International Journal of Ethics in Engineering & Management Education
Website: www.ijeee.in (ISSN: 2348-4748, Volume 1 Issue 7, July 2014)

Micro Genetic Algorithm Based on Pricing of Reactive Power Service in Deregulated Electricity Markets

Ramesh Babu Jarapala
Abhinav Hi-tech college of Engg
Hyderabad, Telangana-India
babu.ramesh444@gmail.com

Bhumaiah Jula
Abhinav Hi-tech college of Engg
Hyderabad Telangana-India
bhumeshjula@gmail.com

Ramesh Jatoth
Methodist College Of Engg & Tech
Hyderabad, Telangana-India
ramesh.jatoth@gmail.com

***Abstract*—This study presents a new evolutionary method for reactive power pricing based on optimal power flow. Adequate reactive power is one of the most important parameters for secure operation of power system. In restructured electricity market, power system is operated near its secure boundaries in order to maximize social welfare. So Appropriate and accurate pricing of this service, can be very considerable in this environment. The main purpose of this paper is usage of Micro Genetic Algorithm method for determination active and reactive power prices produced by generators, based on Locational Marginal Price (LMP). The proposed method has been applied on IEEE 14 bus system and compared with GA**

***Index Terms*— Reactive power pricing, Micro genetic algorithm, genetic algorithm, locational marginal price, restructured power market.**

I. INTRODUCTION

II. Because of competitive structure of energy markets, reduction of regulations in load area and more motivation for using available transmission systems facilities, power system is utilized near its secure boundaries. Considerably ancillary services that provide reliability and voltage security become very important in deregulated environment. Reactive power is one of the most important ancillary services in power system because during normal operations, it is required to maintain the necessary balance between generation and load in real time, to maintain voltages within the required ranges and to transmit active power. Therefore Reactive power value and its influence on system stability, especially during hard and congested conditions, can be very high [1]. Lack of reactive power can make voltage collapse that it is the main reason of recent widespread power outages worldwide such as one occurred in the United States and Canada in 2003 [2].

III. Appropriate and accurate pricing of this service not only covers the costs of reactive power supplying and provides incentives for investment of reactive power equipment so as to maximize overall social welfare, but also gives useful information about necessity of reactive power supporting and voltage control to system operator.

IV. Until now different pricing methods is proposed for pricing this service but some of the proposed methods are usually difficult and hard in practice. Reference [3] presents the analysis of the dominant component determined from the opportunity costs of a generator in the real power markets in the cost structure of this service. Reference [4] suggests a new approach for reactive power pricing that is especially suitable for a power market using pool model. Reference [5] devises a scheme enforced capital investmenton the needed services. In that scheme reactive support of generators is divided into two functions: reactive power delivery and voltage control. reactive power costs [6]. Reactive power pricing is principally based on the costs of reactive power providing that it can be achieved directly by determining marginal cost of reactive power or from market by using supply and demand curve [1]. In mentioned paper the combined reactive power market model is proposed for reactive power pricing. Spot pricing theory which its purpose is maximizing social welfare is proposed by F. C. Shewepp and et al. [7].In that paper for the first time marginal price concept from microeconomics introduced in power systems and used in electricity spot pricing. Nodal pricing among the other schemes based on locational marginal costs of system is most considerable. With nodal pricing of reactive power, prices at each node on a network reflect the marginal cost of generating that power. To estimate these costs, Optimal Power Flow (OPF) which its goal is minimization system operational costs subject to system operational constrains, is used. Two algorithms for solving optimal power flow (OPF) have been presented by [8]: genetic algorithm and ant colony algorithm.

V. In this study, a new approach based on Locational Marginal Price (LMP) for solving OPF in order to minimize objective function and therefore maximize social welfare is presented which results LMP of those powers in each node of system. The objective function is including cost of active and reactive powers produced by generators. The mentioned method is studied on 14-bus IEEE standard network and the results are compared to Genetic algorithm to approve these results are reasonable and practical.

II. MICRO GENETIC ALGORITHM

Genetic algorithms are simple, robust, flexible, and able to find the global optimal solution. They are especially useful in finding solution to problems for which other optimization techniques encounter difficulties [112]. A basic genetic algorithm is constituted by a random creation of an initial population and a cycle of three stages, namely:

International Journal of Ethics in Engineering & Management Education
Website: www.ijeee.in (ISSN: 2348-4748, Volume 1 Issue 7, July 2014)

- evaluation of each chromosome;
- chromosomes selection for reproduction;
- genetic manipulation to create a new population, which includes crossover and mutation. Each time, this cycle is completed, it is said that a generation has occurred.

