ISSN 2229-5518

Optimal Power Dispatch Incorporating UPFC Devices Using Foraging Algorithms Voltage Stability and Reliability Analysis

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Abstract— The Refined Bacterial Foraging Optimization (RBFA) algorithm is biologically inspired computation technique which is inspired on foraging behavior of E-coli bacteria and its improved version of basic Bacterial Foraging Algorithm (BFA). This paper illustrated how a proposed algorithm different from other social behavior algorithm for solving optimization problems especially in multi-objective case and this proposed algorithm is applied to solve the Optimal Power Dispatch (OPD) problem with incorporating Unified Power Flow Controller (UPFC) and optimal location of UPFC based on stability and reliability analysis. This RBFA algorithm provides an enhanced optimal solution of all control variables and results are shown to be robust and improvement in convergence speed, simulations are performed with help of standard IEEE systems.

Index Terms— Ant Colony Algorithm, Bacterial Foraging Optimization, FACTS Devices, Multi-Objective Optimization, Optimal Power Dispatch, Refined Bacterial Foraging Optimization,, Reliability Analysis, Stability Analysis.

1 Introduction

THIS paper illustrates and address the all power system problems with application Foraging Algorithm; the Bacterial Foraging Algorithm (BFA) introduced by Passino in 2002, and BFA is based on behavior of E-coli bacteria.

The Bacterial Foraging Algorithms has been developed and applied to solve various kinds of real valued problems, such has optimal non-linear dynamic system [23], PID controller design [20], optimal power flow [16], transmission network expansion planning [15], constrained optimization [13], Power System Stabilizer [22] and RFID network planning [18]. In this work, the improved version of bacterial foraging algorithm is presented and the proposed algorithm is called as Refined Bacterial Foraging Algorithm (RBFA).

The validity analysis of RBFA was carried out with various benchmark multimodal mathematical functions and results are compared with various social algorithms [13].The proposed RBFA is gives very much focus on towards the solution of chemotaxis behavior via search direction and search dimension. Generally the all optimization algorithms are starts with random point only but end result shows time consuming process. Due to this reason and solution point of view, the BFA algorithm modified in to several stages and improved version of BFA proposed here.The proposed RBFA gives high potential to step length calculation and search dimension via position updating process during chemotaxis behavior. The introduction of the attraction factor and velocity vector for improves the speed of convergence and gives direction to global best according to the environments. The proposed algorithm also focused to process of repelling and attraction factor effects.Finally, in this paper the improved version of BFA algorithm is tested with multiple objectives power system problems or Multi Objective Optimization (MOO) problems.

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This article presents the improved version of BFA (RBFA) algorithm is applied to optimal power dispatch problems. The reliability and voltage profile analyzed with optimal placement of Unified Power Flow Control (UPFC) devices [2]-[9]. This particular OPD problem treated as Multi Objective Problem and this paper organized following manner, the following this section '2' deals MOOPD problem formulation, section '3' illustrates review of Bacterial foraging Algorithms, section '4' gives information about Refined BFA algorithms and algorithms for solving OPD problem with considering FACTS (UPFC) devices, section '5' deliberate the results and discussions followed by comparison results and finally concluding of proposed work listed in section '6'.

2 Problem Formulation

2.1 Objective Function

The multi-objective functions of OPD problem are mathematically stated as follows

Minimize

$$\mathbf{F} = \left[f_1 \; f_2 \; f_3 \; f_4 \right] \qquad (1)$$

Subject **equality and in-equality constraints** are given below sections.

The objective of OPD is to analysis reliability of power system under various operating conditions with results to identify the control variables for optimal operation of power system. The estimation of real power loss is to minimize the power loss via real power dispatch (fuel cost optimization) and reactive power planning with optimal placement of FACTS Devices (UPFC). The introduction of UPFC devices is to improve the stability, optimizing the real and reactive power dispatch and also improves the operating level of power system under critical operating condition.Finally, optimal placement and planning of reactive power requirement and identification critical lines and buses are connected with reliability analysis.

The objective functions are analysed and are given below:

Real Power Loss: This objective is to minimize the real power loss in transmission lines that can be expressed as:

$$f_1 = \sum_{k=1}^{Nl} G_k \left[V_i^2 + V_j^2 - 2V_iV_j\cos\left(\delta_i - \delta_j\right)\right] \quad (2)$$

Where Nl is the number of transmission lines; G_k is the conductance of the k^{th} line; $V_i < \delta_i$ and $V_j < \delta_j$ are the voltages at the end buses i and j of the k^{th} line respectively.

Active Power Losses: $P = P_{gi} - P_{load} \geq 0$

$$f_2 = \sum_{k=N_{gi}} P_{loss} = \sum_{K=n_E} g_{ij}\left(v_i^2 + v_j^2 - 2v_iv_j\cos\theta_{ij}\right) \quad (3)$$

Where P is the total transmission active losses of the power system in MW; P_{gi} is the total active power generated in MW, P_{loss} the total transmission losses in the network to be calculated in MW and P_{load} is the total load of the system in MW.

