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Evaluation of Penalty using Availability Based Tariff (ABT) in Deregulated Power Sector

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***Abstract*— The main objective of this paper is to evaluate the penalty or profit using Availability Based Tariff mechanism for real time imbalances between supply and demand during trading period. For existing markets, the market clearing price is based on bids received from the generators and consumers. Here, calculations are done for the generation side quadratic bid function.**

***Keywords*— Availability Based Tariff, Capacity charge, Energy charge, Unscheduled Interchange Charge**

I. Introduction

The electrical power industry in the world has been changing to encourage the competition among private sector generators and to create new market condition in the power sector. It is considered as necessary, for increasing the efficiency of electrical energy production and transmission, and hence offering a lower price and higher quality. There are a number of forces behind the deregulation of power sector worldwide, high tariffs is one of them.

The electrical power industry in India was facing a lot of problems due to the inadequacy of generation, transmission and distribution and due to the usage of outdated techniques in transmission and distribution, poor maintenance etc. As per the Regulatory commission act 1998, the Central Electricity Regulatory Commission (CERC) is authorized to regulate bulk power tariffs, viz. the tariff for power generation and transmission. This improves the operational frequency. The new tariff mechanism i.e. ABT was introduced through CERC order on ABT dated 04.01.2000. [1]

II. Availability Based Tariff

Any power plant is having fixed and variable costs. The fixed cost comprises of interest on loan and working capital, return on equity, operation and maintenance expenses, insurance, taxes and depreciation. The variable costs are the fuel costs. Availability Based tariffs are the performance based tariffs. It promotes responsibility and accountability in power generation. In it, these two costs are treated separately. Economic efficiency dictates that least cost power should be dispatched in preference to most costly power i.e. termed as Merit Order Dispatch [2]. ABT is having three types of charges as follows

A. *Capacity Charges*

The payment of fixed cost is dependent on availability of the plant, i.e. whether the plant is available for MW generation or not on a day to day basis. The amount payable to the company as a part of fixed cost depends on the average availability of the plant over the year. The percentage availability of a generating station is calculated as [3]

$$Availability = \left\{ \sum_{i=1}^{n} \frac{SOC_i}{1 - AUX/_{100}} + CL \right\} \times \frac{100}{h \times IC} \qquad (1)$$

Where

IC = installed capacity of station in MW

SOCi = send out capability in ith time block

n = number of time blocks in the duration

AUX = normative auxiliary consumption for the plant as a percentage of gross consumption

h = number of hours in the duration

CL = Gross MWh of capacity units kept closed on account of the generation scheduling order

If the average availability of the plant over the year is more than the specified, the generator gets higher payment and vice-versa. This first component of the ABT is termed as the "Capacity Charge" because it is given as per the capacity allocated.

Fixed charges payable by the beneficiary will vary with the level of availability achieved by generator. In present time, these charges are payable against the PLF (plant load factor). To achieving a PLF of 68.49%, full capacity charges are payable, and incentive is payable for each and every unit of electricity generated above this plant load factor [4]. Incentive is as 0.4% of equity for each percentage increase between 70-80%. Beyond 85% this is 0.3%.

B. *Energy Charge*

Define abbreviations and acronyms the first time they are The next part of ABT is the variable cost i.e., also termed as the energy charge which is charged as per the fuel consumption given by the schedule of the day and not on the actual generation. If there are deviations in generation, e.g. if

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scheduled generation of the plant is 50 MW and the plant generates 60 MW, the energy charge would still be paid for 50 MW of energy generation and the remaining 10 MW will be paid as per the system conditions prevailing during that extra generation. If the grid already had surplus power when this extra 10 MW was generated and the frequency was above 50 Hz the rate at which this power is sold will be lower and vice versa.

This leads to conclude that there are three parts in ABT i.e. Capacity charge, Energy charge and the payment for deviations from schedule at the conditions prevailing at the time of deviation. If the third part is negative, it would signify that the payment is made by the generator for violating the schedule..

C. *Unscheduled Interchange Charges*

A payment for the deviation from schedule at a rate dependent on system conditions is termed as the unscheduled interchange charges. Unscheduled can be given as deviation from the pre committed daily schedule. The charges payable or receivable if

- Over drawl of the power by the beneficiary decreases the frequency.
- Under drawl of the power by the beneficiary increases the frequency.
- Generator generates more than the schedule increases the frequency.
- Generator generates less than the schedule decreases the frequency.