A. Standard Micro genetic algorithm

The disadvantage of GAs is the high processing time associated. That is due to their evolutionary concept, based on random processes that make the algorithm quite slow. However, different methods for reducing processing time have already been proposed, such as more appropriate choice of solution coding and reduction of search space using the specialist knowledge. One alternative method known as microgenetic algorithms, whose processing time is considerably smaller, is shown in [12] .

Most GAs produce 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.

The MGA implemented in the present work is reported in the following algorithm:

1) Select a population of n randomly generated individuals. Alternatively, n-1 individuals may be generated randomly together with one good individual obtained from previous search
2) Evaluate fitness and determine the best individual which is always transferred to the next generation. This “elitist” strategy guarantees against the loss of good information embedded in the best individual produced thus far
3) Select individuals for reproduction with the tournament selection strategy (for example with k=2)
4) Apply crossover with probability equal to 1 to favor exchange of genetic information among the population
5) Check for convergence by measuring the amount of diversity left in the population (by counting the total number of bits which are unlike those possessed by the best individual). If population diversity has fallen under a preselected threshold, go to Step 1; otherwise, go to Step 2.

OPF problem is a nonlinear optimization problem whichits goal is minimizing objective function subject to equality and inequality constrains. There are many methods to optimize non linear problems. In this study Micro genetic algorithm(MGA) is applied in solving the OPF problem.

B. Objective Function

As presented in (1), objective function used in this case consists of active and reactive power production cost produced by generators. Consider a network that in it *N* and *Ng* are number of buses and number of generator buses respectively.

$C = \sum_{i=Ng}(c_{gpi}(P_{Gi}) + c_{gqi}(Q_{Gi}))$…………………(1)

Subject to power flow equality and inequality constrains:

$P_{Gi} - P_{Di} = \sum_{q=2}^{n} |v_i||v_i||Y_{ij}|\, Cos\,(\theta_{ij} + \delta_i - \delta_j) = 0$ ………(2)

$Q_{Gi} - Q_{Di} = \sum_{q=2}^{n} |v_i||v_i||Y_{ij}|\, Sin\,(\theta_{ij} + \delta_i - \delta_j) = 0$ ………(3)

$P_{Gi}^{min} \le P_{Gi} \le P_{Gi}^{max}$ ………(4)

$Q_{Gi}^{min} \le Q_{Gi} \le Q_{Gi}^{max}$ ………(5)

$V_{Gi}^{min} \le V_{Gi} \le V_{Gi}^{max}$ ………(6)

$P_{ij} \le P_{ij}^{max}$ …………………(7)

Where

P_{Gi}, Q_{Gi} real and reactive power generation at i^{th} bus

P_{Di}, Q_{Di} real and reactive power demand at i^{th} bus

$c_{gpi}(P_{Gi})$ active power cost function in i^{th} bus

$c_{gqi}(Q_{Gi})$ reactive power cost function in i^{th} bus

For computing Cost function of active power (8) is regarded.

$c_{gpi}(P_{Gi}) = aP^{n}_{Gi} + bP + c$…………………(8)

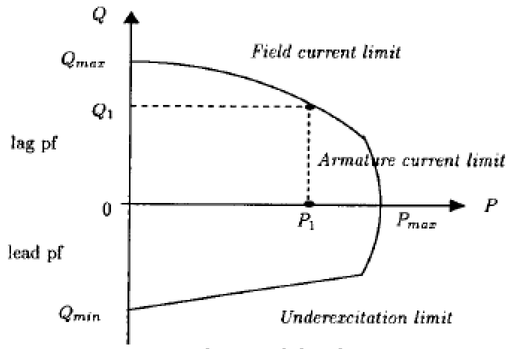

Fig. 1. Loading capability diagram.