Voltage profile optimization: Bus voltage is one of the most important security and service quality indices. Considering only cost-based objectives in OPF problem may result in a feasible solution that has unattractive voltage profile. In this case, a two fold objective function is considered in order to minimize the fuel cost and improve voltage profile

$$f_3 = \sum_{i=1}^{NG} f_i + w\sum_{i\in NL}\left|v_i - 1.0\right| + \lambda_P\left(P_{g1} - P_{g1}^{\lim}\right)^2 + \lambda_V\sum_{i=1}^{NL}\left(V_i - V_i^{\lim}\right)^2 + \lambda_Q\sum_{i=1}^{NL}\left(Q_{gi} - Qg_i^{\lim}\right)^2 \quad (4)$$

by minimizing the load bus voltage deviations from 1.0 per unit.

Average Voltage Deviation:

$$f_4 = V_d = \sum_{i=1}^{N}\left[V_{act} - V_{des}\right]/N \quad (5)$$

Where V_d is the per unit (pu) average voltage difference; V_{act} is the actual voltage at bus bar i (p.u) and V_{des} is the desired voltage at bus bar i (p.u).

Maximum Voltage Deviation:

$$V_m = \mathrm{Max}\,|V_{act} - V_{des}| \geq 0 \quad (6)$$

2.2 Constraints

Voltage Stability Constraints

Voltage Stability includes voltage stability constraints in the objective function and is given by [14]

$$VS = \begin{cases} 0 & \text{if } 0.9<V_b<1.1 \\ 0.9-V_b & \text{if } V_b>0.9 \\ 1.1-V_b & \text{if } V_b>1.1 \end{cases} \quad (7)$$

Where

V_b= Voltage at bus b

UPFC Devices Constraints

The UPFC device limit is given by,

$$-0.5X_L < X_{TCSC} < 0.5X_L$$
$$-200\text{MVAR} < Q_{SVC} < 200\text{MVAR} \quad (8)$$

Where

X_L = original line reactance in p.u

X_{TCSC} =reactance added to line

Q_{SVC} = reactive power injected at SVC placed bus in MVAR

Power Balance Constraints

While solving the optimization problem, power balance equations are taken as equality constraints. The power balance equations are given by,

$$\sum P_G = \sum P_D + P_L \quad (9)$$

Where

$\sum P_G$ =Total power generation

$\sum P_D$ =Total power demand

P_L =Losses in the transmission network

$$P_i = \sum |E_i||E_K|[G_{ik}\cos(\theta_i - \theta_k) + B_{ik}\sin(\theta_i - \theta_k)$$
$$(10)$$
$$Q_i = \sum |E_i||E_K|[G_{ik}\sin(\theta_i - \theta_k) + B_{ik}\cos(\theta_i - \theta_k)$$

Where

P_i = Real power injected at bus i.

Q_i = Reactive power injected at bus i.

(θ_i, θ_k) = The phase angles at buses i and k

E_i, Ek = Voltage magnitudes at bus i and k

Real and Reactive Power Constraints

$$P_{Gi}^{min} \leq P_{Gi} \leq P_{Gi}^{max},\ i=1,\ldots, NG \quad (11)$$
$$Q_{Gi}^{min} \leq Q_{Gi} \leq Q_{Gi}^{max},\ i=1,\ldots, NG \quad (12)$$

Where

P_{gi} = Real power injected at bus i.

Q_{gi} = Reactive power injected at bus i

Voltage constraints

Voltages V_G are restricted by their lower and upper limits as follows:

$$V_{Gi}^{min} \leq V_{Gi} \leq V_{Gi}^{max},\ i=1,\ldots, NG \quad (13)$$

Where NG is number of generators.

Transformer Constraints:

Transformer tap T settings are bounded as follows:

$$T_i^{min} \leq Ti \leq T_i^{max},\ i=1\ldots NT \quad (14)$$

Where NT is number of Transformers.

Switchable VAR Sources Constraints:

Switchable VAR compensation Q_C is restricted by their limits as follows:

$$Q_{Ci}^{min} \leq Q_{Ci} \leq Q_{Ci}^{max},\ i=1\ldots NC \quad (15)$$

Where NC is number of Switchable VAR sources.

