FULL PAPER
International Journal of Recent Trends in Engineering, Vol 2, No. 5, November 2009

Micro Genetic Algorithm based Optimal Power Dispatch in Multinode Electricity Market

S.Surender Reddy[3], P.Praveen[1], M.Sailaja Kumari[2]
[1,2,3] Department of Electrical Engineering,
[2]Email:sailaja_matam@yahoo.com
National Institute of Technology, Warangal
INDIA

***Abstract* --In deregulated environment there exist a number of buyers and sellers. An auction market is one of the competitive electricity market models with an explicit set of rules that determine resource allocations and prices on the basis of bids from market participants. The paper presents the application of the genetic algorithm (GA) to solve the Optimal Power Dispatch (OPD) problem for a multi-node auction market. The OPD problem is a non-linear optimization problem with several constraints. The objective of the proposed GA is to maximize the total participant's benefit at all nodes in the system. The GAs are associated with high processing time. Most GAs produce poor results when populations are small. In contrast, Micro Genetic Algorithms (MGA) explore the possibility to work with small populations in order to reduce the processing time. The proposed algorithm using MGA for OPD of multi-node electricity market is simple to implement and can easily incorporate additional constraints. MGAs are more efficient to solve this kind of problem as they are faster and give nearly global optimal solutions. The developed algorithms are tested on a 17-node, 26-line system.**

***Index Terms*—Multi-node auction market, Optimal power dispatch (OPD) Genetic algorithm (GA), Micro genetic algorithms (MGA), Independent system operation (ISO).**

I. INTRODUCTION

The electricity industries in number of countries have recently been deregulated to introduce competition. In a centralized power industry, the planning is done to minimize the production cost. In a competitive electricity market, generation resources are, scheduled based on offers and bids of the suppliers and consumers. Many approaches have been proposed in literature to solve the optimal power dispatch problem for electricity markets [1,3,4].

One of the competitive electricity market models is the auction market model, in which participants place their bids to sell or buy electricity. In electricity auction market, distribution companies and generation companies submit their bids to an independent system operation (ISO) company. A supply bid is given as a cost per MW and a quantity in MW which a generation company is willing to generate in a particular period. Each generation company may place several bids. A demand bid is given as a cost per MW and a quantity in MW which a distribution company is willing to consume in a particular period. Several demand bids may be placed by each distribution company.

A strong motive for considering auctions for the pricing of electric power is given by the assumption that the electric power industry will move from regulated rate of return pricing to market-based pricing in the near future. This requires consideration of various pricing mechanisms. An additional reason is that the natural gas industry spent much time and effort in researching auction mechanisms for the pricing of natural gas when their industry underwent deregulation. The electric power industry is quite similar to the natural gas industry in that both industries produce, transport and sell their respective commodities. The need for a pricing mechanism coupled with the example of the natural gas industry is sufficient reason for considering auctions in the electric power pricing arena.

The optimal power dispatch models proposed by several researchers [1,3,4] have the objective to maximize the total benefit to the participants in the multi-node auction market. This paper demonstrates the application of MGA to solve the OPD problem for a multi-node auction market. The model used does not directly consider the reactive power market and the transmission cost. The advantage of the proposed MGA is the simplicity of handling non-linear constraints, without having to simplify the power flow constraints. In addition, the algorithm is easy to implement and additional features such as security constraints can be easily incorporated in the algorithm.

II. PROBLEM DESCRIPTION FOR SINGLE NODE ELECTRICITY MARKET

For a single node auction market, the supply and demand curves at each node can be illustrated as shown in fig. 1. The spot price at a single node is the price which matches the supply and demand bids, i.e., the point at which the supply and demand curves intersect each other. At the spot price, the benefit of participants is maximized and is illustrated by the shaded area in Fig.1.

