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Power Generation Pricing Model Based on Long Run Marginal Cost Methodology

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ABSTRACT

This paper proposes a long run marginal cost based formulation for reflecting the usage based pricing of electrical power. The aim of this paper is to develop a novel method that can price the real power on a long term basis in a multi-machine power system. The proposed method has shown that the cost of future investment is governed by the perturbation of generating power. The economic efficiency of the proposed model is demonstrated in a 203 buses 267 lines 23 machines real power system of eastern part of India where total 23 generators are categorized in 5 types according to their ratings and analyzed the price at their optimal operating condition with 10% loading variation.

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1. INTRODUCTION

In a restructured power industry, Electricity transmission and distribution are considered natural monopolies, whereas generation and retailing are open to competition. Open access to the generation system and fair, cost reflective pricing of generation are very imperative for healthy competition in the power sector. Recovery of future investment cost with respect to consumption and production send a good price signals to gencos in deregulated environment.

Generation cost is evaluated in associated research papers where the capacity cost plays a significant role [1].It focuses variable and capacity cost as a key factor in generation cost where The strategies of bidding and operating must be made on basis of the proper integrated analysis of the capacity and variable cost. An effective method based on double dynamic programming has been applied to solve the generation asset allocation problem with all the short term operating constraints satisfied [2]. Participation factor along with non-linear optimal power flow [3] allocates the active power generation cost. A simple electricity tracing method based on OPF is also applied to solve generation and loss cost problem [4]. Start-up costs and risk premia is also incorporated in generation cost using market simulation method for profitability of Gencos [5] for distribution generators. Generation resource distribution and power purchase allocation among the multiple power markets are very important daily decisions for Gencos or demand suppliers with significant economic impact. By considering the unique characteristics of electric power market, a simplified model is represented to obtain the equilibrium forward price [6]. In [7] it has been shown that the spot price today and the equilibrium forward price of tomorrow are not related. A direct and cross hedging strategy using futures contracts is studied in [8]. Based on mean variance portfolio theory, an analytic approach is proposed in [9] for optimized energy allocation between spot market and bilateral contracts market. In other literatures artificial neural networks have been successfully applied for market price forecasting [10-11]. A comprehensive review of the existing mechanisms of generation pricing reveals that it would probably did not show any promising effort on extent of use based cost computation of generating unit on a long run basis.

None of the referred papers has considered generation cost under usage based long run marginal cost (LRMC) concept. Also there is no indication of future investment cost calculation depending upon degree of generator usage. However in the present deregulated power scenario generator usage varies significantly depending upon load perturbation and dynamic pricing policy. In this paper, a novel approach has thus been presented for usage based cost allocation of generating units. The proposed method is based on ac optimal power flow technique with an emphasis of offering a better price model. This method illustrates the future investment cost being governed by generator usage in a multi machine network structure. This method has been tested with a 203 bus 267 lines 23 machines real power system at eastern part of India where the existing generators have been categorized in five varieties according to their ratings. The simulation has been conducted in order to analyze the cost of future investments characterized by long run marginal pricing concept with 10% load variation from the optimum condition.

2. MATHEMATICAL DERIVATION OF THE PROPOSED MODEL

The proposed pricing model can be described by following steps.

Future investment cost (F_c) is consequent using present installation cost (I_c) in addition to depreciation rate (s) of the system for the time period t. The F_c for time t will then be

$$F_c = \frac{I_c}{(1+s)^t} \tag{1}$$

A system having N numbers of generators (where each generator has its maximum capability of P_{max} active power) catering demand (P_d) with the growth rate of d for the time period t, can be written as:

$$P_{\max} = P_d(1+d)^t \tag{2}$$

From equation (2), time t can be determined as

$$t = \frac{\ln P_{\max} - \ln P_d}{\ln(1+d)} \tag{3}$$

It is implicit that t is the total time period when the generator expanded till P_{max} and for the calculation of long run marginal cost, installation cost, depreciation rate of the generators are taken care of.

Incremental change in the future cost with respect to present active power demand is measured as long run marginal cost of the generator. As a result of time domain multiplexing, the incremental future investment cost will be

$$\frac{\partial F_c}{\partial P_d} = \frac{F_c \ln(1+s)}{P_d \ln(1+d)} \tag{4}$$

Dividing the future investment cost with generator power demand, we have

$$\frac{F_c}{P_d} = \frac{I_c}{P_{\max}}\left(\frac{1+d}{1+s}\right)^t \tag{5}$$

Taking the value of ln(1+d) from equation (3) and F_c/P_d from equation (5), the final expression for $\frac{\partial F_c}{\partial P_d}$ becomes

$$\frac{\partial F_c}{\partial P_d} = \frac{tI_c}{P_{\max}}\left(\frac{1+d}{1+s}\right)^t \times \frac{\ln(1+s)}{\ln\left(\frac{P_{\max}}{P_d}\right)} \tag{6}$$

The proposed model for each generator is presented in equation (6) where for t time period the price of power generation depends on demand and generating side of generators if considering other parameters constant. So the projected pricing model is defined as

$$= \sigma * \frac{\partial F_c}{\partial P_d} \quad (7)$$

σ is the profitability factor of the system. For the simulation purpose, here it is assumed as 10%.