Load Bus Voltages:

These include the constraints of voltages at load buses V_L as follows:

$$V_{Li}^{min} \leq V_{Li} \leq V_{Li}^{max},\ i=1,\ldots,NL \quad (16)$$

ISSN 2229-5518

2.3 UPFC Devices

A Unified Power Flow Controller (UPFC) is a multifunctional FACTS controller. The basic components of the UPFC are two Voltage Source Inverters (VSIs) sharing a common dc storage capacitor and connected to the power system through coupling transformer. The primary function of UPFC is power flow control and it's because of series inverter. The series inverter is controlled to inject the symmetrical three phase voltage system (V_{se}) in series with the line and there by enhance the power flow to desirable value, it is by controllable magnitude and phase angle series with the line to control active and reactive power flows in transmission line. The UPFC devices basically consist of two VSI connected back to back with interconnecting DC storage capacitor. One VSI is connected to the system bus by a shunt transformer and other VSI is connected to the transmission line by a series transformer. The power balance between the series and shunt connected VSI is a prerequisite to maintain a constant across the dc capacitor connected between the two VSIs [9]-[12].The Fig.1 clearly describes controlling scheme in UPFC devices, how it's connected in critical lines, power injection to power.

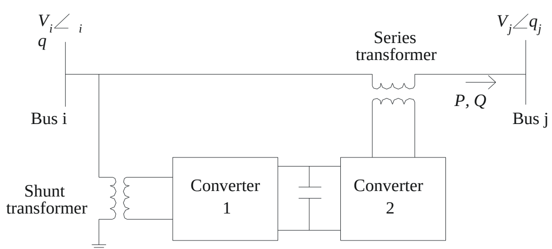

Fig .1 Unified Power Flow Controller device.

2.4 Stability and Reliability Indices

The voltage stability and reliability problems can be effetively The voltage stability and reliability problems can be effetively analysed and solution is carried out with help of stability indices, Voltage Stability Analysis, Fast line flow index, Voltage Stabilty Approch and Q-V Analysis. The detailed analysis of Voltage reliability analysis is listed in [5][7]. These methods examine the viability of the equilibrium point represented by a specified operating condition of the power system. The sensitivity analysis for voltage stability function indicates the evaluation in a system condition and by solving the power flow equation of the network with specific load level and the load levels before the voltage instability.

This voltage indices calculation deals the relationship between voltage profile estimation and reactive power deviationchanges at different buses using reduced Jacobian matrix.From the power flow equation

$$\begin{bmatrix} dP \\ dQ \end{bmatrix} = \begin{bmatrix} \frac{\partial P}{\partial \theta} & \frac{\partial P}{\partial V} \\ \frac{\partial Q}{\partial \theta} & \frac{\partial Q}{\partial V} \end{bmatrix} \begin{bmatrix} d\theta \\ dV \end{bmatrix} \quad (17)$$

The Jacobian matrix J is:

$$J = \begin{bmatrix} \frac{\partial P}{\partial \theta} & \frac{\partial P}{\partial V} \\ \frac{\partial Q}{\partial \theta} & \frac{\partial Q}{\partial V} \end{bmatrix} = \begin{bmatrix} K & L \\ M & N \end{bmatrix} \quad (18)$$

Where K, L, M and N are the Jacobian sub-matrices, the elements of Jacobian matrix give the sensitivity analysis between power flow and bus voltage changes. The ΔP is incremental change in bus real power, Q is incremental change in bus reactive power injection, $\Delta\theta$ is incremental in bus voltage angle and ΔV is incremental change in bus voltage magnitude. In fact system voltage stability is affected by both P and Q. However at each operating point we may keep P constant and evaluate voltage stability by considering the incremental relationship between Q and V. Based on above considerations, equation **(1)**, let $\Delta P=0$. Then equation (1) become

$$\begin{bmatrix} 0 \\ dQ \end{bmatrix} = \begin{bmatrix} \frac{\partial P}{\partial \theta} & \frac{\partial P}{\partial V} \\ \frac{\partial Q}{\partial \theta} & \frac{\partial Q}{\partial V} \end{bmatrix} \begin{bmatrix} 0 \\ dV \end{bmatrix} \quad (19)$$

$$\Delta Q = J_R \, \Delta V \;\; \text{or} \;\; \Delta V = J_R^{-1} \, \Delta Q \quad (20)$$

where

$$J_R = [\, J_{QV} - J_{Q\theta} J_{P\theta}^{-1} J_{PV}] \quad (21)$$

and J_R^{-1} is the reduced Jacobian matrix of the system for sensitivity. J_R^{-1} is also called sensitivity of Voltage stability analysis. A positive sensitivities represent stable operation; the smaller the sensitivity the more the stable the system. As stability decrease, the magnitude of sensitivity becoming infinite at the maximum load ability limit. On the other hand, negative voltage stability approach shows unstable operation. A small negative sensitivity represents a very unstable operation. The magnitudes of sensitivities for different system conditions do not provide a direct measure of relative degree of stability. It is because of the non linear nature of the Q-V relationship and identifying the correct eigen values and eigen vectors for analyzing the Voltage stability characteristics of the system in the reduced Jacobian matrix J_R. and order of the reduction matrix is 1x1therefore the eigen values is equal to value of Jacobian reduction of the system[9]-[12].

