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Reactive Power Pricing Issues in Restructuring Power System

Divya Chaudhari[1], Balram Patel[2]

[1]*P.G Student,* [2]*Assistant Professor, Electrical Engineering Department*
Parul Institute of Engineering and Technology

Abstract — *Voltage control is an inherent part of power system operation. Due to the tight coupling between reactive power and voltage magnitude, reactive support is the means used to maintain the desired voltage profile. The reactive power is treated as a service whose purpose is to support system reliability and security. Reactive power is an important support service in the current power market. Power producers or generators have the opportunity to offer this service to make a profit so reactive power pricing is necessary in electricity markets. A review of the important issues of reactive power support, cost analysis, reactive power pricing is shown in this paper. An IEEE-14 bus system is used for the Optimal Power Flow using MAT power.*

Keywords- Reactive Power, Voltage Control, Ancillary Services, Electricity markets, Pricing

I. INTRODUCTION

Elements of AC systems consists two kinds of power: active power and reactive power. Reactive power is required for transmission of active power, control of voltage and system and normal operation of power systems. Therefore reactive power service is one of the most important ancillary services in electricity market [1]. Currently electric power systems all over the world are moving from a regulated environment based upon traditional vertically integrated utilities so It is needed to address the issues related to reactive power in electrical services [6].

Reactive power support may be provided by a variety of devices, including generators, synchronous condensers, shunt capacitors and reactors and static VAR compensators (SVCs). In the deregulated power system, these all devices have their own prices and advantages [8]. In the competitive electricity energy markets, the supply of reactive power is important support services. If the supply of reactive power is insufficient, it can be lead to the power system voltage stability problem and system loss. The reactive power support which is necessary to maintain the voltage profile and stability of the system and also affects the active power transmission capability of a network is one of the ancillary services [7]. At present, cost of reactive power support in transmission system is usually recovered from transmission charge. However cost recovery of the reactive compensators should be separated from the transmission charges in order to improve the competence in the future design of reactive market [3].

II. REACTIVE POWER ISSUES

A. Reactive Power Cost

The two classes of costs in the reactive support are the fixed costs and the variable costs. The fixed costs are the investment costs for the equipment and do not depend on the quantity produced. Fixed cost is the primary investment of equipments. Fixed costs are costs that are independent of output. Generators, are producing real power, they play an important role in all other types of ancillary services [9]. Variable costs in economics are those costs related to the output. The variable costs involved in reactive power production and absorption by a generator include maintenance and opportunity cost [9].

Opportunity cost is taken as the most important part of reactive power cost. The generation capacity of generators is limited by the synchronous generator armature current limit, field current limit, and under-excitation limits as shown in Figure 1. Because of these limits, the generation of reactive power may require a reduction of real power output [3-4]. The generator is entitled to receive payment with its opportunity cost of reduced real power generation [4].

B. Voltage Control and Reactive Power

Voltage control and reactive-power management are two aspects of a single activity that both supports reliability and facilitates commercial transactions across transmission networks [6]. On an alternating-current (AC) power system, voltage is controlled by managing production and absorption of reactive power [10]. There are three reasons why it is necessary to manage reactive power and control voltage.

1. Both customer and power-system equipment are designed to operate within a range of voltages, usually within ±5% of the nominal voltage. At low voltages, many types of equipment perform poorly; light bulbs provide less illumination, induction motors can overheat and be damaged, and some electronic equipment will not operate at. High voltages can damage equipment and shorten their lifetimes.

2. Reactive power consumes transmission and generation resources. To maximize the generation of active power that can be distributed across a congested transmission interface, reactive power can be minimized. Same as reactive-power production can limit a generator's real-power capability.

3. Moving reactive power on the transmission system incurs real-power losses. Both capacity and energy must be supplied to replace these losses.

