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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

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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 Petcharaks (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 Ravikhumar (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 aware ness 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:

$$LMP = LMP^{ref}+LMP^{loss}+LMP^{cong} \tag{1}$$

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 its 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 Petcharaks (2007). In this algorithm it is inspired from the movement of a type of bacteria called Ecoil seeking for food and is located insid 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 Ecoil, 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 $J(\theta)$, $\theta \in R^p$.θ represents the bacteria simulation and $J(\theta)$ represents the amount of food in location θ. $J(\theta)<0$, $J(\theta) = 0$ and $J(\theta)>0$, respectively indicate that bacteria in location θ are in 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:

$$\theta'(j+1, k, l) = \theta'(j, k, l)+c(i)(cp)(i) \qquad (2)$$

Specifically, $\theta'(j, k, l)$ indicates the ith bacteria in jth phase of Chemotaxis, kth generator an lth 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 tuken 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 Ns.

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:

$$P(j, k, l) = \{\theta^i(j, k, l)\ I = 1, 2, \ldots, S\} \qquad (3)$$

Given the mathematical rules, Swarming could be represented as Eq. (4). which $J_{cc}(\theta, P(i, k, l))$ 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:

$$(\theta, P(i,j,l)) = \sum_{i=1}^{s} J^i{}_{CC}(\theta, \dot{\theta}(j,k,l))$$
$$= \sum_{i=1}^{s}\left[-d_{attract}\exp\left(-w_{attract}\sum_{m=1}^{P}\left(\theta_m - \theta^i{}_m\right)^2\right)\right] \qquad (4)$$
$$+\sum_{i=1}^{s}\left[-d_{repelent}\exp\left(-w_{repelent}\sum_{m=1}^{P}\left(\theta_m - \theta^i{}_m\right)^2\right)\right]$$

$d_{attract}$, $w_{attract}$, $h_{attract}$, $w_{repelent}$ are the distinctive coefficients which should be selected wisely.

Reproduction: Bacteria go towards death by $S_r = S/2$ ratioa 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 ordisperse 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, N_c, 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_c, S, N_{re} and N_{ed} should be selected wisiely A similar condition by which the amounts of the parameters relating to swarming effect, $d_{attract}$, $w_{attract}$, $h_{replent}$, $w_{replent,}$ 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 nutritive 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

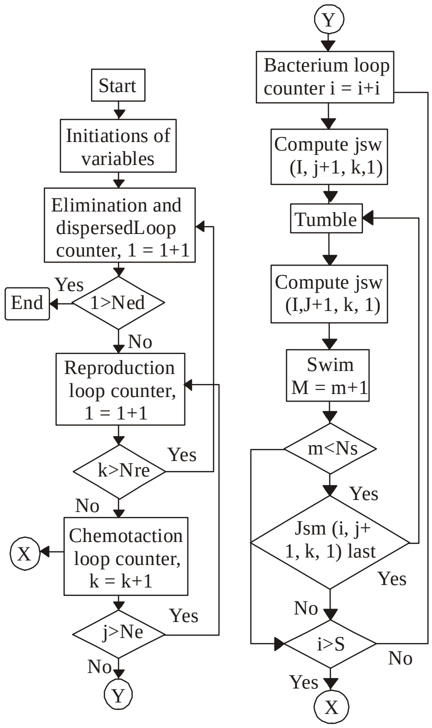

Fig. 1: Flowchart of BFO algorithm (Yong *et al*., 2007)

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:

$$Min \sum_{i=1}^{Ng} F_i(P_{G_i}) \tag{5}$$

S.t:

$$\sum_{i=1}^{Ng} P_{Gi} = \sum_{i=1}^{Nb} P_{Li} \tag{6}$$

$$\left| f_j \right| \leq f_j^{\max} \tag{`7}$$

$$P_{G_i}^{\min} \leq P_{G_i} \leq P_{G_i}^{\max} \tag{8}$$

where, fi is the unit i production cost function and P_{Gi} is the unit i produced power. The first constrain of this problem is the balance of power in the network, as P_L indicates the amount of load in basbar i. The second and third constrains are the limitation of power cross of lins 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_k is the crossing power flow from line and f_k^{max} is the maximum flow of that line P_G^{max} and P_G^{min} are the maximum and minimum production power of units:

$$f_k = p_{ij} = \frac{1}{X}(\delta_i - \delta_j) \tag{9}$$

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

$$P_k = \beta.\delta \Rightarrow \delta = \beta^{-1}.P_k \tag{10}$$

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

$$f_k = p_{ij} = \frac{1}{X}(\beta_i^{-1} - \beta_j^{-1}).Pk \tag{11}$$

where, PDTF = 1/X $(\beta_i^{-1} - \beta_j^{-1})$ 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:

$$F_i(P_{Gi}) = \sum_{i=1}^{ng}(a.P_{Gi}^2 + b.P_{Gi} + c) + \lambda(\sum P_L - P_G) \tag{12}$$

$$\frac{\partial F(P_{G_i})}{\partial P_{G_i}} = 0 \tag{13}$$

$$p_{G_i} = \frac{\lambda - b}{2a} \tag{14}$$

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 tuned 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:

$$\lambda.P_{Gi} - (a.P_{Gi}^2 + b.P_{Gi} + c) \geq 0 \tag{15}$$

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:

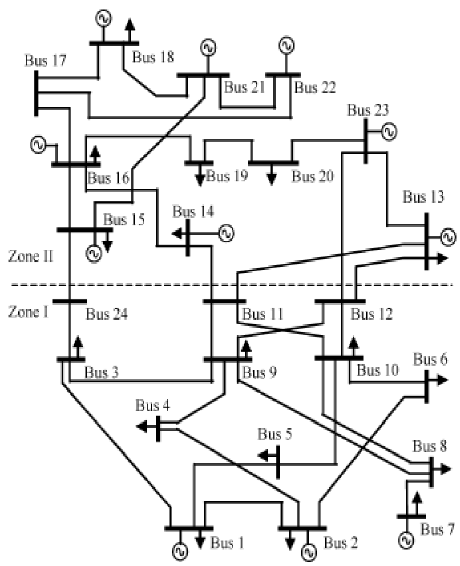

Fig. 2: Sample 24 buses network (Panigrahi and Ravikhumar, 2009)

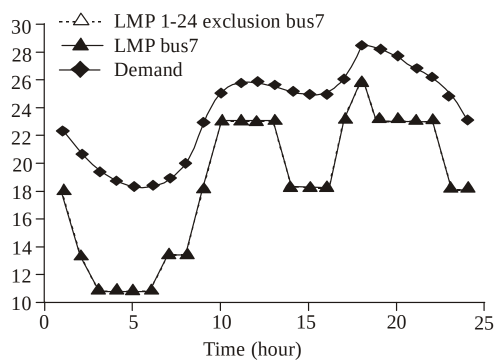

Fig. 3: Plot of marginal price of 24 buses network IEEE with network load (without line limit)

$$S_i(t) = \beta_i + \alpha_i(1 - e^{\frac{-toff}{\tau_i}}).(1 - I_i(t-1)).I_i(t) \quad (16)$$

where, β and α 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. τ_i 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:

$$LMP = -[landa\,eqline + \sum_{1}^{34} PDTE.(landa\,ineqlin)) - \sum_{31}^{68} PDTE.(landa\,ineqlin))] \quad (17)$$

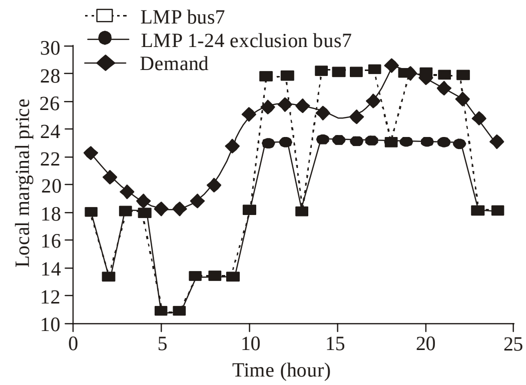

Fig. 4: Plot of comparision of marginal cost of 24 buses network IEEE with network load per unit (by line limit)

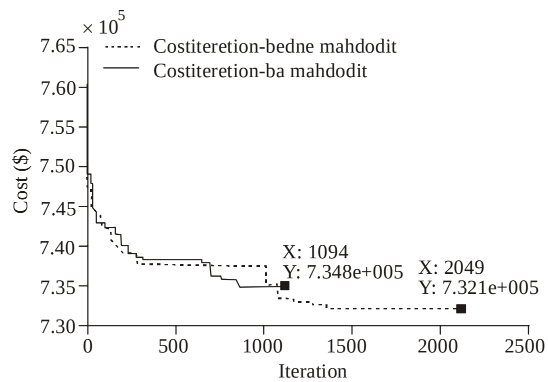

Fig. 5: Comparison of utilization cost of two condition: without limit and by limit

in which landa. equine is the Market Clearing Price (MCP) and Landa. ineqline is the dual of line constrains which if its value is zero, it means that no line is congested and 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:

$$fvalt\cos t = \sum_{i=1}^{ng}(a.P_{Gi}^2 + b.P_{Gi}) + \sum c.I(t)) + \sum((\beta + \alpha..(1 - e^{(toff})).I(1-t) \quad (18)$$

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

Unit	minup (h)	min down (h)	init cond (h)	α_i($)	β_i($)	τ_i($)
1--5	0	0	-1	0	0	1
6--9	0	0	-1	20	20	2
10--13	3	-2	3	50	50	3
14--16	4	-2	-3	70	70	4
17--20	5	-3	5	150	150	6
21--23	5	-4	-4	200	200	8
24	8	-5	10	300	200	8
25--26	8	-5	10	500	500	10