3 Bacterial Foraging Algorithms

In 2000, Kevin.M.Passino [24] proposed the idea of Bacterial Foraging Methodology or Algorithm to solve the optimization problems. The base work of BFA was based on behavior of bacteria and very clearly states the foraging behavior of E-Coli Bacteria. In the BFA, the optimization process consists of Chemotaxis, swarming (cell to cell signaling and foraging) reproduction and elimination- dispersal activities. The optimization problem can be solved by in BFA, the way of search nutrients, evade noxious environments, the moving circumstance and the way of imitating the existence of the bacteria.

The solution set of BFA is based optimal sets of own. The position of each bacterium in the population is represented by [17][24].

$$P(\mathrm{j,k,l}) = \theta^{\mathrm{i}}(\mathrm{j,k,l})(i=1,2,....S)$$

Equations () describes the position of each bacteria, for i^{th} is the bacteria,j^{th} chemotactic step, k^{th} reproduction step and l^{th} elimination-dispersal event in θ co-ordinate axis in the solution surface.

The aim of BFA algorithm is to fit the best or minimum fitness function and the evaluating the fitness value of each bacterium is consist of following process cell-to-cell communication, its happens via attractant and repellent effect factor. This is given by the following equation

$$j_\alpha\left(\theta^i(j,k,l),\theta(j,k,l)\right)=\Sigma_{i=1}^{S} j_{cc}^{i}\left(\theta,\theta^i(j,k,l)\right)$$

$$=\Sigma_{i=1}^{S}\left[-d_{attract}\exp\left(-w_{attract}\Sigma_{m=1}^{p}\left(\theta_m-\theta_m^i\right)^2\right)\right]$$

$$+\Sigma_{i=1}^{S}\left[h_{repellant}\exp\left(-w_{repellant}\Sigma_{m=1}^{p}\left(\theta_m-\theta_m^i\right)^2\right)\right] \quad (22)$$

The finding of nutrient position and movement of each bacterium is based on the tumble-run process, the every bacterium in the population will tumble once and the bacteria identify and have better fitness value after the tumble, the bacteria takes place run process with swim or swarm. The run length and step size important parameters in the BFA algorithm. The bacteria movement after the tumble-run process is given by in the equation

$$\theta^{\mathrm{i}}(\mathrm{j}+1,\mathrm{k,l}) = \theta^{\mathrm{i}}(\mathrm{j,k,l})+\mathrm{C}(\mathrm{i})\cdot\Phi(\mathrm{j}) \quad (23)$$

The evaluation of fitness and search process takes turns to execute until the life time of bacteria. After the cell to cell communication process, the reproduction schemes in follows and in this process the healthy bacteria identified. Finally, in this reproduction schemes the whole population will only keep half of the bacteria. Finally the elimination- dispersal process is takes place to eliminate the worst bacteria and by replacing the best bacteria [18][19][21].

4 Refined Bacterial Foraging Algorithm

The survival of species in any natural evolutionary process depends upon their fitness criteria, which relies upon their food searching and motile behavior. The law of evolution supports those species who have better food searching ability and either eliminates or reshapes those with poor search ability. The genes of those species who are stronger are propagated in the evolution chain since they posses ability to reproduce even better species in future generations. So a clear understanding and modeling of foraging behavior in any of the evolutionary species, leads to attempts better solution for any optimization. So, this is way here proposed the new algorithm.

The basic foraging algorithm consists of four steps are Chemotaxis, swarming, reproduction, elimination and dispersal [1]. Chemotaxis is the activity of bacteria gathering to nutrient-rich areas spontaneously. A cell-to-cell communication mechanism is established to simulate the biological behavior of bacteria swarming. Reproduction comes from the concept of natural selection and the bacteria able to survive only if the bacteria adapted to their environment in best manner and transmit their genetic characters to succeeding generations while those less adapted tend to be eliminated. Elimination – dispersal event selects parts of the bacteria to diminish and disperse into random position in the environment. The proposed method based on foraging behavior of bacteria and some modifications is made through from basic foraging algorithm. The modified algorithm named as Refined Bacterial Foraging Algorithm (RBFA) and RBFA is proposed in this paper. The performance of basic foraging algorithms is well suitable in single objective problems and static environments and step length of the basic BFA is a constant parameter which may guarantee good searching results for small optimization problems. However it is applied to multiple objectives, dynamic environments and high dimensional problems and its gives poor performance in convergence characteristics and also many times it trapped into local optima solutions. The process of search direction and step length is important in multiple objectives and dynamic environments. The proposed approach made some modification in step length; Chemotaxis behavior and adding velocity vector for improve speed of convergence and attaining global solution and also suitable diversity for global search and its improves speed of convergence.