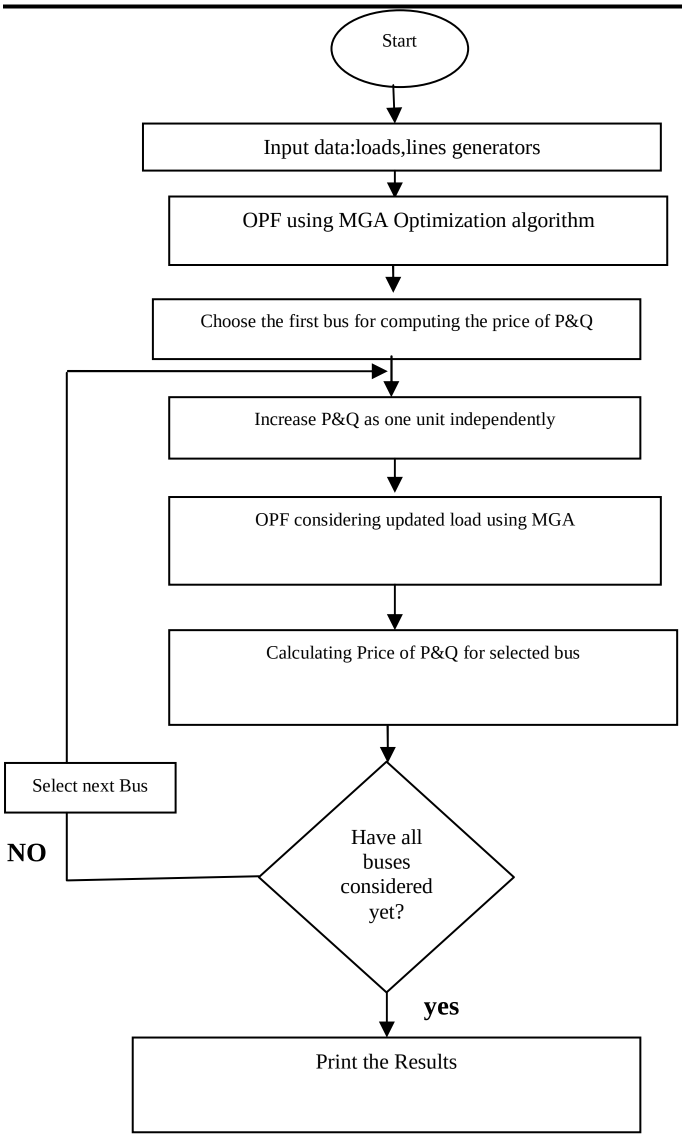

Fig. 2. The flow chart of active and reactive power pricing

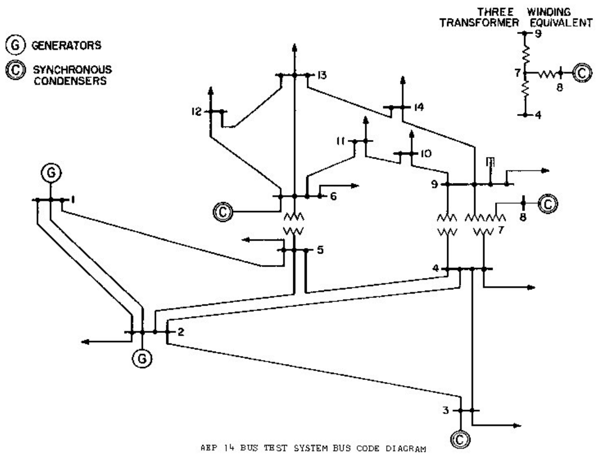

Fig. 3. IEEE14-Bus system

Cost function for reactive power produced by generator is based on opportunity cost deduced via loading capability diagram shown in Fig. 1. Essentially opportunity cost is based on market process, but since it is hard to determine its precise and exact value, in this paper its simplest form is used where *Gi Q* and *Gi*,max *S* are reactive power of generator in *ith* bus and maximum apparent power in *ith* bus, respectively. *K* is reactive power efficiency rate which is usually between 5-10% which in this paper *K* = 5% is considered

$$C_{gq}(Q_{Gi}) = [C_{gpi}(S_{Gi,\max}) - C_{gpi}\, srqroot\, (S_{Gi,\max}2 - (Q_{Gi})2)$$

..9

C. Flowchart and methodology

In this paper Locational marginal price (LMP) method is used for active and reactive power pricing. As illustrated in Fig. 2 Active power prices in each bus is determined from difference between optimum cost while constant loading and optimum cost while active power demand increases 1MW in subjected bus. Reactive power prices in each bus is determined from difference between optimum cost while constant loading and optimum cost while reactive power demand increases 1MVAr in subjected bus.

III. TEST RESULTS

MGA optimization method has been applied on IEEE14 bus system which its single lines diagram shown in Fig. 3.Table I and Table II list the line parameters of network and characteristics of the network loads, respectively. Cost function coefficients of active power production by generators are in Table III. In this study mentioned objective function is calculated for 3 cases:

1) By the system base load that totally is 259 MW and 73.5 MVAr.

2) 40 MVAr reactive powers in bus 2, 3, 4 and 50MVAr in bus 5 are injected. These buses are selected because they consume more VAr in respect of others.

3) Active demand loads in all buses are increased by 1.2.