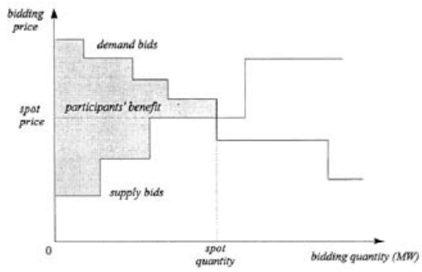

Figure 1. Example of the supply and demand curves

Assuming that there are M_k supply bids and N_k demand bids at the k^{th} node. Let S_{ik} be the i^{th} supply bid at node k and is

ACEEE

© 2009 ACADEMY PUBLISHER

given by $S_{ik} = \{x^s_{ik}, p^s_{ik}\}$, where x^s_{ik} is the selling price an p^s_{ik} is the selling quantity. In addition, let B_{ik} be the i^{th} demand bid at node k and is given by $B_{ik} = \{x^d_{ik}, p^d_{ik}\}$, where x^d_{ik} is the buying price and p^d_{ik} is the buying quantity. If $\hat{x}_k$ denotes the spot price and $\hat{p}_k$ denotes the spot quantity, then the maximum participants' benefit, which is the sum of suppliers' benefit and consumers' benefit can be given as

$$B_k = \sum_{i \in M_k^s} (\hat{x}_k - x_{ik}^s)\tilde{p}_{ik}^s + \sum_{j \in N_k^d} (x_{jk}^d - \hat{x}_k)\tilde{p}_{jk}^d \tag{1}$$

Where $\tilde{p}^d{}_{ik}$ and $\tilde{p}^s{}_{ik}$ are consumer's and supplier's dispatched quantity respectively, M_k^s and N_k^d are the sets of all dispatched suppliers and dispatched consumers respectively.

III. Problem Description for Multi Node Electricity Market

For a multi-node electricity market, there are transmission lines connected between bidding nodes. The connections result in real power P_k and reactive power Q_k injection to the network at each node. The real power injection to a node can be modeled as an additional demand bid (or a supply bid if the real power injection is negative) by the network for the quantity P_k at the selling (or buying) price $\hat{x}_k$, which is equal to the spot price[1]. As an example, Fig. 2 illustrates the dispatch of the bids when the real power injection is considered. In Fig. 2(a), the injection of P_k to the node is supplied by the partly dispatched generator bid. The spot quantity has increased and the price has not changed. If the injected power is greater than the undispatched amount of the partly dispatched supply bid then the additional amount cannot be supplied at the same price. Therefore, the spot price will increase as shown in Fig. 2(b). This will result in displacing some consumers as shown by *dc* in Fig. 2(b). It can be seen in Fig. 2 that the spot price and spot quantity may be changed due to the effect of the real power injection. This may result in changing the sets B_{ik} and S_{ik} of all dispatched suppliers and dispatched consumers. Consequently, the participants' benefit at node k is now given by [1]

$$B_k^{'} = \sum_{i \in \dot{M}_k^s} (\dot{x}_k - x_{ik}^s)\tilde{p}_{ik}^s + \sum_{j \in \dot{N}_k^d} (x_{jk}^d - \dot{x}_k)\tilde{p}_{jk}^d - \dot{x}_k p_k \tag{2}$$

where $\dot{M}_K^S$ and $\dot{N}_K^d$ are the new sets of all dispatched suppliers and dispatched consumers respectively, $\dot{x}_k$ is the new spot price and the last term is the amount paid by the transmission line. In addition, the total participants' benefit at all nodes can be expressed as

$$B_k^{'} = \sum_{k=1}^{K} \left\{ \sum_{i \in \dot{M}_k^s} (\dot{x}_k - x_{ik}^s)\tilde{p}_{ik}^s + \sum_{j \in \dot{N}_k^d} (x_{jk}^d - \dot{x}_k)\tilde{p}_{jk}^d - \dot{x}_k p_k \right\} \tag{3}$$

where K is the number of nodes.