Search direction and Chemotaxis process: The Chemotaxis behavior is modeled by a tumble-run process that consists of a tumble step and several run steps. The tumble run process follows gradient searching principles, which means the bacteria's position is updated in the run steps by the gradient information provided by the tumble step. In each bacteria step size, unit length, dimension and random direction coordination are much important, a search direction W_{id} (j) and a step length L_{id} (j) are calculated separately for each bacteria i, on each dimension d for each time step or tumble-run process or iteration j, W_{id} (j) =1 means the i-th bacteria goes towards the positive direction of the coordinate axis on the dimension d, its indicates the follow tumble process and consecutive run process. W_{id} (j) = -1 means the bacteria goes towards the negative direction, its follow again tumble process and W_{id} (j) =0 means the bacteria stays at the current position; it means the bacteria reaches more nutrient position. When any one of bacteria finds best position, it should attract other bacteria so that they converge in that location. In this search direction estimation leads to finding the distance of global bacteria from rest of others and the process convergence time minimized. While the distance known, it's easy to attain the swarming process for new Chemotaxis stage. The current position i_{th} the bacterium, in d dimensional search space and j_{th} tumble-run process is updated

$$\mathrm{X}_{\mathrm{id}}(j+1)=\mathrm{X}_{\mathrm{id}}(j)+\mathrm{L}_{\mathrm{id}}(j)\mathrm{W}_{\mathrm{id}}(j) \quad (24)$$

Once the direction and angle is decided by the tumble step, to reach the position it takes several steps (until the position of worst). The rotation angle Φ is related to the number of the dimensions, the number dimensions desired by objectives.

$$\phi=\frac{\pi}{round\sqrt{d+1}} \quad (25)$$

Where, d- search dimension and π is the number of dimensions.

Position updating process: In this process the step size calculation are initiated with help of position updating process. The basic methodology is adopted in BFA, In order to meet these criteria. The E-coli cells provides attraction signal to each other, so that they swarm or swim together and towards to the best location and swarming pattern based on cell-to-cell communication. But in this process shows slow converge only and in order to improve this process, the velocity factor added with other bacteria so as to reach best bacteria position and this velocity vector added according to other bacteria position. The position updating process mainly focus on best bacteria and each dimension is given by

$$X_{id}(j) = \alpha\left(X_{id\ best} - X_{id}\right) \qquad (26)$$

Where α is a factor to desire the strength of the bacterium's attraction factor for improving the strength of the bacterium's attraction towards to the best position and for faster convergence., X_{best} indicates the position of current best global solution updated after each function evaluation, and Xi is the position of the i_{th} bacterium at the j_{th} iteration after the tumble run process.

If a anyone bacteria reaches better position in order to direct the other bacteria to best position, the attraction signal is not enough to reach the best position. Therefore, in order to attract other bacteria and also obtain the bacteria position by using equation

$$X_{id}(j+1) = \alpha\ \left(X_{id\ best} - X_{id}\right) + V_j \qquad (27)$$

So, in the process the velocity factor V_j is binding with position updating process and also is pilot to determine the best position according to the previous best positions. Update best bacteria position and add the velocity according to reach the best position, the velocity factor desired by depending upon according to position of best and other bacteria. The velocity factor V_j also gives direction to global best value or its used to identify global best value.

Step length: The basic BFA shows a step size is a constant parameter and it's suitable to finding the solution in single and small optimization problems. However, when applied to multiple objective problems and dynamic environmental problems it shows poor performance**.** The basic BFA with fixed step size is failure in reaching the optimal point for the following reasons. The first case, if step size is very high then the accuracy gets low although the bacterium reaches the locality of optimum point quickly and it moves around the maxima for the remaining chemotactic steps. The second case, if the step size is very small, it takes many chemotactic steps to reach the optimum point and its lead to slow convergence and rate of convergence decreases. Meanwhile to reach the optimal point it takes convergence time and number of iterations increases. So, in order to reach the optimal point, speed of convergence and search ability the controlling of step length is essential**.** In this paper the proposed RBFA following consideration in determining step length process with help of search dimensions, If deviation is very high then the step size must be increased and if the deviation is small in which case the bacterium is close to the optimum point the step size is to be reduced and also improve the performance the swim walk considered instead of the constant step.

For a each bacteria, the location of the *i*th bacterium at the *j*th chemotactic step, *r*th reproduction step and *l* th elimination / dispersal event is represented by $X_{id}(j,k,l) \in \Re^p$. After a tumble, the location of the *i*th bacterium is represented by

$$X_{id}(j+1,r,l) = X_{id}(j,r,l) + L(i,j)\phi(j) \qquad (28)$$

Where $L(i,j) = L_{id}(j)W_{id}(j)$

The J(i,j,k,l) is cost function of corresponding X_{id} *(j,k,l)*.The fitness value of the i_{th} bacterium at $X_{id}(j,k,l)$ is represented by j_{id} (j,k,l). In this paper the minimum fitness value j_{min} is defined as the global optimum.