Table 2: System generators information (Panigrahi and Ravikhumar 2009)

Unit	$\underline{p_i}$ (MW)	$\overline{Pi}$ (MW)	a_i (k\$/MW^2)	b_i (k\$/MW)	c_i (k\$)	Bus No
1	2.4	12.0	0.02533	25.5472	24.3891	15
2	2.4	12.0	0.02649	25.6753	24.4110	15
3	2.4	12.0	0.02801	25.8027	24.6383	15
4	2.4	12.0	0.02842	25.9318	24.7605	15
5	2.4	12.0	0.02855	26.0611	24.8882	15
6	4.0	20.0	0.01199	37.5510	117.7551	1
7	4.0	20.0	0.01261	37.6637	118.1083	1
8	4.0	20.0	0.01359	37.7770	118.4576	2
9	4.0	20.0	0.01433	37.8896	118.8206	2
10	15.2	76.0	0.00876	13.3272	81.1364	1
11	15.2	76.0	0.00895	13.3538	81.2980	1
12	15.2	76.0	0.00910	13.3805	81.464	2
13	1.52	76.0	0.00932	13.4073	81.6259	2
14	25.0	100.0	0.00623	18.0000	217.8952	7
15	25.0	100.0	0.00612	18.1000	218.3350	7
16	25.0	100.0	0.00598	18.2000	218.7752	7
17	54.25	155.0	0.0463	10.6940	142.7348	15
18	54.25	155.0	0.0473	10.7154	143.0288	16
19	54.25	155.0	0.00481	10.7367	143.3179	23
20	54.25	155.0	0.0487	10.7583	143.5972	23
21	68.95	197.0	0.00259	23.0000	259.1310	13
22	68.95	197.0	0.00260	23.1000	259.6490	13
23	68.95	197.0	0.00263	23.2000	260.1760	13
24	140.0	350.0	0.00153	10.8616	177.0575	23
25	100.0	400.0	0.00194	7.4921	310.0021	18
26	100.0	400.0	0.00195	75031	311.9102	21

Table 3: Load information in one period 24 h (Ranjbar *et al*., 2008)

Time (h)	Demand (MW)	Time (h)	Demand (MW)
1	2230	13	2565
2	2052	14	2508
3	1938	15	2480
4	1883	16	2480
5	1824	17	2594
6	1825	18	2850
7	1881	19	2821
8	1995	20	2765
9	2280	21	2679
10	2508	22	2622
11	2565	23	2479
12	2593	24	2309

SIMULATION RESULTS

The studied network: To show the results of bacterial foraging algorithm execution a network with 24 busses, 26 production units and 34 standard IEEE line is selected (Fig. 2).

Given the production units and lines information (Table 1) and the units cost functions which exists in ref (Ongsakul and Petcharaks, 2007) and the network load in 24 h which is given in Table 1 and 2. The plan of load dispersal in two conditions:

- Without the line limitation
- By the line limitation

was executed and the following results achived (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)ISO(, we should select optimization parameters mor accurately. In this thesis, parameters amount were chosen as follows: N_{param} = 24, N_{ed} = 10, N_{rep} = 10, C_i = 1, N_s = 50 and N_{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

Fallahi Meyabadi, A. and T. Niknam, 2003. management of electrical energy market in reconstructed power system. Scientific Investigative Bull. Electr., 37: 45-54.

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

Method	Supply cost minimization Problem	Without lineconstraint		With lineconstraint		Time (s)
		Bid cost (\$)	Consumer payment (\$)	Bid cost (\$)	Consumer payment (\$)	
BFO	SCM	7.3261e+5	$1.151019e^{+6}$	7.3610e+5	$1.46531e^{+6}$	363
MFLR	SCM	7.8657	$1.21032e^{+6}$	8.160 e+5	$2.07949e^{+6}$	240

Mozaffari, B. and A. Ranjbar, 2003. The copability to transmit power over reconstructed power system. Sci. Invest. Bull. Electr., 37: 22-31.

Ongsakul, W. and N. Petcharaks, 2007. Fast Lagraian relaxation for constrained generation scheduling in a centralized electricity market. IEEE T. Power Syst., 12(1): 1220-1228.

Panigrahi, B.K. and V. Ravikhumar, 2009. Congestion management using adaptive bacterial foraging algoritm. IEEE T. Power Syst., 25(4): 1202-1209.

Ranjbar, A., A. Khodaei and F. Fallahi, 2008. A new method for calculating ultimate local price in reconstructed power network. 11th Conference of Electrical Engineering, Iran, pp: 422-427.

Yong, F., M. Shahidehpourand and L. Zuyi, 2007. Security-constrained unit commitment with ac constraints. IEEE T. Power Syst., 20(3).