and ach bacterium in the other healthiest one splits into two bacteria which takes the same position.

$$S_r = \frac{S}{2} \quad (11)$$

After N_{re} production steps and elimination/dispersal event takes place for N_{ed} Number of excisions. In this operation each bacterium could be moved to explore other parts of the search space. The probability for each bacterium to experience the elimination/dispersal event is determined by a predefined fraction P_{ed}.

IV. MODIFIED BACTERIZL FORAGING ALGORITHM

The unit step length of the basic BFA is constant which may guarantee good searching results for small optimization problems. However, when applied to complex problems with high dimensionality it shows poor performance. The run length parameter is the key factor for controlling the local and global search ability of the BFA. From this Perspective, balancing the exploration and exploitation of the search could be achieved by adjusting the run length unit. In this paper we propose a non linear decreasing dynamic function to perform the swim walk instead of the constant step this function in expressed as,

$$C(i, j+1) = \frac{C(i,j) - C(N_c)}{N_c + C(N_c)}(N_c - j) \quad (12)$$

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Where j is the chemotactic step and N_c is the maximum number of chemotactic steps while $C(N_c)$ is a predefined parameter.

IV. A. The algorithm of the proposed technique is as follows:

Step 1: Initialization of the following parameters

P : Dimension of the search space

S : The number of bacteria in the population

N_c : Number of chemotactic steps

N_s : The length of a swim when it is on a gradient.

N_{re} : The number of reproduction steps.

N_{ed} : The number of elimination dispersal events

P_{ed} : The probability that each bacterium will be eliminated / dispersed.

C (i, j): Initial run length unit

C (Nc):The run length unit at the end of the chemotactic steps (j=Nc)

θ : The initial random location of each bacterium.

Θi : The initial random location of each bacterium.

Step 2 : Elimination / dispersal loop, l = l+1

Step 3 : Reproduction loop, k = k +1

Step 4 : Chemotaxis loop, j=j+1

Step 5 : If $j < N_c$ go to step 4 (j = j+1)

Step 6 : Reproduction

Step 7 : If $K < N_{re}$ go to step 3 (k = k+1)

Step 8 : Elimination / dispersal

Step 9 : It l < N, go to step 2(l = l + 1), otherwise end

V. SIMULATION RESULTS

The MBF Algorithm was applied to the IEEE – 30 bus standard test system.

a. Base case

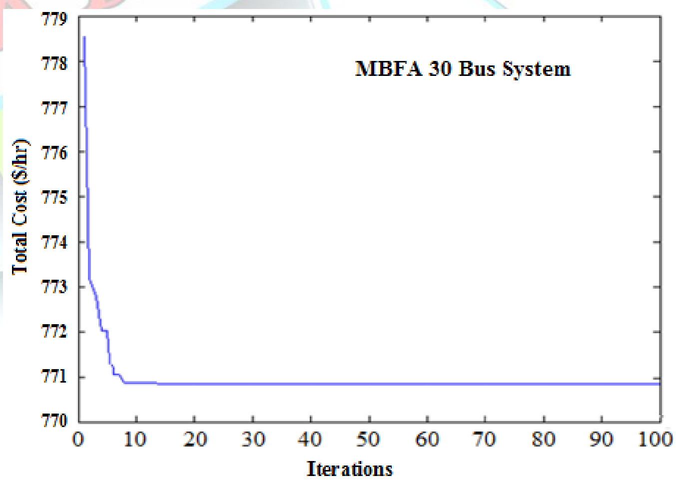
Optimal Generation of 6 – Generating plants)

For the base case the optimal generation (MW) of the generation, units of the utility is presented in the Table 1.

The total cost of generation for the base case optimal work is C = 770.90 $/hr.

Table 1. Base case

Output		
Total Power Demand		299 MW
Power Generated	P_1	179 MW
	P_2	26MW
	P_5	23MW
	P_8	24MW
	P_{11}	15MW
	P_{13}	32MW
Total Fuel Cost		770.90 $ / hr
No. of Iterations		100
Execution Time		1.3591 Sec.



VI. CONCLUSION

A modified bacterial foraging algorithm is used to the optimal power flow problem in a dynamic manner the proposed technique, which applies a non-linear function to update the solution vector and enhance the algorithm convergence the proposed method which aims at minimizing fuel cost with satisfying several constraints. But as the other evolutionary methods MBFA achieved better or optimal results for all cases.

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