The Congestion Management of Transmission Line using Bacterial Foraging Algorithm

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Abstract: The power systems movement to the electricity industry restructuring circumstance is done with the purpose of deformation of this industry up to elimination of exclusion and fairy competition increment and freely accessing to transmission line. But the possibility of congestion creation in the transmission line could encounter market role makers with problems such as energy price exclusion, difference in energy price at some busses and abusing of some jobbers in the market in these new systems. The study and survey in the interest of prevention and lowering of this phenomenon is done in the name of 'Congestion Management'. In this study after investigation of energy markets and the definition of congestion, local marginal price concept and ordinary method are introduced and then Bacterial Foraging Optimization Algorithm will be investigated in order to optimal determination of Local Marginal Price (LMP) in the busses with purpose of production minimizing in pool market and lately it will be tested on a 24-bus standard network to formulate the optimization problem and to make it applicable.

Keywords: Algorithm bacterial foraging, congestion management, local marginal pricing, market power, optimal power flow, pool market

INTRODUCTION

Prior to end of 19th century up to ending of 20th, the electricity industry has been utilized as an exclusive, arranged and supervisory structure. In this structure, owners concurrently had the production, transmission and dispatching systems on their hand and supplied the products at the set and under local organizations supervision prices to customers. In many of under development countries, the aforesaid owner was the government. The basis of traditional methods was inspired from motivations and ideas which were completed gradually and by technological developments. The emergence of restructuring in electricity industry is of new problems in recent years. The ultimate goal in this motion is the economical yield or efficiency in power systems increment. On the other side, power transmitting limitation on the lines, has converted transmission network as a serious problem on the way of this restructuring.

For different reasons like the lines breakdown, generators breakdown and variation in power exchange contracts amount, some parts of transmission network will face with overload. In the traditional structure, this problem was being resolved with some instructions. By the free access to transmission network plan in restructured systems, the lines congestion has been severed and its occurrence has been changed from a specific and constant state in traditional systems into an undetermined, risky and sometimes in a non-predetermined place state. The congestion management of transmission line problem in restructured systems has been researched as a special issue in recent years. The relationship between this issue with issues like different energy markets, transmission tariffs, transmission right allocation, power stations and transmission lines reparation scheme on one hand and difference in restructuring forms in different countries have caused the variety in investigations and studies done in this context. Congestion of transmission lines would prevent the electricity market from attaining its goals and inhibit consumers' access into the cheaper energy (Fallahi et al., 2003). After restructuring of electricity industry, the first designation of the market was MCP. After a while it determined that MCP gives error signals to market participants and causes problems in utilization of network at time of lines congestion and this will reduce the functionality and efficiency of market in its turn. These unfavorable experiences caused the change of different countries market design from MCP method into
Locational Marginal Price (LMP) method. Because LMP is achieved from the sum of production final price, transmission lines congestion price and losses final price, it's a location dependant pricing method which supplies a logical and acceptable pricing and the congestion causes the LMP of specific locations to be more than that point original LMP (Mozaffari and Ranjbar, 2003).

General points of LMP have been given in Fallahi et al. (2003) and a new method for calculation of final local prices LMP in restructured systems in Mozaffari and Ranjbar (2003). This method uses the basic state of load distribution to gain LMP in each busbar. In Ranjbar et al. (2008) a model has been introduced that calculates the losses final price on basis of DC load distribution and using distribution reference busbar. In Ongsakul and Petcharak (2007) a simple method for LMP calculation is introduced in which the production agents are used to assess the impact of the units production power changes on lines crossing power. In Panigrahi and Ravikuhmar (2009) Lagrange fast algorithm is used for production planning and at last in Yong et al. (2007) an innovative algorithm is used for congestion management.

Given the inability of the classic methods to solve the scientific problems because of some constraints such as non differentiability, needing the objective function and non linearity of objective function, therefore to solve the problems quickly and flexibly, one would use the methods based on evolutionary algorithms which their purpose is to find the optimum point of the problem without any awareness about information of the objective function gradient or its second order derivatives and the constraints of the problem. These methods idea typically originate from natural phenomena accurate observation and discovering the relationships dominating them in real world optimally. In this study, for the first time, the distribution of the optimum load using bacterial algorithm is used calculations of the optimum points of production and LMP calculation on the buses.