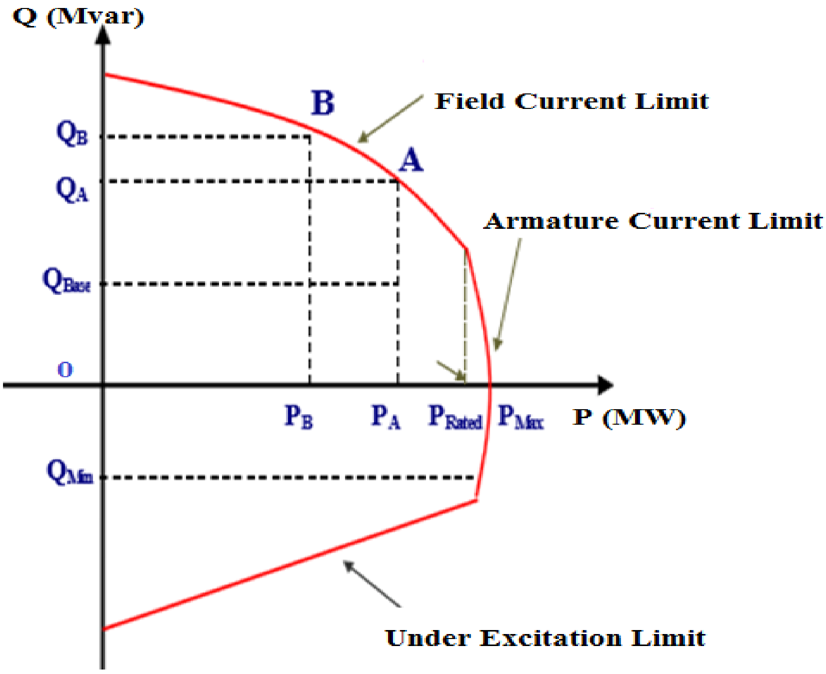

Figure 1. Synchronous generator capability curve

C. Reactive Power Pricing

Reactive power pricing and remuneration should be designed to encourage two efficient outcomes. First, it should encourage efficient and reliable investment in the structure needed to sustain the reliability of the transmission system. Second, it should supply incentives for the reliable and efficient generation and consumption of reactive power from the existing structure, taking into consider the opportunity costs [3]. The important of any pricing system allows the system operator real-time control over reactive power resources.

Reactive power pricing in real time shows the important service of supplying information to both the utility and customers about the true burden on the system in terms of the cost and other system parameters viz. voltage drop and increases transmission losses from time to time [4]. Real time pricing of reactive power has been shown to perform better than power factor penalty scheme in terms of providing incentive to all customers to reduce their consumption of reactive power irrespective of their power factor. In other words Reactive Power Pricing is a fair chance of earning normal profits. Reactive power pricing also provide signals that encourage customer to make efficient choice about how they use or consume reactive power [7].

D. Reactive Power Market

To set up a competitive reactive power market is the most effective way to upgrade the social welfare. By making price more clear, it may further more efficiencies in the generation and consumption of reactive power. The purpose of unbundling reactive power services is about how reactive power generation should be organized and priced, and how reactive power prices should be remunerated from consumers. A societal advantage function is maximized for the ISO to find out how to procure reactive power service from the providers. A compromise function consider total payment, system loss and transaction curtailment [3-4].

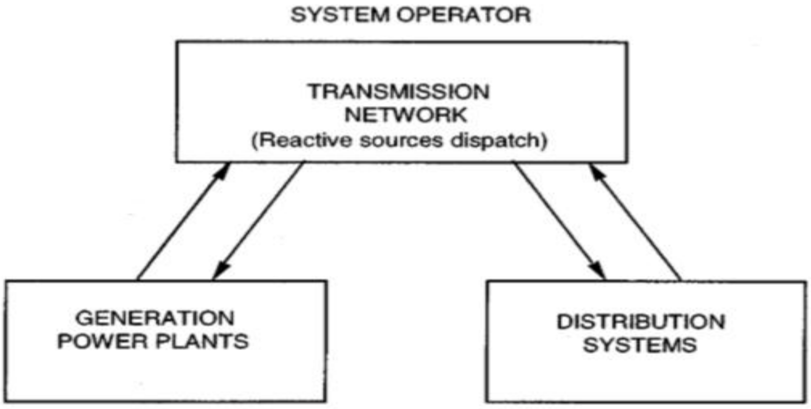

Figure 2. Reactive power market

III. OPTIMAL POWER FLOW RESULTS

In the power system production business has become a reality due to the restructuring of electricity industries. Active power provided by power producers has become a commodity. The reactive power is treated as a service whose purpose is to support system security. Transmission system operators procure reactive power support service at a cost. Each generator should provide a certain amount of reactive power to support its own active power selling activity.