The UI rates can be calculated as

$$UI = Actual\ Energy - Schedule\ Energy \quad (2)$$

If UI is positive, incentive will be given and if the UI is negative penalty will be charged as per the prescribed rates. The Frequency Linked Unscheduled Interchange curve is shown as [5]

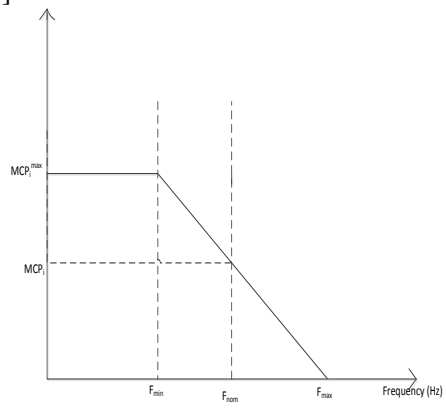

Figure 1

The frequency linked UI price can be calculated by the expression

$$UIprice = MCP_i \times \frac{F_{max} - f}{F_{max} - F_{min}} \quad (3)$$

Where,

MCP_i = Market Clearing Price at i^{th} hour

F_{max} = maximum range of frequency

F_{min} = minimum range of frequency

F_{nom} = nominal frequency

f = current frequency

III. Case Study: IEEE 14 Bus System

Considering an IEEE 14 bus system as shown in following figure

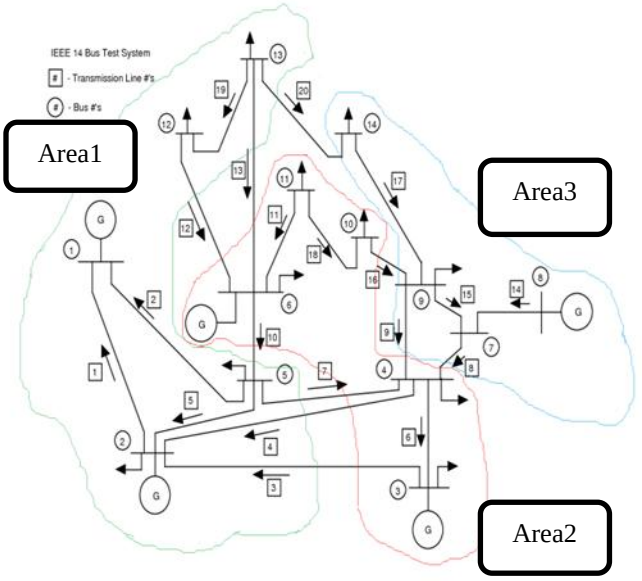

Figure 2

For matching up the problem of deregulation, we will divide the system into three areas as:

Area1 consisting of Gen1, Gen2, Load2, Load5, Load12, Load13

Area2 consisting of Gen3, Gen6, Load3, Load4, Load6, Load10, Load11

Area3 consisting of Gen8, Load7, Load9, Load14

Here we will consider 2 cases, in first case there is no change in commitment hence there will not be the provision of penalty or profit, while in second case penalty or profit will be calculated for quadratic generation bid function at 4% droop.

Case1: No Change in Commitment

(a) Calculation At Area1

Table 1.1 - Result obtained for Area 1 of Case 1

Bus No.	P_{sch} (MW)	P_{act} (MW)	Market Clearing Price (Rs/MW)	UI_{price} (Rs/MW)	Unsche-duled amount (MW)	Penalty/ Profit (Rs)
1(GEN)	194.33	194.33	36.724	36.724	0.00	0.00
2(GEN)	36.72	36.72	38.360	38.360	0.00	0.00
2	21.70	21.70	38.360	38.360	0.00	0.00
5	7.60	7.60	39.661	39.661	0.00	0.00
12	6.10	6.10	40.379	40.379	0.00	0.00
13	13.50	13.50	40.515	40.515	0.00	0.00