THE CONCEPT OF LMP AND ORDINARY METHOD

LMP has two concepts: physical and mathematical. The physical concept of LMP is the ultimate cost for supplying the (next/dimensional) increment in electrical energy at a specific basbar of the network by regarding the ultimate cost of the production and constraints of the transmission line. The mathematical concept of LMP is a dual variable for the provision of the power balance on a certain basbar to solve the optimum load distribution problem.

Although, there are differences in different networks, but LMP have general utilization aspects. Energy producers, based on the amount of LMP in their power delivery points, to network, gain money. Energy consumers, also buy their requesting energy based on the amount of LMP in their junction point to the network. Mutual contracts, will pay the congestion costs based upon the differences in LMP between catching and injection points of the contracted power.

The amounts of LMP, for different periods of time could be calculated regarding the determined regulations of different markets. Most of networks have day-ahead market which determines the organized amounts of production and consumption for different participants in market based on their price suggestions. These planned amounts are relating to one day-ahead LMPs. Some other networks have the hour-ahead market in which the amounts of LMP might be calculated in the process of each hour liquidation (Ranjbar et al., 2008).

The common method is to divide LMP into energy, losses and congestion components. Usually, when we consider the transmission losses, in order to calculate the losses, LMP would be decomposed. Despite LMP is not dependent on the reference basbar selection, but decomposition of LMP into aforesaid components is completely dependent on it. This dependency reveals that the achieved components, singularly, have no any importance and application and the Maine application is about the subtraction of congestion component in different basbars and nonteworthy is that this amount doesn’t depend on the reference basbar as well.

By using the decomposition method, LMP component is as following:

$$LMP = LMP_{\text{ref}} + LMP_{\text{loss}} + LMP_{\text{cong}}$$

(1)

In each basbar i, LMP comprised from these three components the first component, is the ultimate price of production in the reference basbar and depends on selection. The second one, is the losses component and for its calculation, the delivery factors in each basbra are required. The last component, is about congestion and the production changing factors and also the constrain. Cost in each congested Line should be achieved to be able to calculate it. The energy and losses component could be combined and converted into one component Ranjbar et al. (2008).

BACTERIAL FORAGING ALGORITHM

BFO algorithm was introduced with Ongsakul and Petcharak (2007). In this algorithm it is inspired from the movement of a type of bacteria called Ecolon seeking for food and is located inside the human colon. In this algorithm, it is well portrayed how bacteria move and look for food (as such the E/T portion maximizes, in which E is the resulted energy and T is the time dedicated to searching) and the bacteria impact on each other in a colony of bacteria is demonstrated. In this algorithm, chemotactic steps were done on each bacterium and after this loop, it starts reproduction and elimination of a group
of bacteria which are in a worse condition than the others. After this loop, it is time for bacteria distribution in a new environment by possibility of ped.

The idea of this method is based on reality. In nature, the best way in food finding is to eliminate low powered animals and corporate with high powered one to find food. After many reproductions, those who have low power are being eliminated or change their shapes into good figures. Bacteria Ecoli, located in human colon, by following four processes:

- Chemotaxis
- Swarming
- Reproduction
- Elimination and dispersal

Chemotaxis: This process is gained with two functions, swimming and tumbling. Based upon flagella period, the bacteria decide in which direction they should tumble and if the new situation after tumbling is better, bacteria start to swim in that path. We suppose that we want to find the minimum of \( J(\theta) \), \( \theta \in \mathbb{R}^p \). \( \theta \) represents the bacteria simulation and \( J(\theta) \) represents the amount of food in location \( \theta \). \( J(\theta)<0 \), \( J(\theta)=0 \) and \( J(\theta)>0 \), respectively indicate that bacteria in location \( \theta \) are completely. Nutritive, neutral and harmful environments. To present a tumbling, a random vector by unit length, called \( \varphi(i) \) is produced. This vector is used to identify a motion direction after a tumbling:

\[
\theta(j+1, k, l) = \theta(j, k, l) + c(i)(\varphi(i)) \tag{2}
\]

Specifically, \( \theta(j, k, l) \) indicates the \( j \)th bacteria in \( j \)th phase of Chemotaxis, \( k \)th generator an \( l \)th step of elimination and dispersal. \( C(i) \) is the measure of taken step in random direction which is determined by tumbling. If in location \( \theta(j+1, k, l) \), the cost of \( J(I, j, k, l) \) is lower than \( \theta(j, k, l) \), the next step by \( c(i) \) measure will be taken in \( \varphi(i) \) direction and bacteria start to swim in \( \varphi(i) \) direction. This swimming would continues up to the cost decrement. Whole of this process continues to predefined number of step \( N_s \).