3. NUMERICAL TEST RESULT

The proposed model is depicted in 203 buses 267 lines 23 machines real power system of eastern part of India, where the 23 numbers of generators are divided according to their ratings in five types. These are 50 MW, 110MW, 300MW, 500MW and 600MW generators respectively. The pricing model is validated for each generator where the investment cost for all generators has been considered as 100billlion INR per MW and the growth rate and depreciation rate have been assumed 10% and 15% each. The proposed methodology has been implemented based on the ac optimal power flow solution with 10% varying load demand. Considering 10% profitability for Genco side, the respective generators' pricing are varied with variable load demand has been shown in Table 1.

From Table 1, it has been shown that due to the different rating of the generators with different installation cost, generator prices are varying for each MW production with variable demand, while the depreciation, profitability, growth rate, total time period are considered to be same for each generator. The profile of changes of pricing is shown in Figure 1.

Table 1. Power Price for each generator with varying load

Generator Type	Generators' proposed power price with varying demand					
Gen A	Demand (MW)	10	15	20	30	40
	Price (Billion INR/MW)	568	759	997.8	1790	4097
Gen B	Demand (MW)	20	36	40	50	60
	Price (Billion INR/MW)	536	818.5	903.85	1159	1508
Gen C	Demand (MW)	120	135	150	180	220
	Price (Billion INR/MW)	997.87	1145	1319	1790	2948
Gen D	Demand (MW)	279	314	348	382	417
	Price (Billion INR/MW)	1567	1965	2523	3396	5037
Gen E	Demand (MW)	520	538	548	558	575
	Price (Billion INR/MW)	6389.5	8383	10086	12599	21484

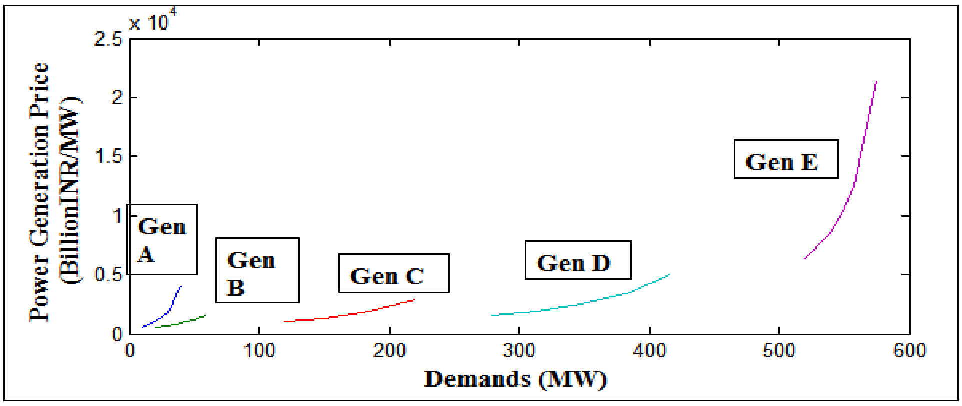

Fig 1. Variation of price with respect to demand for different generators.

Figure 1 illustrates that for higher rating generators the pricing is gradually increased with demands compared to lower rating generators but it has been clearly observed that for each and every generator the proposed price depends on their demand side. If the demand is increased per MW pricing is also increased gradually. Moreover from Table 1, it has been observed that for same demand higher rating generator power price is less than the lower rating generator, i.e. for 20MW demand, Generator A power price is 997.8BillionINR/MW where as for same demand, Generator B power price is 536 BillionINR/MW. So it implies that present variable demand has an obvious effect on future investment cost of gencos.This usage based generation price allocation methodology gives an significant effect in power market.

4. CONCLUSION

This paper proposed a novel method for providing pricing based on long run marginal cost of the generators where generator capacity and demand play a great role. This paper stressed on recovery of future investment cost of generators by Gencos in deregulated environment. The proposed methodology has been tested in a 203 buses 267 lines 23 machines real power system of eastern part of India where total 23 generators are categorized in 5 types according to their ratings. Simulation results have established that the proposed method is promising for large scale environments. The generator's power price can be derived using this formula effortlessly. This methodology provides forward-looking economic messages and reflected the degree of generator's usage factor.

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