(b) Calculations At Area2

Table 1.2 - Result obtained for Area 2 of Case 1

Bus No.	P_{sch} (MW)	P_{act} (MW)	Market Clearing Price (Rs/MW)	UI_{price} (Rs/MW)	Unsche-duled amount (MW)	Penalty/ Profit (Rs)
3(GEN)	28.74	28.74	40.575	40.575	0.00	0.00
3	94.20	94.20	40.575	40.575	0.00	0.00
4	47.80	47.80	40.190	40.190	0.00	0.00
6(GEN)	0.00	0.00	39.734	39.734	0.00	0.00
6	11.20	11.20	39.734	39.734	0.00	0.00
10	9.00	9.00	40.318	40.318	0.00	0.00
11	3.50	3.50	40.155	40.155	0.00	0.00

(c) Calculations At Area3

Table 1.3 - Result obtained for Area 3 of Case 1

Bus No.	P_{sch} (MW)	P_{act} (MW)	Market Clearing Price (Rs/MW)	UI_{price} (Rs/MW)	Unsche-duled amount (MW)	Penalty/ Profit (Rs)
7	0	0	40.172	40.172	0.00	0.000
8(GEN)	8.50	8.50	40.170	40.170	0.00	0.000
9	29.50	29.50	40.166	40.166	0.00	0.000
14	14.90	14.90	41.198	41.198	0.00	0.000

Penalty collected = 0

Profit allocated = 0

Hence Savings = Part of Social Benefit = 0

In this case since no change in generation and load will result in no change in UI price which being equal to Marginal price, Hence no Penalty or Profit.

Case2: Change in Commitment at Area1, 2 and 3

Consider an increase in load at bus 5 by 3 MW and at bus 12 by 1 MW of Area1, and increase in load at bus 9 by 1 MW and at bus 14 by 5 MW of Area3, and decrease in load at bus 4 by 3 MW and bus 11 by 2 MW. Due to this the frequency at Area1 is 49.84 Hz, at Area2 is 49.76 Hz and at area 3 is 50.20 Hz for 4% droop.

(d) Calculations At Area1

Table 2.1- Result obtained for Area 1 of Case 2

Bus No.	P_{sch} (MW)	P_{act} (MW)	Market Clearing Price Rs/MW	UI_{price} Rs/MW	Unsche-duled amount (MW)	Penalty / Profit (Rs)
1(GEN)	194.3	194.97	36.778	48.5470	0.64	7.5321
2(GEN)	36.72	36.83	38.416	50.7091	0.11	1.3522
2	21.70	21.70	38.416	50.7091	0	0
5	7.60	10.60	39.753	52.4740	3	38.1629
12	6.10	7.10	40.567	53.5484	1	12.9814
13	13.50	13.50	40.760	53.8032	0	0

(e) Calculations At Area 2

Table 2.2 - Result obtained for Area 2 of Case 2

Bus No.	P_{sch} (MW)	P_{act} (MW)	Market Clearing Price (Rs/MW)	UI_{price} (Rs/MW)	Unsche-duled amount (MW)	Penalty/ Profit (Rs)
3(GEN)	28.74	30.11	40.602	60.0910	1.37	26.6999
3	94.20	94.20	40.602	60.0910	0	0
4	47.80	44.80	40.252	59.5730	-3	-57.9629
6(GEN)	0	0	39.828	58.9454	0	0
6	11.20	11.20	39.828	58.9454	0	0
10	9.00	9.00	40.365	59.7402	0	0
11	3.50	1.50	40.159	59.4353	-2	-38.5526

(f) Calculations At Area3

Table 2.3 - Result obtained for Area 3 of Case 2

Bus No.	P_{sch} (MW)	P_{act} (MW)	Market Clearing Price (Rs/MW)	UI_{price} (Rs/MW)	Unsche-duled amount (MW)	Penalty/ Profit (Rs)
7	0	0	40.233	24.1398	0	0
8(GEN)	8.50	11.54	40.231	24.1386	3.04	-48.9209
9	29.50	30.50	40.229	24.1374	1	-16.0916
14	14.90	19.90	41.619	24.9714	5	-83.2380

Penalty recovered = 244.766 (Rs)

Profit allocated = 86.7285 (Rs)

Hence Savings = Part of Social Benefit = 158.0375 (Rs)

IV. Conclusion

Evaluation of penalty or profit based on the bids submitted by the generators of IEEE 14 bus system has been proposed in this paper. The bids may be stepped bids or quadratic function of real power but here, bids are assumed to be quadratic function of real power.

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