Swarming: It is always desirable that a bacterium which seeks for the optimum path of the food. Tries to observe the other bacteria As they arrive to the deliberate location rapidly. Swarming collects bacteria in group and therefore they move as concentric pattern with high bacteria density.

We replace:

\[
P(j, k, l) = \{ \theta(j, k, l) \mid l = 1, 2, \ldots, S \} \tag{3}
\]

Given the mathematical rules, Swarming could be represented as Eq. (4), which \( J_m(\theta, P(i, k, l)) \) is a time-variative function due to all cells motion and sum with \( J(i, j, k, l) \), because cells try to find food and refrain from harmful things and concurrently try to move toward the other cells, but not very close to them. “S” is the total number of bacteria and “P” is the number of parameters to be optimized which presents the location of each bacterium:

\[
(\theta, P(i, j, l)) = \sum_{i=1}^{s} P(j, k, l) J_m(\theta, \theta(j, k, l)) + \sum_{i=1}^{s} J(i, j, k, l)
\]

(4)

\[
= \sum_{i=1}^{s} -d_{\text{attract}} \exp \left( - w_{\text{attract}} \sum_{m=1}^{s} (\theta_m - \theta_{\text{attract}})^2 \right)
+ \sum_{i=1}^{s} -d_{\text{repelent}} \exp \left( - w_{\text{repelent}} \sum_{m=1}^{s} (\theta_m - \theta_{\text{repelent}})^2 \right)
\]

\[
d_{\text{attract}}, w_{\text{attract}}, h_{\text{attract}}, w_{\text{repelent}} \text{ are the distinctive coefficients which should be selected wisely.}
\]

Reproduction: Bacteria go towards death by \( S_o = S/2 \) ratio and each other healthy bacteria divides into two bacteria which locate on the same situation as their bacteria this task keeps the population of bacteria constant.

Elimination and dispersal: It is possible that in a local environment, the energy reservoir of a population of bacteria changes gradually via food materials consumption or abruptly due to some other impacts. The accidents which could kill or disperse bacteria in a area. These accidents affect the eliminability of chemotaxis process, but may contribute the chemotaxis phase. Hence, the dispersal might locate bacteria in a better situation. Elimination and dispersal phase prevents bacteria from becoming apart from optimum location. The possibility of each elimination and dispersal occurrence for each bacteria is indicated by ped.

Optimizing bacterial foraging algorithm: On of the problems exists in BF algorithm, is the selection of \( S, N_s, N_{re} \) and \( N_{ed} \) parameters. The convergence speed of above parameters with different values, is different Therefor, in order to achieve the quickest convergence, the amounts of \( N_s, N_{re} \) and \( N_{ed} \) should be selected wisely A similar condition by which the amounts of the parameters relating to swarming effect, \( d_{\text{attract}}, w_{\text{attract}}, h_{\text{attract}}, w_{\text{repelent}} \), are being selected Improper amounts of these parameters could result in extra absorption or repulsion of bacteria So, these parameters affect convergence of algorithm.

Algorithm execution progress is as such that firstly search starts with a number of stochastic bacteria as the primary answers of problem. In continue, regarding the algorithm progress, bacteria (problem answers) move to nutritious points (points by minimum cost in problem) and deviate from areas with harmful materials (point by high cost); i.e., it is tried to decrease the cost function identified for problem After a while, the algorithm
converges to optimum answer. The flowchart of BFO optimization algorithm is as follow (Fig. 1).