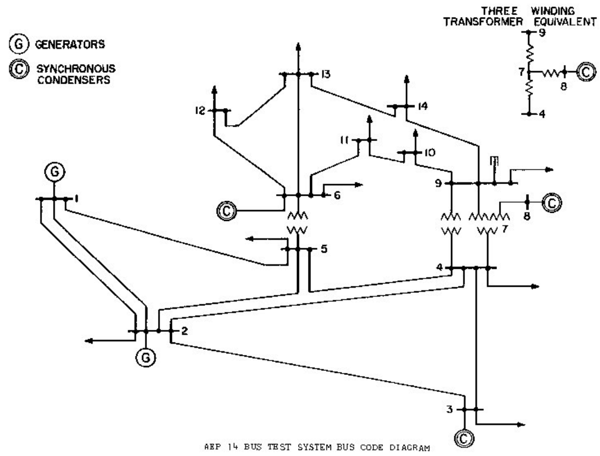

Fig. 3. IEEE 14-bus system.

International Journal of Ethics in Engineering & Management Education
Website: www.ijeee.in (ISSN: 2348-4748, Volume 1 Issue 7, July 2014)

Then the determined prices by MGA optimization method are compared with those are calculated by Genetic (GA) method in Table IV where parameter λ presents the price of active and reactive power produced by generators. Case 2 declares when reactive power is injected to system in critical buses the price of active power is reduced but in this system the prices of reactive power is nearly constant in respect of case 1. Case 3 shows that, in this network, when active demands are increased, the prices of generator active power are increased too. As can be seen the result determined by MGA optimization method are reasonable and approximately equal to ones determined by GA

TABLE I INE PARAMETERS OF 14 BUS IEEE NETWORK

Line no.	From node	To node	R(pu)	X(pu)	Yc(S)
L1	1	2	0.01938	0.05917	0.0528
L2	2	3	0.04699	0.19797	0.0492
L3	2	4	0.05811	0.17632	0.0438
L4	1	5	0.05403	0.22304	0.034
L5	2	5	0.05695	0.17388	0.0346
L6	3	4	0.01335	0.04211	0.0128
L7	4	5	0.0.01335	0.04211	0
L8	5	6	0.0	0.25202	0
L9	4	7	0.0	0.20912	0
L10	7	8	0.0	0.17615	0
L11	4	9	0.0	0.55618	0
L12	7	9	0.0	0.11001	0
L13	9	10	0.03181	0.08450	0
L14	6	11	0.09498	0.19890	0
L15	6	12	0.12291	0.25581	0
L16	6	13	0.06615	0.13027	0
L17	9	14	0.12711	0.27038	0
L18	10	11	0.08205	0.19207	0
L19	12	13	0.22092	0.19988	0
L20	13	14	0.17093	0.34802	0

TABLE II LOAD CHARACTERISTICS

Bus	Active Power(MW)	Reactive Power(MVAr)
1	0	0
2	21.7	0
3	94.2	0
4	47.8	0
5	7.6	0
6	11.2	0
7	0	0
8	0	0
9	29.5	0
10	9	0
11	3.5	0
12	6.1	0
13	13.5	0
14	14.9	0

TABLE II GENERATORS CHARACTERISTICS

Generator	A($/H)	b($/H)	c($/H)	Pmax(MW)	Pmin(Mw)
1	0.11	2	150	332.4	0
2	0.25	5	225	140	0
3	0.09	1.2	600	100	0
6	0.04	1	335	100	0
8	0.10	3	400	100	0

TABLE IV RESULT AND COMPARISON

	Case-I		Case-II		Case-III	
Mincost($/H)	MGA	GA	MGA	GA	MGA	GA
λ($/HMW)	3441.9	3440.1	3446.1	3435.9	4137.7	4136.01
λ($/HMW)	11.6	11.62	10.13	11.71	14.50	15.48
λ($/HMW)	11.66	11.75	10.27	11.68	14.78	14.77
λ($/HMW)	11.86	12.03	10.29	11.93	15.07	15.14
λ($/HMW)	11.32	11.41	10.02	11.48	14.41	14.40
λ($/HMWr)	12	11.91	10.39	11.97	14.95	14.99
λ($/HMWr)	0.18	0.334	1.52	0.17	0.13	0.31
λ($/HMWr)	0.08	0.325	1.96	0.38	0.15	0.33
λ($/HMWr)	0.12	0.268	1.84	0.22	0.13	0.27
λ($/HMWr)	0.18	0.012	1.61	0.093	0.16	0.021
λ($/HMWr)	0.02	0.213	1.68	0.095	0.287	0.2414