It can be easily seen that the participants' benefit at each node ($B_k{'}$) is a function of the real power injection. Therefore, the optimization problem of the total participants' benefit at all nodes is similar to the conventional optimal load flow problem, with the exception that the objective is to maximize the participants' benefit, rather than minimize the generation cost. This optimization problem can be described as

$$\text{Maximize} \quad \sum_{k=1}^{K} \left\{ \sum_{i \in \dot{M}_k^s} (\dot{x}_k - x_{ik}^s)\tilde{p}_{ik}^s + \sum_{j \in \dot{N}_k^d} (x_{jk}^d - \dot{x}_k)\tilde{p}_{jk}^d - \dot{x}_k p_k \right\} \tag{4}$$

subject to the following constraints:The capacity constraints which provide the limits on real power (p_k) and reactive power (q_k) injection to the network by any node i.e.,

$$\underline{p}_k \le p_k \le \overline{p}_k \tag{5}$$

$$\underline{q}_k \le q_k \le \overline{q}_k \tag{6}$$

Where $\underline{p}_k, \overline{p}_k$ and $\underline{q}_k, \overline{q}_k$ are the minimum and maximum real and reactive power output limits of generators associated with node k respectively. Power flow Constraint is given by (7)

$$\left| p_{kl} \right| \le \overline{p}_{kl} \tag{7}$$

Where $\overline{p}_{ki}$ is the maximum power flow limit in a line *kl*. In addition, the real and reactive power injection at each node can be determined using (8),(9) These are given by

$$p_k = \sum_{\substack{l=1 \\ l \ne k}}^{K} p_{kl} \tag{8}$$

$$q_k = \sum_{\substack{l=1 \\ l \ne k}}^{K} q_{kl} \tag{9}$$

where p_{kl} and q_{kl} are the real power and reactive power flow along the transmission line connecting node k and node l, respectively. Furthermore, the real power and reactive power flow are given by the following equations

$$p_{kl} = G_{kl}(v_k^2 - v_k v_l \cos(\theta_k - \theta_l)) - B_{kl}(v_k v_l \sin(\theta_k - \theta_l)) \tag{10}$$

$$q_{kl} = -B_{kl}(v_k^2 - v_k v_l \cos(\theta_k - \theta_l)) + G_{kl}(v_k v_l \sin(\theta_k - \theta_l)) \tag{11}$$

where G_{kl} and B_{kl} are real and imaginary component of the admittance of the line connecting node k and node l, θ_k and θ_l are angles at node k and l and v_k and v_l are voltages at node k and node l.

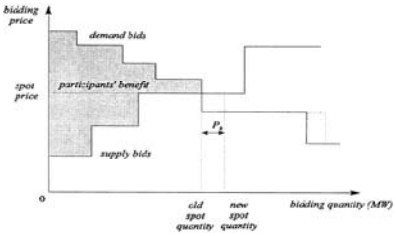

Figure. 2 (a)

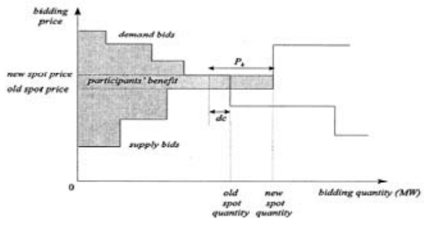

Figure. 2 (b)

Figure 2. Examples of the network effects.

This optimization problem has non-linear constraints which is difficult to solve using the linear programming technique. A GA is proposed in the following section to solve the above

© 2009 ACADEMY PUBLISHER

problem. GAs are simple to implement and additional constraints can be easily incorporated into the problem.

IV. Application of Genetic Algorithms (GA) to Optimal Power Dispatch

The essential schemes need to be designed in order to apply GA to a multi-node electricity market are the encoding scheme, fitness function, crossover method and control parameters.

A. Encoding scheme

The optimization problem considered in this case is to find the spot price and spot quantity at all nodes which maximize the participants' benefit (4). The spot price and quantity at each node depend on the real power (p_k) injection which is in turn depending on the voltage (v_k) and the angle(θ_k). Therefore, a candidate solution at each node can be either an array of the real power and reactive power injection or an array of the voltage and angle. Although an array of random voltages and angles at all nodes may lead to easy evaluation of power flows (10 and 11) and real power injections (8) at all nodes, the evaluated results are unlikely to satisfy the power capacity limit constraints at all nodes and the line capacity constraints at all transmission lines.