**PROBLEM FOR MULIZATION**

Since, the purpose of this paper is to minimize the production cost; hence the problem formulization will be as follows:

\[
\text{Min} \sum_{i=1}^{N_g} F_i(P_{G_i})
\]  

(5)

**S.t:**

\[
\sum_{i=1}^{N_g} P_{G_i} \leq \sum_{i=1}^{N_b} P_{Li}
\]  

(6)

\[
|f_i| \leq f_{i}^{max}
\]  

(7)

\[
P_{G_i}^{min} \leq P_{G_i} \leq P_{G_i}^{max}
\]  

(8)

where, \(f_i\) is the unit \(i\) production cost function and \(P_{G_i}\) is the unit \(i\) produced power. The first constrain of this problem is the balance of power in the network, as \(P_{Li}\) indicates the amount of load in basbar \(i\). The second and third constrains are the limitation of power cross of lines and the units production limitation, respectively. \(N_b\) and \(N_g\) indicate number of basbars and number of production units of the network, respectively. \(f_i\) is the crossing power flow from line and \(f_{i}^{max}\) is the maximum flow of that line \(P_{G_i}^{max}\) and \(P_{G_i}^{min}\) are the maximum and minimum production power of units:

\[
f_i = p_y = \frac{1}{\lambda}(\delta_{j} - \delta_{j}^{1})
\]  

(9)

Because, in this problem DC load dispersal is used, as a result, the produced power equation will be as follows:

\[
P_L = \beta_i \delta \Rightarrow \delta = \beta_i^{-1}.P_L
\]  

(10)

By resplacing Eq. (10) in (9), we have:

\[
f_i = p_y = \frac{1}{\lambda}(\beta_i^{1} - \beta_j^{1}).P_k
\]  

(11)

where, \(PDTF = \frac{1}{\lambda}(\beta_i^{1} - \beta_j^{1})\) and the objective function will be defined as sum of total cost of turned on units on certain hour and Lagrange coeficient of production and consumption balance equation, If the losses of lines are neglected, we have:

\[
F_i(P_{G_i}) = \sum_{j=1}^{N_b} (a_i.P_{G_i}^2 + b_i.P_{G_i} + c_i) + \lambda(\sum P_L - P_{G_i})(12)
\]

\[
\frac{\partial F(P_{G_i})}{\partial P_{G_i}} = 0
\]  

(13)

\[
P_{G_i} = \frac{\lambda - b}{2a}
\]  

(14)

That relation (14) determines that units production power according to random primary cost and the direction of decision upon that unit’s being turned on (\(u = 1\)) or turned off (\(u = 1\)) in a certain hour, could be understood from the unit profitability or harmfulness in that hour. It can be available from the following relation:

\[
\lambda_i.P_{G_i} - (a_i.P_{G_i}^2 + b_i.P_{G_i} + c_i) \geq 0
\]  

(15)

Also, the minimum up time and downtime of the units should be considered (if \(u\) (time) - \(u\) (time-1) <0, unit stayson and otherwise off). To calculate setup cost considering the minimum downtime of unit which is given in tables (initial-state) the following relation could be used:
Fig. 2: Sample 24 buses network (Panigrahi and Ravikhumar, 2009)

![Sample 24 buses network](image)

Fig. 3: Plot of marginal price of 24 buses network IEEE with network load (without line limit)

\[ S_i(t) = \beta_i + \alpha_i(1 - e^{-\frac{t_{off}}{\tau}})(1 - I_i(t-1))I_i(t) \]  

(16)

where, \( \beta \) and \( \alpha \) are coefficients that indicate production units costs and are given in dollar currency in tables and \( t_{off} \) indicate that the unit how long was off. \( \tau \) is the time constant of the boiler heat loss which as much it is off, water temperature will be decreased and the cost increases. \( I_i(t) \) and \( I_i(t-1) \) determines the unit on and off conditions.

To calculate the local marginal price in each buss by neglecting the lines losses, the following relation is used:

\[ LMP = \{\text{MCP} - \sum \text{PDTE.}(\text{Landa. ineqlin})\} - \sum \text{PDTE.}(\text{Landa. ineqlin}) \]  

(17)

![Plot of marginal price of 24 buses network IEEE with network load (without line limit)](image)

Fig. 4: Plot of comparison of marginal cost of 24 buses network IEEE with network load per unit (by line limit)

![Plot of comparision of marginal cost of 24 buses network IEEE with network load (without line limit)](image)

