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A Dynamic Pricing Methodology for Generator Based on UI Mechanism Under ABT

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ABSTRACT

In the present paper three random variables, (a) Load as per RLDC generation schedule a day ahead, (b) the availability of units to be generated, and (c) the unscheduled interchange rate (UI Rate) which is linked with the grid frequency are used to compute the predicted revenue a day ahead. For dynamic pricing of generator A model to optimize the revenue by declaring generation availability a day ahead using UI mechanism under the 'Availability Based Tariff' is developed with programming. An example with suitable station data is also shown to support the model.

KEYWORDS: Random variables, optimize the revenue, sampling, iterative process, co-efficient of variation

I. INTRODUCTION

The new opportunities offered by the 'Availability Based Tariff' UI mechanism, have a true reflection on the Dynamics of economics of energy.

Frequency linked availability tariff (ABT) has been successfully implemented in India at the regional grid level. The five electrically demarcated Regions in the country are under the (ABT).Availability tariff have three components, capacity charge, energy charge, & unscheduled interchange charge i.e. a payment for deviations from schedule, at a rate dependent on system frequency. ABT has resulted in improved grid discipline in terms of maintaining system frequency close to nominal value.

This work leads to develop a model to optimize the declaration of the day ahead, generation availability in the 'Availability Based Tariff' regime in India. The mathematical formulation presented in this work maximizes the expected revenue of the generator by considering various stochastic parameters. The computational model developed in this work computes the expected optimal station availability for next day's declaration. A numerical example of a generating station is illustrated to show the revenue maximization strategy by this optimization.

Availability Based Tariff (ABT) is a rational tariff structure for power supply from generating stations, on a contracted basis. The power plants have both fixed and variable costs. The fixed cost elements are interest on loan, return on equity, depreciation, O&M expenses, insurance, taxes and interest on working capital. The variable cost comprises of the fuel cost, i.e., coal and oil in case of thermal plants and nuclear fuel in case of nuclear plants. In Availability Based Tariff, the payment of fixed cost to the generating company is linked to availability of the plant, that is, its capacity to deliver MWs on a day-by-day basis. The total amount payable to the generating company over a year towards the fixed cost depends on the average availability (MW delivering capacity) of the plant over the year. In case the average actually achieved over the year is higher than the specified norm for plant availability, the generating company gets a higher payment. In case the average availability achieved is lower, the payment is also lower. This component of tariff is termed 'capacity charge'. In case there are deviations from the schedule (e.g., if a power plant delivers 1000 MW while it was scheduled to supply only 980 MW), the energy charge payment would still be for the scheduled generation (980 MW), and the excess generation (20 MW) would get paid for at a rate dependent on the system conditions prevailing at the time. If the grid has surplus power at the time and frequency is above 50,cycles/second, the rate would be lower. If the excess generation takes place at the time of generation shortage in the system (in which condition the frequency would be below 50 cycles), the payment for extra generation would be at a higher rate.

The process of restructuring of power sector and implementation of ABT with electricity act-2003, benchmarks set by CERC, in India, led us to change accordingly. for that Introduction and concept of 'Availability Based Tariff 'ABT is discussed thoroughly here in [1] by Bhanu Bhushan "ABC of ABT ----A Primer On Availability Tariff " June 2005.Pre -2002 scenario & measures taken; with the Indian version of ABT,frequency linked pricing deviations are discussed in this paper[2] by Bhanu Bhushan Power Grid Corporation of India Ltd. and Anjan Roy P.entaya,WRLDC. Reduction of internal cost and enhancing revenues were the difficulties faced by generators because of various unpredictable variables.Due to risk involved in a competitive power market they need models which help us to take decision to minimize the risk and maximize the revenue. Some work is carried out considering three stochastic parameters the model is developed to find optimal declaration of availability for generator on day ahead basis [5] by N.Vaitheeswaran and R.Balasubramanian, "Stochastic Model for Optimal Declaration of Day Ahead Station Availability in Power Pools in India. For optimal operational methodology of generators in a day ahead deregulated markets three conceptual mathematical models are published [6] by I.J. Perez-Arriaga and C. Meseguer, "Wholesale Marginal Prices In Competitive Generation Markets.

Problem Definition

The objective of every generating station is to maximize the the expected capacity charges after accounting for the risk of UI UI charges. This calls for the generating station under ABT to to optimally declare the station generation availability in day Ahead pool. The proposed computational model considers,

Three random variables-

i) The generating unit's availability,
ii) Unscheduled Interchange (UI) and
iii) Load (same as RLDC's generation schedule).

Nomenclature

u =Index for number of units
Tu = Total number of units
m = Index of time blocks
Tm = Total number of time blocks in a day
G u = Capacity of uth unit in MW
Elossm = Energy loss at mth time interval in MWH
Lm = Load at time interval 'm'- (Stochastic Variable)
PGmaxm = Maximum station availability in MW at time block m (Stochastic variable)
PGic = Installed net station capacity in MW.

Paux = Normative Station Auxiliary Power Consumption in MW specified by Regulatory Authority.
PGd = Declared station Availability in MW for 96 time blocks after Station Auxiliary Power Consumption, Paux.
PGminm = Technical minimum of station generation in MW
MTTFu = Mean time to fail of uth unit in hours
MTTRu = Mean time to repair of uth unit in hours
Rsaifc = Station average incremental fuel cost Rs./ MWH
Rccm = Capacity charge for each time block in Rs/MW
Ruim = UI rate at mth time interval
Ruimax = Maximum value of UI rate in Rs /MWH
Rdaily = Expected daily revenue
1/4 = Length of each time block in hours

Formulation of Problem
In the ABT regime the objective of a generating station is to declare the daily availability in such a manner that it would be able to maximize the daily capacity charges after accounting for the risk of UI.