On the other hand, with an array of real and reactive power injections, power flows in the network can only be determined via an iterative load flow solution [6], but the power capacity limit constraints can be incorporated into the encoding scheme. Both representations were tried during the early part of our work and it was found that the choice of real power and reactive power is better than voltage and phase angle.

B. Fitness value

The objective function (4) can be used as GA fitness function. Therefore, the fitness value of each chromosome can be determined by

$$F = \sum_{k=1}^{K} \left\{ \sum_{i \in M_k^s} (\dot{x}_k - x_{ik}^s)\,\tilde{p}_{ik}^s + \sum_{j \in N_k^d} (x_{jk}^d - \dot{x}_k)\,\tilde{p}_{jk}^d - \dot{x}_k\, p_k \right\} \qquad (12)$$

In addition, the load flow solution is to be evaluated for each chromosome to ensure that none of the transmission line constraints are violated. In this work, the Fast-Decoupled Load Flow (FDLF) is used to solve the load flow[7]. If a solution violates the power flow limit, a penalty will be assigned to its fitness. This will result in a small fitness value and the violated solution is unlikely to be selected as a parent in the next reproduction process.

C. Crossover and Mutation schemes

Several of the crossover operators include *one point crossover*, *two point crossover* and *uniform crossover*. There is no simple way of choosing the best crossover method; the success or failure of a particular crossover method also depends on the selection of the fitness function and control parameters. A simple mutation method is to randomly toggle the content of each binary bit position in a chromosome.

D. Control Parameters

The performance of the GA also depends on control parameters, such as population size, crossover probability and mutation probability.

V. Application of Micro Genetic Algorithms (MGA) to Optimal Power Dispatch

Most GAs produces poor results when populations are small, because insufficient information is processed about the problem and, as a consequence, premature convergence to a local optimum occurs. Population size generally varies from 30 to 300 individuals. In contrast, MGAs explore the possibility to work with small populations (from five to 20 individuals usually) in order to reduce the processing time. From a genetic point of view, it is known that frequent reproductions inside a small population may disseminate hereditary diseases rarely found in large populations. On the other hand, small populations can act as natural laboratories where desirable genetic characteristics quickly can emerge. In MGAs, mutations are unnecessary because after a certain number of generations, the best chromosome is maintained and the rest are substituted by randomly generated ones. On the other hand, it requires adoption of some preventive strategy against loss of diversity in population.

Basically, two mechanisms are used to prevent loss of diversity in population [12]. First, the individuals are selected (only once) for a tournament where couples are randomly formed to compete between themselves. The most adapted individual of each couple wins. Then, the tournament is repeated and the selected individuals form couples to begin crossover. In this way, not only do the most developed individuals have an opportunity to participate in the reproduction but all of them do. The second mechanism is to insert new individuals each time the population becomes homogeneous. Each time the population reaches a homogeneous degree previously chosen; the best individual is kept and inserted into a new population randomly created. When it occurs, a generation has occurred. If the same individual is the best one along a certain number of generations, the algorithm stops and this individual represents the solution.

A. Micro Genetic Algorithm (MGA) operators

1) Tournament Selection

To increase the diversity of individual population, the tournament selection is used instead of the roulette wheel selection. With the roulette wheel selection, [8] a small population size, can cause the premature (suboptimal) convergence. Using the tournament selection, the diversity of individual population is higher. It is thereby particularly suitable for MGA requiring a small population size.

2) Crossover

In MGA uniform crossover is performed over the entire length of the string of bits.

3) Elitism

In addition to performing the fitness evaluation, tournament selection, and uniform crossover, MGA uses the elitism mechanism. The tournament selection and uniform crossover do not guarantee that the offspring individuals are always better than their parent individuals. Elitism, on the other hand, guarantees that the best string individual survives until the last generation. More specifically, if the best offspring individual is worse than the best parent individual, the best parent individual will randomly replace any offspring individual. That is, the

ACEEE

© 2009 ACADEMY PUBLISHER

offspring individuals in the current generation become parent individuals in the next generation.