Fig. 5: Comparison of utilization cost of two condition: without limit and by limit

in which \( \text{Landa. equine} \) is the Market Clearing Price (MCP) and \( \text{Landa. ineqlin} \) is the dual of line constrains which if its value is zero, it means that no line is congested and \( \text{PDFT} \) (Landa. ineqlin) product, is the money share of the unit that it crosses over the flow line and is non-zero at congestion time The utilization cost could be given by following relation:

\[ f_{valc} = \sum_{i=1}^{n} (aP_{Gi}^2 + bP_{Gi}) + \sum c_i I_i(t) + \sum ((\beta + \alpha)(1 - e^{t_{off}})).I_i(1-t) \]

(18)

Table 1: Production unit’s information (Panigrahi and Ravikhumar, 2009)

<table>
<thead>
<tr>
<th>Unit</th>
<th>min up (h)</th>
<th>min down (h)</th>
<th>init cond (h)</th>
<th>( \alpha ) ($)</th>
<th>( \beta ) ($)</th>
<th>( \tau ) ($)</th>
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<td>0</td>
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<td>10-13</td>
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Table 2: System generators information (Panigrahi and Ravikhumar 2009)

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<th>Unit (MW)</th>
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<th>( P_i^2 ) (MW)</th>
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<th>( b_i ) ($/MW)</th>
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Table 3: Load information in one period (Ranjbar et al., 2008)

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<th>Demand (MW)</th>
<th>Time (h)</th>
<th>Demand (MW)</th>
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<td>2594</td>
</tr>
<tr>
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<td>1825</td>
<td>18</td>
<td>2850</td>
</tr>
<tr>
<td>7</td>
<td>1881</td>
<td>19</td>
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</tr>
<tr>
<td>8</td>
<td>1995</td>
<td>20</td>
<td>2765</td>
</tr>
<tr>
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<td>21</td>
<td>2679</td>
</tr>
<tr>
<td>10</td>
<td>2508</td>
<td>22</td>
<td>2622</td>
</tr>
<tr>
<td>11</td>
<td>2565</td>
<td>23</td>
<td>2479</td>
</tr>
<tr>
<td>12</td>
<td>2593</td>
<td>24</td>
<td>2309</td>
</tr>
</tbody>
</table>

Table 4: Comparison of utilization cost in two conditions by the purpose of minimization production cost

<table>
<thead>
<tr>
<th>Method</th>
<th>Supply cost minimization Problem</th>
<th>Bid cost ($)</th>
<th>Consumer payment ($)</th>
<th>Bid cost ($)</th>
<th>Consumer payment ($)</th>
<th>Time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BFO</td>
<td>SCM</td>
<td>7.3261e+5</td>
<td>1.151019e+6</td>
<td>7.3610e+5</td>
<td>1.46531e+6</td>
<td>363</td>
</tr>
<tr>
<td>MFLR</td>
<td>SCM</td>
<td>7.8657</td>
<td>1.21032e+5</td>
<td>8.160 e+5</td>
<td>2.07949e+5</td>
<td>240</td>
</tr>
</tbody>
</table>

- Without the line limitation
- By the line limitation

was executed and the following results achieved (Table 3 and 4).

CONCLUSION

In this thesis, a new optimization algorithm with bacterial foraging method, to manage the electricity competitive market and by the purpose of minimizing production cost is investigated and it was tested on a 24 buses network to make algorithm applicable. In order to better management by system independent user JISO, we should select optimization parameters more accurately. In this thesis, parameters amount were chosen as follows: \( N_{\text{param}} = 24, N_{\text{ed}} = 10, N_{\text{rep}} = 10, C_i = 1, N_s = 50 \) and \( N_{\text{ini}} = 10 \).

By executing the program in two conditions without lines limitations and by-lines limitation-we observe that in the first condition, there is no congested line and price in the buses has became the same and the total cost is \( 7.3261e+5 \) dollar and in the second condition, congestion occurred in some hours on bus 7 and the price in buses has became different and the total cost is \( 7.3610e+5 \). The issue of optimization of the objective function could be assessed from both the producer and consumer perspective, but in this study it was assessed just from producer view and in the lines in which we have congestion, there is a need for constructing line and in the buses which difference in price increment exist, the need for constructing production line exists. Also, the achieved results in comparison with the results of utilization and consumer cost which is achieved from FLR algorithm method in Table 4 and Fig. 3, 4 and 5 from ref (Panigrahi and Ravikhumar, 2009), are better and this originates from the good functionality of this algorithm in reaching to optimum answer and its flexibility in planning development.

REFERENCES