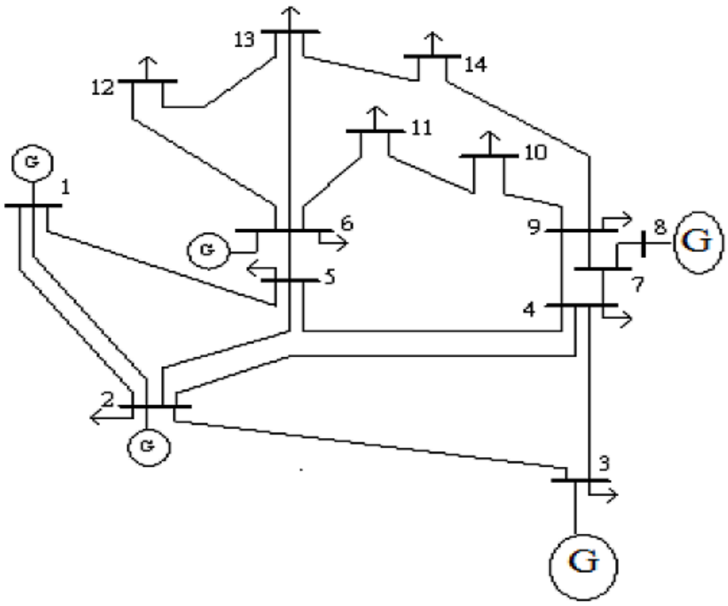

Figure 3. Single line diagram for IEEE 14 bus

Consider Figure 3 representing a standard IEEE 14 Bus single line diagram. 5 Generators are connected to 5 buses. For a given system load, total system generation cost should be minimum. By using the MAT power the optimal power flow done on this system. From the optimal power flow of the test system we observe the generation of active power, reactive power, system loss, total loss, voltage magnitude and cost on the generator 2-3 and bus 2-3. By injecting reactive power on generator 2 we observe the results of the system.

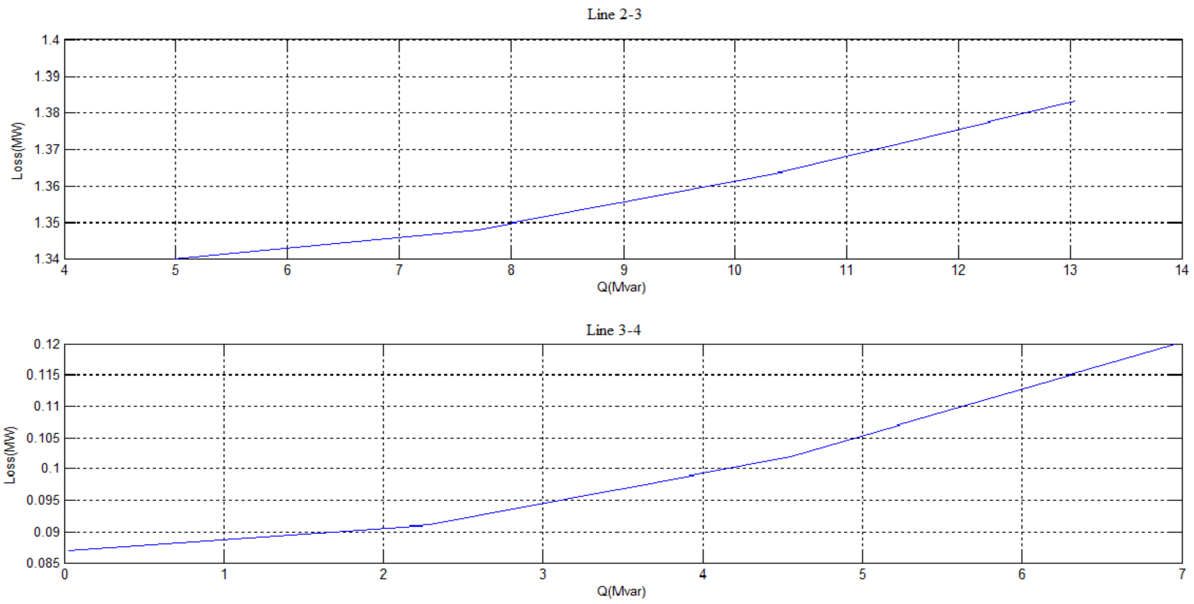

Figure 4. Q (Mvar) ~Loss (MW)