In a run, consecutive steps of size L(*i,j*) is the same direction as the tumble is taken, in condition X_{id} (*j*+1,*k,l*) the cost function J (*i,j*+1, *k,l*) is better (lower) than J(*i,j,k,l*). In this condition, the fitness value of the i_{th} bacterium in the r_{th} step of the run Ns indicates the maximum number of steps in a run and also r is smaller than N_s. This swimming operation is repeated as long as a lower cost is obtained until a maximum preset number of steps, N_s, is reached.

In BFA the step length *L* is a constant and it ensures accuracy and speed of the search. The size of the step length is dynamically adjusted in the reproduction and elimination-dispersal process, which ensures the bacteria moving towards the global optimum quickly at the beginning, and converging to the global optimum accurately in the end. So the i_{th} bacteria in d_{th} dimension search space the step length controlling vector is given by

$$L(id) = \min\left\{\left(L(id) - \mu\right), n\right\} \qquad (29)$$

Where

μ - step length vector, n = constant controlling the decreasing rate of the step length. The value of 'n' is desired by according to position updating process and Chemotaxis process.

5 ALGORITHM FOR REFINED BACTERIAL FORAGING

The multi-objective based OPD problem is can be solved by using Refined BFA.

Read system data, here the standard IEEE30 bus system data [14] is considered. It contains load data, line data and generator data [14] with cost coefficients.

Randomly initialize the position of each bacterium in the domain, set the position and fitness value of the best bacterium. Initialize the parameters: S, p, N_c, N_S, N_{re}, $N_{c,}$ P_{ed}, L(i), $d_{attract}$, $w_{attract}$, $h_{repellant}$ and $w_{repellant}$

Randomly initialize the position of each bacterium in the domain, set the position and fitness value of the best bacterium as X_{id}^b(j,k,l) and j_{min} (j, k, l) respectively.

FOR (each bacterium i=1: S)

FOR (chemotactic loop j=1: $N_{c)}$

FOR (dimensions=1: π)

FOR (reproduction loop k=1: N_{re})

FOR (elimination-dispersal loop l=1: N_{ed})

Evaluate the cost function *J(i,j,k,l)*

Let J_{last} = *J(i,j,k,l)* so that a lower cost could be found Calculate J^i (j, k, l) and set it as J_{last};

Tumble:

Search direction identified with help of identification process according to RBFA

For bacterium I, set J*i*(j,r) as Jlast. A random vector Δ(i), with each element Δ_m(i), m=1,2….. p, a random number in the range [-1,1].

Move:

Move to a random direction $\frac{\Delta}{\sqrt{\Delta' \times \Delta}}$ by a unit walk, the new position is calculated by equation and start another chemotactic step.

Compute $J(I,j+1,k,l)$ and use to compute J_{cc} (θ, P (j+1,k,l)) then use to find the new J(i,j+1,k,l).
Swim: let m = 0 (counter for swim length)
While $m< N_s$ (no climbing down too long)
Let $m=m+1$
If $J(I,j+1,k,l)<J_{last}$ let $J_{last} = J(I,j+1,k,l)$ then take another step in the same direction and compute the new J(I,j+1,k,l).

Swim:
Update X_{id}(j+1, k, l).
Recalculate J^i(j+1, k, l);
IF ($J_{current}< J_{last}$)
WHILE (J^i_{r+1}(j+1, k, l)<J^i_r(j+1, k, l)
and r<N_s)
Set J^i_r (j+1, k, l) as j_{last};
Run:
Update X_{id} (j+1, k, l)
Set new J^i_{r+1}(j+1, k, l) as $J_{current}$;
Swim:
Update X_{id} (j+1, k, l)
Recalculate J^i_{r+1}(j+1, k, l);
END WHILE
END IF
END FOR (bacterium)
Calculate J_{min} (j+1, k, l)
END FOR (chemotaxis)
Sum:
Evaluate the sum of the fitness value J^i_{health} for the i_{th} bacterium.
Sort:

Sort bacteria according to their health J^i_{health} in ascending order.
Split:
The bacteria with the highest J^i_{health} values, computed by die while the other S_r with the lowest values split and take the same location of their parents
Eliminate other then health bacteria are to be eliminated.
Update:
Update the step length L (i,j).
END FOR (reproduction)
Disperse:
Disperse certain bacteria to random places in the optimization domain with probability P_{ed}.
Update:
Update the step length L (id)
END FOR (elimination-dispersal)
END

If it's optimal solution is achieved means, the program will stopped

5.1Computational Procedure:

Step 1: Read system data, here the standard IEEE30 bus system data [14] is considered. It contains load data, line data and generator data [14] with cost coefficients. Input parameters of system, and specify the lower and upper boundaries of each variable.
Step 2: Initialize the number of bacteria and obtain the step length according foraging behavior.
Step 3: The load flow solution and control variables are initialized.
Step 4: After the load flow Solution, the multi-objective and mutli-disciplinary OPF are solved by using Refined BFA and all objectives are optimized by simultaneous optimization.
Step 5: Get the final optimal solution and quit the program, the above all procedure are clearly described in figure.2.