B. Convergence Checking

MGA checks for the convergence after applying the elitism mechanism. If the best string individual at each generation, which has the highest fitness value, has the total number of bit difference from the other individuals less than *5%* of the total number of bits in the population size, the MGA algorithm for that population is converged. Then MGA retains the best offspring individual whereas the other offspring individuals are re-initialized. This is because MGA tries to explore a new population, which would result in a higher probability to bail the solutions out of the local optimal solutions towards the optimal solution region.

C. Algorithm for multi node electricity market using MGA

1. Read the system data and GA data.
2. Read the suppliers bidding data and consumers bidding data (quantity of power injection, price).
3. Randomly generate a *p* initial population and go to step8.
4. Randomly generate (p-1) population and add it to the best chromosome from the last generation.
5. Decode the chromosome.
6. The decoded values give the real and reactive power injections at all the buses except slack bus.
7. Run Fast Decoupled Load Flow.
8. Compute power flows through all the lines, real and reactive power injections of slack bus.
9. Evaluate fitness value (total benefit) using (12).
10. Select individuals for reproduction using tournament selection, and apply crossover.
11. Calculate the fitness of the new chromosomes using (12).
12. Repeat steps 10, 11 until the population reaches the homogeneous degree previously chosen.
13. Find the best chromosome, keep it, and discard the others.
14. Repeat steps 4 to 13, until the best individual is identified after a maximum number of generations.
15. Calculate spot price, participants benefit, lines benefit and total benefit at all the nodes.

VI. RESULS AND DISCUSSION

The developed GA and Micro Genetic Algorithm (MGA) have been tested on a 17-node, 26-line system [1]. The objective is to maximize the total participants' benefit at all nodes in the system, which in turn depends on the real power injection to the system. The encoding chromosome consists of 2*10*(*K*- 1) bits, ('K' is the number of nodes), in which each 10-bit binary string is used to represent a range between the maximum and minimum real power (or reactive power) limit at each node. In addition, the real power and reactive power injection at the reference node can be obtained from the load flow solution. Fig. 3. Shows the encoding scheme

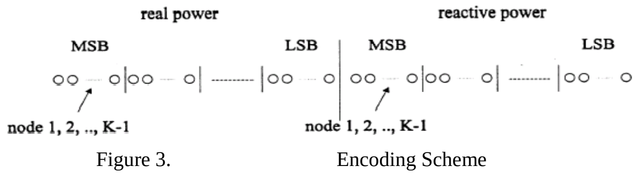

Figure 3. Encoding Scheme

The total participants' benefit is given as a chromosome's fitness and it has been determined by solving the load flow problem. The real power injection at a given node is maximum when all selling bids are dispatched. Therefore the maximum possible injection is equal to the total amount of power offered by suppliers at that node. Similarly, the minimum power injection (i.e. maximum negative injection) is when no selling bids are dispatched and all buying bids are dispatched. In this case, it is equal to the total amount of power bid by the consumers.

A. Optimal Power Dispatch using GA

The GA approach uses a population size of 40, probability of elitism 10%, uniform crossover with probability is 0.7, and mutation probability is 0.01. Table I gives the power injections, voltage and phase angles at all nodes using GA.

TABLE I. POWER INJECTION, VOLTAGE AND PHASE ANGLES

Node	P(MW)	Q(MVAR)	Voltage(V)	Angle(deg.)
1	162.00	139.51	1.05	7.00
2	281.34	11.72	1.05	8.99
3	-51.16	-38.19	1.049	6.92
4	-123.55	-39.37	1.05	6.90
5	46.40	-36.98	1.05	5.18
6	15.23	30.54	1.05	3.47
7	234.84	81.92	1.05	2.50
8	-156.52	-85.05	1.05	1.72
9	-35.0	-2.17	1.042	2.42
10	-3.26	12.99	1.05	1.67
11	-234.14	-160.73	1.05	1.32
12	231.23	363.40	1.05	1.82
13	-113.96	-60.97	1.05	1.76
14	-30.10	-5.26	1.041	0.751
15	-437.96	-158.88	1.05	0.58
16	443.20	126.14	1.05	4.24
17	-213.00	-310.80	1.0	0.0