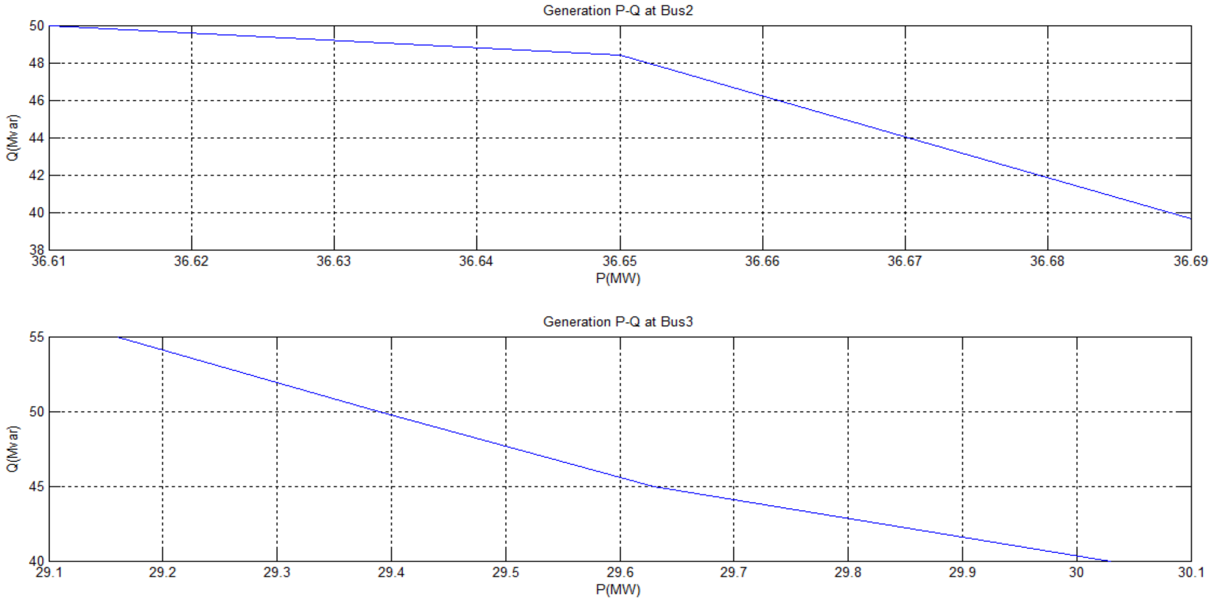

Figure 5. P (MW) ~ Q (Mvar)

Table 1. Q (Mvar) ~Loss (MW)

Q (Mvar) Injection	Bus 2-3		Bus 3-4	
	Q(Mvar)	Line Loss(I^2R) P(MW)	Q(Mvar)	Line Loss(I^2R) P(MW)
40	13.04	1.383	6.96	0.120
45	10.45	1.364	4.55	0.102
50	7.71	1.348	2.29	0.091
55	4.98	1.340	0.02	0.087

Table 2. P (MW) ~ Q (Mvar)

Bus-2		Bus-3	
P(MW)	Q(Mvar)	P(MW)	Q(Mvar)
36.61	50.00	30.03	40
36.65	48.43	29.63	45
36.67	44.03	29.39	50
36.69	39.67	29.16	55