Therefore the objective function is

$$\text{Maximize } R = 96 * Rccm * PGd + \sum_{k=1}^{k} Elossm\,(Rsaifc - Ruim)$$

$$\text{Where, } Elossm = \text{Maximum } \{0, (I_k - Gmax_k)\} * 1/4$$

$$0 \le Ruim \le Ruimax, ; 0 \le PGmax_m \le PGic$$

$$\text{The range of PGd is } 0 \le PGd \le PGic$$

$$\text{where} \quad PGic = \sum_{u=1}^{Tu} Gu - Paux.$$

The Optimization Procedure
The implementation of the computational model is summarized in following steps.

1. Find the probability distributions of Availability, UI rate and Load from the past data.
2. initially, set day ahead capacity for declaration 'PGd' to 100% station capacity.
3. Using sampling method, the up/down duration of generating units can be simulated from the respective MTTRu and MTTFu. From this available station capacity, PGmaxm, for each time interval for the entire study period can be obtained.
4. Generate the stochastic value of Ruim for each interval
5. Generate the load and UI from past data.
6. Compute energy loss Elossm for every time block.
7. Estimate the expected daily revenue from capacity charges 'R' after accounting for Ruim.
8. Decrement station availability PGd by a small value ΔPGd and repeat steps 3-8 to obtain the value R corresponding to new value of PGd. The above procedure is to be repeated for progressively decreasing value of PGd in small steps until the optimal solution is reached.

Sample Data
The annual capacity charges recoverable by the station are Rs 350 Crores. As per the regulatory norm, the station can recover full capacity charges at 80% annual availability. Therefore, the capacity charge C is Rs 86.167915/MW/15 minutes time block. The 100% base availability of this station is 1518 MW, after accounting for auxiliary power norm. The technical minimum GMIN is1000 MW. The average fuel cost of generation, Rsaifc, is taken as Rs.3000/MWH.

A Station Data:-
For unit no. 1: Capacity of unit: 400 MW; MTTFu = 950 Hrs and MTTRu = 80 Hrs, for unit no. 2: Capacity of unit: 400 MW; MTTFu = 960 Hrs and MTTRu = 90 Hrs, for unit no. 3: Capacity of unit: 500 MW; MTTFu = 970 Hrs and MTTRu = 85 Hrs and for unit no. 4: Capacity of unit: 350 MW; MTTFu = 965 Hrs and MTTRu = 88 Hrs.

Illustration & Example
A generating station having four units with total installed capacity 1650 MW is considered here. The data pertaining to MTTRu, MTTFu, number of units and their individual capacity is given in ststion data. The UI charge for different time blocks has been calculated from the past data Similarly the load for different time intervals has been generated from the past data. The declared availability PGd has been considered to vary from 1350 to 1450 MW. The results of the simulation performed for a 4-unit sample station, 1650 MW, are given below. Availability declaration, load schedule and UI are considered for 96 time blocks of 15 minutes each. The model has been implemented in C++.

Analysis Of Results
Maximum expected revenue occurs at the declared availability corresponding to iteration no.5. The test results show that by declaring full station availability the expected revenue over the time period cannot be maximized, as the risk of UI charge increases. Declaring full station availability would increase the earning of capacity charges, but this benefit is negated by increased risk of UI charges. Thus the net revenue of generator is not getting maximized. In this test case, the optimum availability for day ahead declaration, PGd, for the utility is 1499.11 MW i.e. 99 %. As against a 100% declaration, 99% declaration brings additional revenue of Rs. 49900/- per day or additional expected monthly revenue of 1.821 Cr. Rupees.

Conclusion
The expected value of daily revenue was computed for different value of declared availability. We get the optimal value of availability minimizing risk of UI.

Iteration Number	Declared Availability (%)	Declared Availability GD (MW)	Expected Revenue Daily 'Rmax'
1	100	1518.000	11934300
2	99.75	1514.343	11891300
3	99.50	1510.420	11861600
4	99.25	1506.640	11897100
5	99.00	1499.110	11984200
6	98.75	1495.37	11777000
7	98.50	1491.63	11856100
8	98.25	1487.900	11842400

Table:1

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[1] Bhanu Bhushan "ABC of ABT --A Primer On Availability Tariff" June 2005. [2] Bhanu Bhushan Power Grid Corporation of India Ltd. Corporate Centre Gurgaon, India and Anjan Roy P. Pentayya WRLDC. [3] (www.powermin.nic.in/). "Indian Electricity Act-2003" [4] (www.cercind.org/). Central Electricity Regulatory Commission ,Government Of India [5] N.Vaitheeswaran and R.Balasubramanian, "Stochastic Model For Optimal Declaration Of Day Ahead Station Availability In Power Pools In India," IEEE Trans, power system,vol.20,pp.701-708,june 2006. [6] I.J. Perez-Arriaga and C. Meseguer, "Wholesale Marginal Prices In Competitive Generation Markets ,"IEEE Transactions on Power Systems, Vol. 12, pp.710-717, May 1997