IV. CONCLUSION

This paper use Micro genetic algorithm method for solving Optimal Power Flow (OPF) in order to minimize the objective function which consists of active and reactive power costs produced by generators. Particle swarm optimization is a very simple algorithm that appears to be effective for optimizing a wide range of functions [9]. This approach has been applied on IEEE 14 bus system. The simulation results of this work in comparison with Genetic algorithm show that the method is physically reasonable and its implementation is simpler than other optimization methods such as GA. The presented technique can also be applied to manage and set the price of the reactive power supplied by other sources than generators and in different market types

REFERENCES

[1]. M. Sedighizadeh, A. Rezazadeh and M. Seyed Yazdi"Pricing of Reactive Power Service in Deregulated Electricity Markets Based on Particle Swarm Optimization, International Journal of Computer and Electrical Engineering,Vol.2, No.6, December, 2010 1793-8163.

International Journal of Ethics in Engineering & Management Education
Website: www.ijeee.in (ISSN: 2348-4748, Volume 1 Issue 7, July 2014)

[2]. G R. Deksnys, R. Staniulis, "Pricing of Reactive Power Service," Oil Shale, Estonian Academy Publishers, Vol. 24, No. 2 Special, pp. 363–376, April 1955.
[3]. Principle for Efficient and Reliable Reactive Power Supply and Consumption. FEDERAL ENERGY REGULATORY COMMISSION, STAFF REPORT, Feb. 2005.
[4]. S.N. Khalid, M.W. Mustafa, H. Shareef, A. Khairuddin, "Unbundled Reactive Support Service: Key Characteristics and Dominant Cost Component," Universities Power Engineering Conference, Australasian 9-12, pp.1 – 6, Dec. 2007.
[5]. Y. Zhao, M.R. Irving, Y. Song, "A cost allocation and pricing method for reactive power service in the new deregulated electricity market environment," IEEE/PES transmission and Distribution Conference & Exhibition: Asia and Pacific, pp. 1-6, 2005.
[6]. G. M. Huang, H. Zhang, "Pricing of generators reactive power delivery and voltage control in the unbundled environment," IEEE, Transactions on Power Systems, Vol. 15, pp. 1226-1231, 1998
[7]. J. W. Lamont and J. Fu, "Cost analysis of Reactive Power Support," IEEE Transactions on Power Systems, Vol. 14, pp. 890-898, 1999.
[8]. F. C. Schwepp.e, M. C. Caramanis, R. D. Tabors, R. E. Bohn, "Spot Pricing of Electricity," Kluwer Academic Publishers, 1988
[9]. T. Niknam, H. Arabian and M. Mirjafari, "Reactive Power Pricing in Deregulated Environments Using Novel Search Method," Proceedings of the Third International Conference on Machine Learning and Cybernetics, Shanghai, 26-29 August 2004.
[10]. J. Kennedy, R. C. Eberhart, and Y. Shi, "Swarm intelligence," San Francisco, CA, USA: Morgan Kaufmann Publishers Inc., Mar. 2001.
[11]. G.K. Venayagamoorthy, R.G. Harley, "Swarm intelligence for transmission system control," Power Engineering Society General Meeting, IEEE, pp. 1-4, 2007.
[12]. V. Kranthi Kumar1, J. Ramesh Babu2 and M. Ramesh3 "Micro Genetic Algorithm Based Electrical Power Dispatch for Deregulated Electricity Market," Advance in Electronic and Electric Engineering.ISSN 2231-1297, Volume 3, Number 6 (2013), pp. 739-746.

About the Authors:

Ramesh babu Jarapala received his B.Tech degree in Electrical and Electronics Engineering and M.E in Power system from University College of Engineering, Osmania University , Hyderabad, Telangana, India, in 2007 To 2009 respectively. 2009 to 2012, he is Assistant Professor in KSIT Engineering college, since 2012 to Till date AHTC and PBIT engineering college in Hyderabad Telangana.

Bhumaiah Jula received his B.Tech degree in Electrical and Electronics Engineering and M.Tech in Power Electronic from Vardhaman College of Engineering, JNT University , Hyderabad, Telangana, India, in 2010 to 2012 respectively. since 2012 he is Assistant Professor AHTC and PBIT engineering college in Hyderabad Telangana.

Ramesh Jatoth received his B.Tech degree in Electrical and Electronics Engineering and M.Tech in Power System from NIT calicut, Kerala, India, in 2008 to 2010 respectively. since 2014 he is Assistant Professor Methodist College Of Engineering &Tech Hyderabad, Telangana-India