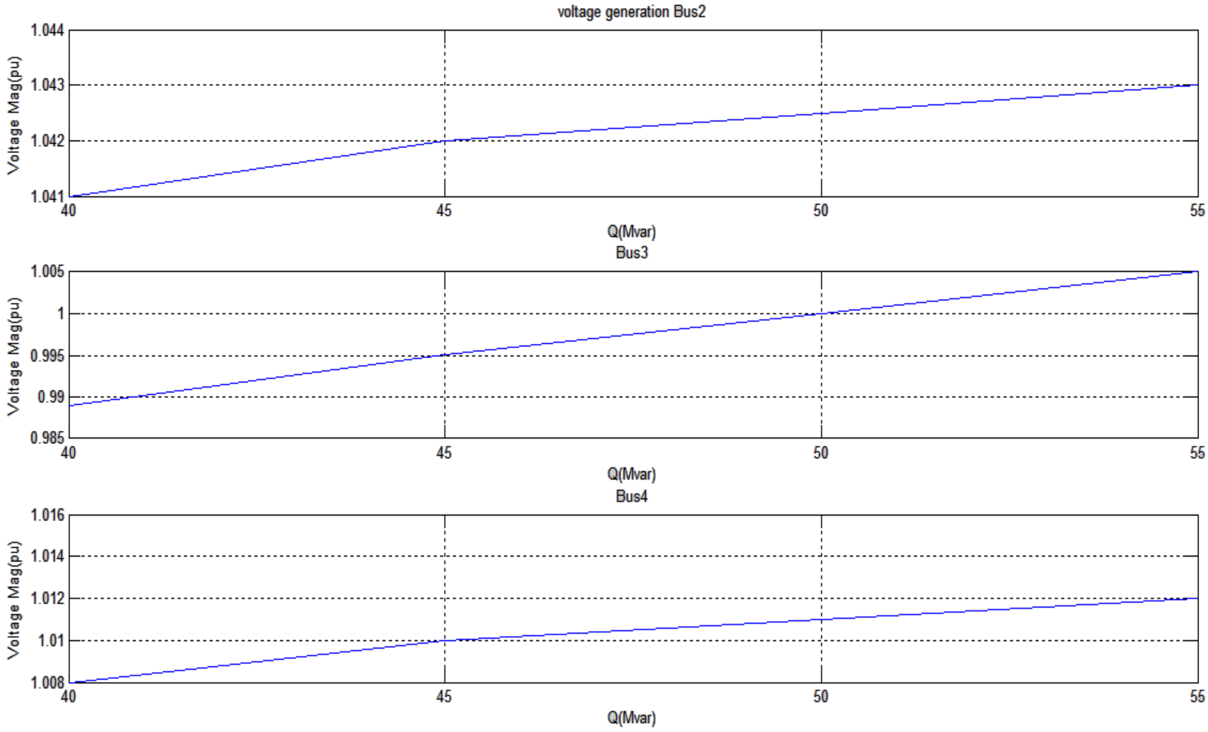

Figure 6. Q (Mvar) ~ Voltage Mag (pu)

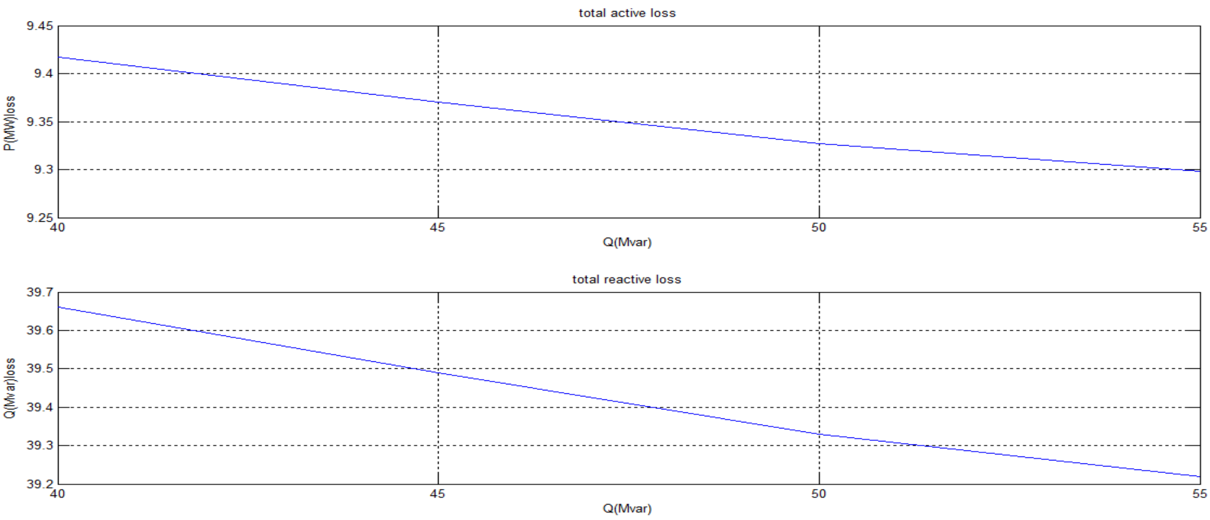

Figure 7. Q (Mvar) ~ P (MW) Loss / Q (Mvar) Loss

Table 3. Q (Mvar) ~ Voltage Mag (pu)

Q (Mvar) Injection	Total Loss	
	P(MW)	Q(Mvar)
40	9.417	39.66
45	9.370	39.49
50	9.327	39.33
55	9.298	39.22

Table 4. Q (Mvar) ~ P (MW) Loss / Q (Mvar) Loss

Q (Mvar) Injection	Voltage Mag(pu)		
	Bus-2	Bus-3	Bus-4
40	1.041	0.989	1.008
45	1.042	0.995	1.010
50	1.041	1.000	1.011
55	1.041	1.005	1.012

By optimal power flow of the test system, first we observe that line loss of the system is directly proportional to the injection of reactive power. Injecting Reactive power at specific bus produces real power loss in that line. The graph plotted in Figure 4 as per the data in Table 1.