TABLE II. PARTICIPANTS BENEFITS AND SPOT PRICES

Node	With Network Effect			
	Spot price ($/MW)	*Total benefit($)*	*Participant's benefit($)*	*Line's benefit($)*
1	1.14	-170.08	14.60	-184.68
2	1.20	118.98	456.60	-337.61
3	1.10	72.48	16.20	56.28
4	1.20	161.66	13.40	148.26
5	1.10	-42.74	8.30	-51.04
6	1.20	-7.68	10.60	-18.28
7	1.10	2.42	260.75	-258.32
8	1.20	204.72	16.90	187.82
9	1.20	44.7	2.70	42.00
10	1.20	21.71	17.8	3.91
11	1.20	333.16	52.20	280.96
12	1.20	-245.67	31.80	-277.47
13	1.20	177.25	40.50	136.75
14	1.20	40.82	4.70	36.12
15	1.20	640.16	114.60	525.56
16	1.20	-373.94	157.90	-531.84
17	1.20	295.90	40.30	255.60
Total		**1273.88**	**1259.85**	**14.03**

Table II presents the Participants benefits and spot prices at all nodes. The results show that the proposed algorithm provides a good solution.

B. Optimal Power Dispatch using MGA

With MGA the population size is 5, the best fit chromosome is copied in elitism operation and the crossover probability is 1.

ACEEE
© 2009 ACADEMY PUBLISHER

Table III gives the power injection, voltage and phase angle results, and Table IV presents the Participants benefit and spot prices at all nodes using MGA.

TABLE III. POWER INJECTION, VOLTAGE AND PHASE ANGLES

Node	P(MW)	Q(MVAR)	Voltage(V)	Angle(deg.)
1	141.23	146.31	1.05	7.50
2	285.74	-26.06	1.05	9.62
3	-65.20	-34.38	1.049	7.44
4	-129.90	-58.35	1.05	7.49
5	44.24	-20.01	1.05	6.03
6	47.98	10.50	1.05	4.73
7	235.83	47.64	1.05	3.59
8	-169.88	-108.78	1.05	2.93
9	-12.55	11.59	1.052	3.71
10	35.86	-4.64	1.05	3.45
11	-217.35	-135.77	1.05	2.37
12	229.53	374.76	1.05	2.83
13	-113.78	-73.16	1.05	2.54
14	-30.49	-19.03	1.039	1.63
15	-401.66	-195.50	1.05	1.37
16	439.64	105.40	1.05	4.84
17	-303.84	-297.48	1.0	0.0

TABLE IV. PARTICIPANTS BENEFITS AND SPOT PRICES

Node	With Network Effect			
	Spot price ($/MW)	*Total benefit($)*	*Participant's benefit($)*	*Line's benefit($)*
1	1.14	-146.40	14.60	-161.00
2	1.20	113.70	456.60	-342.89
3	1.10	87.92	16.20	71.72
4	1.20	169.28	13.40	155.88
5	1.10	-40.37	8.30	-48.67
6	1.20	-46.98	10.60	-57.58
7	1.10	1.32	260.75	-259.42
8	1.20	220.75	16.90	203.85
9	1.20	17.77	2.70	15.07
10	1.20	-25.23	17.80	-43.03
11	1.20	313.02	52.20	260.82
12	1.20	-243.63	31.80	-275.43
13	1.20	177.04	40.50	136.54
14	1.20	41.28	4.70	36.58
15	1.20	596.60	114.60	482.00
16	1.20	-369.67	157.90	-527.57
17	1.20	404.91	40.30	364.61
Total		**1271.33**	**1259.85**	**11.48**

C. Comparision of GA and MGA

For the given system the benefit for the single node market without the network effect is 651.56$.