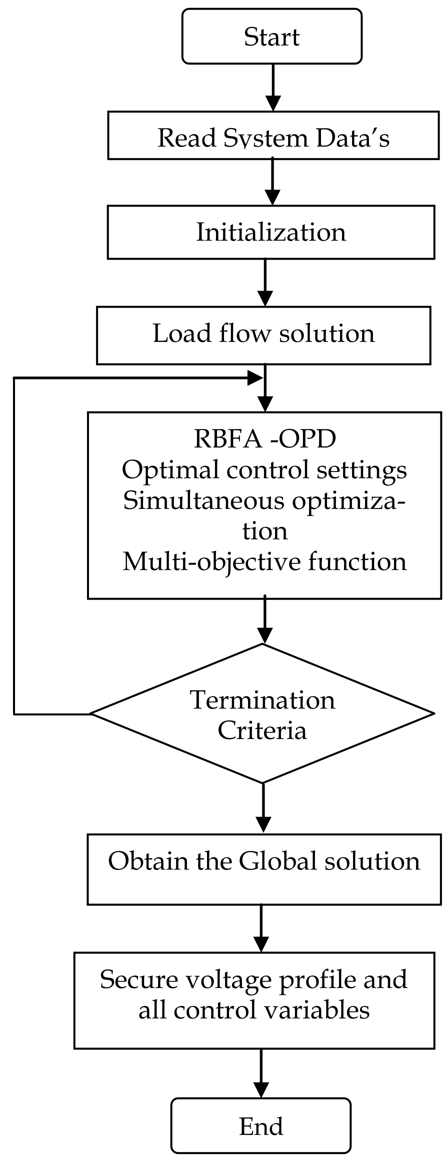

Fig.2: Flow chart for computational Procedure of proposed algorithm

6 Results and Discussion

The applicability and feasibility of the aforesaid technique for practical applications have been tested with IEEE standard systems. The obtained results are compared with similar social behavior algorithms like ACO, Basic BFA and Modified BFA. The cases for taken for validity analysis and study comparison purpose the IEEE6 and IEEE30 bus taken.

The entire simulation is carried out with the help of

MATLAB software and the challenging task of using the bio-inspired algorithms and tuning of FACTS devices (UPFC) are coded and all the tasks are obtained with MATLAB Packages. The fitness evaluation of the particles and the bacteria are carried out and evaluation of the proposed algorithm was tested with various multimodal function and analyzed in [].

6.1 IEEE 6 Bus System

In order demonstrate the effectiveness and robustness of the proposed technique the IEEE6 bus system is considered as first case and IEEE30 bus system is considered as second case. The solution of this problem with address of the minimization of real power loss, voltage deviation, voltage profile with stability and reliability analysis and entire analysis carried out in two ways one is including UPFC devices and second way not considering the UPFC devices. The results of stability and reliability analysis and also optimized values are listed in Table.1. The results of proposed technique and comparison of results are tabulated in Table.2.

TABLE 1
RESULTS IEEE 6 BUS SYSTEM

Bus No.	Optimized results of voltage values	
	Optimal placement of UPFC devices	
	Before	After
1	1.0000	1.0000
2	1.0000	1.0210
3	0.9334	0.9356
4	0.9445	0.9963
5	**0.8723**	**0.9863**
6	0.9321	0.9551
	Critical lines	Line 2-5
	Critical bus	Bus 5

The problem was handled as a multi-objective optimization problem where all the objectives are simultaneously optimized and problem analyzed with proposed technique and also similar algorithms. The real power loss and voltage profile are considered as main function with proper identicfication of critical lines buses with help of stability indices [].

TABLE 2
COMPARSIONS OF RESULTS

method	Optimized values		
	System losses in MW	Simulation time in sec	No of Iterations
ACO	8.921	24	54
BFA	8.925	19	33
MBFA	8.825	21	45
RBFA	8.716	23	36

6.2 IEEE30 Bus System

The IEEE 30 bus system has 6 generator buses, 24 load buses and 41 transmission lines of which four branches are with tap settings transformers. The line data, bus data and other data are taken from []. The voltage magnitude limits at all buses are 0.95 p.u and the upper limits are 1.1 p.u. for all the PV buses and 1.05 p.u for all the PQ buses and the reference bus. The lower and upper limits of the transformer tappings are 0.9 and 1.1 p.u respectively. The capacitor bank ratings are set as 0-15 MVAR.

TABLE 3
RESULTS IEEE 30 BUS SYSTEM

Method	Real Power loss in p.u		Voltage deviation	Weakest bus
	Optimal	Initial		
ACO	0.5817	0.6895	0.197	26
BFA	0.5778	0.585	0.193	30
MBFA	0.5778	0.585	0.2134	30
RBFA without Indices	0.5272	0.585	0.225	26,30
RBFA with Indices	0.4965	0.585	0.189	26,30

TABLE 4
VOLTAGE PROFILE OF IEEE 30 BUS SYSTEM.