In the second result, we observe that the by injecting reactive power the active power will decrease. Injecting reactive power at bus minimizes the real power from specific limit of generator and that limit of generator is known as reactive power limit Q_{min}. As we know voltage is controlled by managing production and absorption of reactive power. So that to maximize the amount of active power that can be transferred across a congested transmission interface, reactive-power flows must be minimized. The graph plotted in Figure 5 as per the data in Table 2.

In the third result, we observe that the voltage profile improvement is done. With the injecting reactive power at the bus the voltage magnitude of the system will be increased. Voltage profile improvement is beneficial for the social welfare. The graph plotted in Figure 6 as per the data in Table 4.

In the fourth result, we observe that by injecting reactive power at bus the total loss of the system can be minimized. So that reliability of the transmission system will also increase. The graph plotted in Figure 6 as per the data in Table 5.

IV. CONCLUSION

This paper makes a survey of the important issues about reactive power in deregulated power system. Set up a reactive power market is not only possible but also advantageous. Provision for reactive power support and appropriate pricing mechanisms for that is an important issue. Reactive power capability curve of a synchronous generator has been analyzed in detail to formulate an Expected Payment Function based on the cost of reactive power production. From the optimal power flow of the IEEE 14 bus using MAT power we observe and conclude the different result. Reactive power support and pricing is necessary and advantageous to the supplier and consumer both. It is one of the ancillary services.

REFERENCES

[1] FERC Staff Report, Principles for Efficient and Reliable Reactive Power Supply and Consumption, Feb. 2005.

[2] Er. Sagar, Dr. Rajesh Goel "A Latest Approach for Pricing of Reactive Power in Modern Power System", International Journal of Emerging Technology and Advanced Engineering, vol. 4, pp.347-351, August 2014.

[3] Ismael El Samahy, Kankar Bhattacharya, Claudio Cañizares, Miguel F. Anjos, and Jiuping Pan "A Procurement Market Model for Reactive Power Services Considering System Security", IEEE Transactions on Power Systems, vol. 23 No. 1, pp. 137-149, February 2008.

[4] Yuanning Wang and Wilsun Xu "An Investigation on the Reactive Power Support Service Needs of Power Producers", IEEE Transactions on Power Systems, vol. 19 No. 1, pp. 586-593, February 2004.

[5] C.Y. Chung, T.S. Chung, C.W. Yu, X.J. Lin "Cost-based reactive power pricing with voltage security consideration in restructured power systems." , Electric Power Systems Research Elsevier 70, pp. 85-91, November 2003.

[6] Julián Barquín, Tomás Gómez San Román, Juan José Alba Ríos, and Pedro Sánchez Martín, "Reactive Power Pricing: A Conceptual Framework for Remuneration and Charging Procedures", IEEE Transactions on Power Systems, vol. 15 No.2, pp. 483-489, May 2000.

[7] Kankar Bhattacharya and Jin Zhong, "Reactive Power as an Ancillary Service", IEEE Transactions on Power Systems, vol. 16 No. 2, pp 294-300, May 2001.

[8] Dapu Zhao, Yixin Ni, Senior Member, IEEE, Jin Zhong, Shousun Chen, "Reactive Power and Voltage Control in Deregulated Environment", IEEE/PES Transmission and Distribution Conference & Exhibition: Asia and Pacific Dalian, China, 2005

[9] Sergio B. Barragán Gómez, Yoram Astudillo Baza, Manuel A. López Zepeda, "Reactive Power Generation Curve", International Journal of Engineering And Science (IJES), Vol.1 Issue 2, pp. 48-53, 2012.

[10] Jin Zhong, Emilia Nobile, Anjan Bose, Kankar Bhattacharya, "Localized Reactive Power Markets Using the Concept of Voltage Control Areas", IEEE transactions on power systems, vol. 19, No. 3, August 2004