Table V shows the comparison of total benefit using GA and MGA for OPD in multi node electricity market. It shows the MGA can obtain better optimal solution in minimum time compared to GA. Fig. 4 shows the variation of error with generations for GA and MGA algorithms.

TABLE V. COMPARISON OF GA AND MGA

Algorithm	Total benefit	Execution time(sec)
GA	1273.88	8.610
MGA	1271.33	1.672

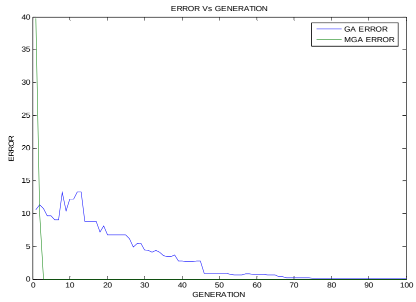

Figure 4. Graph of Error Vs Generation.

VII. CONCLUSIONS

This paper presented GA and MGA approaches for solving the optimal power dispatch in a multi-node electricity market. The objective of the algorithm is to maximize the total participants' benefit at all nodes in the system.

GAs are inspired by nature, and have proved themselves to be effective solutions to optimization problems. However, these techniques are not a panacea, despite their apparent robustness. Their slow convergence is a hindrance when applied to a real time system studies. Any improvement in the convergence of such algorithms is appropriate as far as the real time studies are concerned. MGAs are more efficient to solve this kind of problems, as they are faster and converge to better optimal solutions.

REFERENCES

[1] T. Numnonda, U.D. Annakkage, "Optimal power dispatch in multinode electricity market using genetic algorithm", Elect. Power Syst. Res. 49 (1999) pp 211–220.

[2] R.A.S.K. Ranatunga, U.D. Annakkage, N.C. pahalawaththa, C.S. Kumble, "A Case Study of Network Characteristics Based Optimal Pricing and Dispatch", IEEE Trans. Power Syst. (1999) pp 190–196.

[3] D.L. Post, S.S. Coppinger, G.B. Sheble, "Application of auctions as a pricing mechanism for the interchange of electric power", IEEE Trans. Power Syst. 10 (1995) pp 1580–1584.

[4] R.W. Ferrero, S.M. Shahidehpour, "Optimality conditions in power transactions in deregulated power pools", Elect. Power Syst. Res. 42 (1997) pp 209–214.

[5] T.T. Maifeld, G.B. Sheble, "Genetic-based unit commitment algorithm", IEEE Trans. Power Syst. 11 (1996) pp 1359–1370.

[6] S.O. Orero, M.R. Irving, "Economic dispatch of generators with prohibited operating zones:: A genetic algorithm approach", IEE Proc. Gener. Trans. Distrib. 143 (1996) pp 529–534.

[7] J. Arrilaga, C.P. Arnold, Computer Analysis of Power Systems, Wiley, New York, 1990.

[8] D.E. Goldberg, Genetic Algorithms in Search, Optimisation and Machine Learning, Addison-Wesley, Reading, MA, 1989.

[9] Kankar Bhattacharya, Math H.J. Bollen, Jaap E. Daadler, Operation of restructured power systems, Kluwer Academic Publishers, 2001.

[10] B.A. de Souza, H. do Nascimento alves, H.A. Ferreria, "Microgenetic algorithms and Fuzzy logic applied to the optimal placement capacitor banks in distribution networks", IEEE Trans. Power Syst., Vol. 19, No.2 (2004), pp 942-947.

[11] M. Delfanti, P. G. Granelli, P. Marannino, and M. Montagna, "Optimal capacitor placement using deterministic and genetic algorithms," IEEE Trans. Power Syst., vol. 15, pp. 1041–1046, Aug. 2000.

[12] W. Ongsakul and J. Tippayachai, "Micro genetic algorithm based on migration and merit order loading solutions to the constrained economic dispatch problems," Elect. Power Energy Syst., vol. 24, pp. 223–231, 2002.

ACEEE

© 2009 ACADEMY PUBLISHER