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# Bacterial Chemotaxis Algorithm for Load Flow Optimization

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*Abstract:* -In this paper the optimization of the electric power system load-flow is performed by the Bacterial Chemotaxis Algorithm (BCA). The BCA is a modern heuristics that finds inspiration by the motion of particular micro-organisms (bacteria). A correlation between bacterium activity (bacterial chemotaxis) and a numerical algorithm has been recently proposed as a new optimization technique. The BCA has been here applied with the aim of reducing power losses in transmission lines for an assigned power load. Validation versus classical load flow computation methods is presented.

*Key-Words:* - Optimization, Heuristics, Bacterial Chemotaxis Algorithm, Load flow, Gauss-Seidel method, Joule losses

## 1 Introduction

The load flow computation is a fundamental task for the planning and the management of electrical power systems. This well known non-linear problem is usually solved by classical mathematical approaches such as Newton Raphson or Gauss-Seidel methods. These classic methods, however, do not optimize the load flow. e.g. by minimizing the joule losses on transmission lines. With the aim to obtain an optimization of the load flow, heuristics have been recently applied, e.g. Genetic Algorithms or Particle Swarm Optimization [1]-[4]. In this paper an alternative heuristic is investigated for the joule losses minimization for an assigned power to be delivered to loads: the Bacterial Chemotaxis Algorithm (BCA) [5] [6]. The BCA is an heuristic which emulates the activity of bacteria in their habitat (that is a chemical aqueous solution). In nature, each bacterium looks for a better habitat to stay and its motion is influenced by this necessity. Doing this search, the bacterium follows behavioral rules which are similar, but not equal, to the classical gradient algorithm. For computational scopes, a correlation between bacterium behavior and numerical optimization has been ideated [5]: the best bacterium habitat corresponds to the numerical optimum. In the present paper the effectiveness of BCA has been investigated for the evaluation of an optimum load flow. The goal is the reduction of joule losses on transmission lines.

## 2 Load flows

The minimization of the power losses requires the evaluation of optimum values of voltages, current flow magnitudes in transmission lines and the active and reactive powers both for generation and load busses. A *n-bus* power system can be mathematically described by a set of non-linear equations describing the active and reactive powers in each particular bus:

$$\begin{cases} P_k = \sum_{i=1}^{n} V_k V_i Y_{ki} \cos(\vartheta_k - \vartheta_i - \gamma_{ki}) = P_{ko} \\ Q_k = \sum_{i=1}^{n} V_k V_i Y_{ki} \sin(\vartheta_k - \vartheta_i - \gamma_{ki}) = Q_{ko} \\ E_k = E_{ko} \end{cases} \quad (1)$$

where the next Table 1 summarized the list of unknown:

Table 1

| | **Fixed variables** | **Unknown variables** |
|---|---|---|
| Generation Buses | $P_g$, $V_g$ | $Q_g$, $\vartheta_g$ |
| Load Buses | $P_c$, $Q_c$ | $V_c$, $\vartheta_c$ |
| Slack Bus | $V_n$, $\vartheta_n$ | $P_n$, $Q_n$ |

The trigonometric functions appearing in (1) makes the system non-linear. Thus, the solution must be obtained by applying iterative numerical methods based on subsequent approximations (e.g. Newton-Raphson or Gauss Seidel). However, these methods can not give an optimum load flow, since they furnish only a solution of (1) by starting from assigned guess values. For the optimization of the power systems (i.e. minimization of power losses), heuristic approaches have been recently applied, such as genetic algorithms or Particle Swarm Optimization algorithm, or Ant Colony Optimizatiuon [1]-[4]. In the present paper an alternative heuristics is investigated: BCA.

## 3 The implemented BCA

The BCA [5] [6] takes inspiration by the motion of particular micro-organisms (bacteria) which is observable in nature. The bacterium activity is due to the different chemical properties encountered into its habitat. This behavior is called bacterial chemotaxis. In particular a bacterium is sensitive both to the gradient of the nutritive substance concentrations (approach) and to the gradient of harmful substances (removal). Thus, the bacterium motion mechanism is due to the evolution of the bacterium position for achieving survival or, simply, a better life conditions. Thus, all scientific observations of a particular bacterium specie behavior (e.g. Escherichia coli and Salmonella typhimurium), can be effort for heuristic evolutionary computation (virtual bacterium). Thus, from the knowledge of chemical mechanisms governing the bacterial chemotaxis, mathematical abstractions and implementation of numerical algorithms has been made for optimization problems [6]. A mathematical description of a 2D bacterium motion can be developed by the determination of suitable probabilistic distributions referred both to the motion duration and to the velocity vector (speed and direction) of the bacterium. This 2D description can be easy extended to a n-dimensional hyperspace [6] by assuming an assigned duration for the virtual-bacterium path and a velocity vector made of $n$ speeds and $n$ directions. Thus, in the present implemented BCA for load flows optimization, the virtual bacterium motion follows the next listed rules:

*a)* the bacterium population consists of 10 individuals

*b)* each bacterium follows its own path each consisting of a sequence of rectilinear trajectories

*c)* each path segment is identified in a N-dimension space (i.e. the N parameter values to be optimized) by speeds (v), direction (α) and duration (τ)

*d)* both speeds v and directions α are updated for each calculation step according to the Error Index of solutions

*e)* new speeds and directions are generated by means of a Gaussian probabilistic functions

*f)* the path duration τ is assumed to be constant

## 4 Validation

The BCA has been tested for a 3-bus power system. The used system is shown in Figure 1 [4]. The optimization goal is the minimization of the global joule power loss. The BCA results have been compared with non-optimized results from Gauss-Seidel method. All values indicated in Figure 1 are referred to the Gauss Seidel results. The slack bus is indicated with "0" in Figure 1.

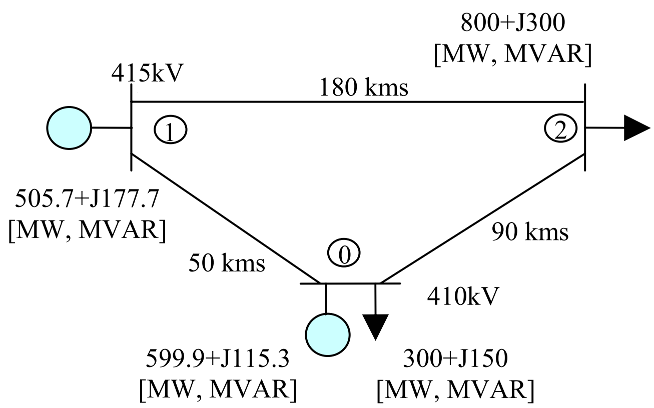


Figure 1: 3-bus power system scheme used to test the BCA (the indicated values are referred to the Gauss-Seidel solution).

### 4.1 Gauss Seidel Results

The non-minimized power losses have been estimated with Gauss-Seidel iterative method [7]. The evaluated losses are equal to *5.7744 MW*.

### 4.2 BCA Results

The implemented BCA (Matlab® 7) finds an optimized power flow according to the following new constrains:

- The tolerances on the input voltages have been set *5%*;
- The tolerances on the active and reactive load power have been set *0.5%*.

The BCA results are:

- The global power loss is reduced to a value close to *5* MW. This value is lower than 12% compared with Gauss-Seidel results.

- The BCA running time is under 5 minutes on a Pentium 4 PC

In the next Figure 2, the error index versus algorithm iteration steps, referred to two single bacteria, optimization is shown.

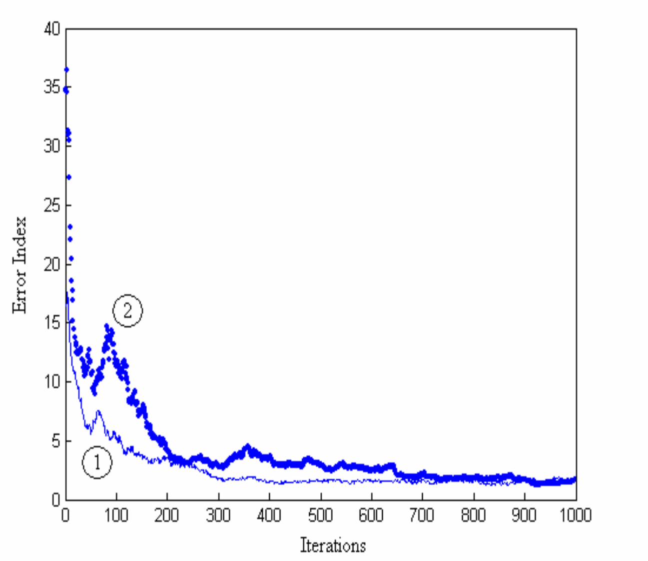


Figure 2: observed error index of two single bacteria, indicated by numbers 1 and 2.

## 6 Conclusions

A BCA approach for the minimization of power losses has been investigated. From the results obtained by applying BCA, it appears that BCA is an interesting heuristic method for solving and optimizing electric power systems. Since the running-time of the present approach is quite low for a 3-bus power system, the use of BCA could be suitable also for larger power system architectures [2].

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