RBFA method -Voltage profile optimization			
Bus no	Voltage Magnitude	Bus no	Voltage Magnitude
1	1.0600	16	1.0447
2	1.0430	17	1.0391
3	1.0215	18	1.0279
4	1.0129	19	1.0253
5	1.0100	20	1.0293
6	1.0121	21	1.0321
7	1.0034	22	1.0327
8	1.0100	23	1.0272
9	1.0510	24	1.0216
10	1.0444	25	1.0189
11	1.0820	26	**1.0001**
12	1.0574	27	1.0257
13	1.0710	28	1.0107
14	1.0424	29	1.0059
15	1.0378	30	**0.9996**

6.3 Comparison of Results

The validity of proposed algorithm and effectiveness of the solution are evaluated with help of the way of constraints handling, voltage stability and profile optimization and also Q-V analysis of the system [].

6.4 Handling of Constraints

The co-ordinate control of generator bus voltages, tap settings limits and reactive power limits are effectively optimized. The line losses reduced with optimal location of UPFC devices. The real power loss and reactive power loss greatly reduced with optimal location of UPFC devices with optimal control of control variables. The multi-objective OPD problem consists of equality and inequality constraints, the proposed approach is very efficient in handling of constraints and especially in in-equality constraints. The main focus of this problem is to obtain the optimal solution without violating any desired operating conditions.

When considering the bacteria search space and step length is very important, so as to achieve the good results the bacteria position is carried out in each step and velocity factor added to update the current position. The every possible solution the constraints should stay in the in their limits and here, it's represented as power generation boundary limits. Whenever the bacteria out of search space or bacteria swims out of the search space boundaries means the inequality constraint is violated. In this proposed RBFA, the step length, search direction and position updated frequently, this will to find the better position of bacteria to achieve best solution and even if it moves out of the boundaries.

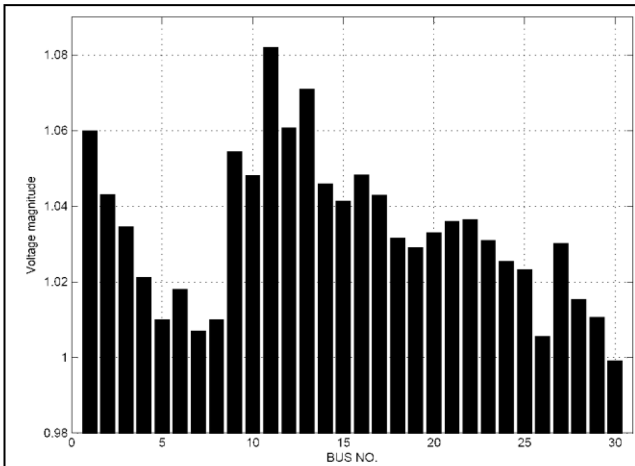

Fig.2. Voltage profile optimization of IEEE 30 bus system

6.5 Voltage Stability and Voltage Profile

The real and reactive power output in set by UPFC devices for during any contingency condition, therefore the optimal location of UPFC devices can maintain the voltage constant. The bus voltage deviation and average bus voltage deviation can be effectively minimized with help of optimal placement of FACTS devices. The voltage stability approach and stability indices are effectively identify the critical lines and critical buses with RBFA algorithm. So, the real power loss and voltage profile improvement are better. The results are tabulated in Table.1, Table.2, Table.3 and Table.4, the end results shows improvement in voltage stability. The voltage profile optimization of IEEE30 bus system is clearly described in Fig.2.

The sensitivity analysis is better against critical conditions and load ability condition, So critical lines and buses are identified according to the series injection of UPFC devices and optimal location of UPFC devices with help of proposed algorithm. The impact of optimal location of UPFC is improvement in voltage stability and real power loss, finally the optimal dispatch is effectively analyzed with addressing all the issues in the real time operation of power system.

7 CONCLUSION

This paper presents an improved version of bacterial foraging algorithm (RBFA) to solve multiobjective comprehensive model of optimal power dispatch problems with addressing the various objectives of optimal power dispatch problem, like real power loss, voltage stability, profile improvement and in addition to that optimize a various controls. The versatile optimal power dispatch has been developed into modified environment in modern power systems with optimal operating and planning of resources. In feature include: optimal location of UPFC devices and voltage stability and reliability analysis for better voltage profile, reactive power planning, allocation of resources and reduction in line losses. The overall multi-objective solution effectively treated with proposed RBFA algorithm and this proposed method tested with various IEEE standard systems. The comparison of results using the proposed method is great improvements in speed, constraints handling, accuracy, optimal placement of UPFC devices and convergence in solving multi-objective and multi-constraint optimization problem.

ACKNOWLEDGMENT

The authors wish to thank Govt. Collge of Technology and RVS College of Engg and Tech for providing R&D lab and other facilities to carryout this work.

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