INVESTIGATION OF GENERATION AND LOAD UNCERTAINTIES ON ELECTRICITY MARKETS

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ABSTRACT*: Nowadays, the increase of demand for electric power systems has increased voltage and power levels. On the other hand, governments tend to personalize their power systems, thus; the impact of a new device which is installed in power system must be studied. Owners of power plants like to know about their profits in electricity market. Also, to make decision for electricity market, the operators need the accurate amount of generation and demand. Although several advances have been occurred in recent decades, there are several sources of errors. In this paper, the effects of generation uncertainties and load uncertainties on electricity market are studied. Using a Direct Current Optimal Power Flow in an 8 bus bar system, the value of LMPs is calculated. Total cost, Generation of the power plants and their benefits are considered under uncertainties and their variations in different conditions are analyzed.*

Key Words: Electricity market, *LMP, Uncertainty, Total cost, Benefit, DCOPF*

1.INTRODUCTION

In recent years, due to technological advances, a large numbers of governments incline to personalize their power systems; as a consequence, the power plant's owner and electricity market operators like to know about affects of any variation or installation of a new device in power systems. In other words, owners are going to know about the variation of their benefits.

Any variation in generations and loads can affect the electricity market; as a result, the accurate amount of errors and uncertainties in generations and demands must be calculated.

In recent decades, scientists all around the world have studied more about the uncertainties [1-3]. In order to calculate uncertainty, several approaches are introduced: Monte Carlo Simulation method (MCS), Beta method, point Estimation [4-5] and Quantile Regression [6] are some of them.

In several studies, the impacts of these uncertainties on electricity markets have been investigated. Zeineldin, *et. al.* [7] studied the impacts of various distributed generations (DGs) on whole market price. In [8], the England Electricity market's unbalanced price has been investigated.

Botterud, *et. al.* in [9] have studied the wind energy trading in real time and day ahead electricity market. They investigated the balance between risk value and returned costs under locational marginal price (LMP) then provided a method for optimum bidding strategy. In [10], based on Kernel density estimation (KDE) method the probable distribution of unbalanced prices has been calculated. Also, based on Conditional value at risk (CVAR) and considering the uncertainties of unbalanced prices, the strategies for optimal bidding have been introduced.

In this paper, the impacts of generation and load uncertainties on LMP are analyzed. In section 2, the LMP's formulation is introduced. Afterwards, in section 3, the impact of uncertainties on LMPs and benefits is explained. Ultimately, in section 4, the conclusion of the paper is presented.

2. LMP FORMULATION

There are two common pricing methods: Marginal Clearing Price (MCP) and LMP. In a large number of studies, the second method has been considered. Indeed, LMP is the cost of increased generation at a special bus when the generator at the mentioned bus increases its production 1MW.

LMP is affected by three components: Congestions, Losses and LMP at the cheapest bus. Based on afore-mentioned points, ISO which is independent unit is paid attention by both ~~of~~ sellers and buyers. ISO by solving an optimization problem helps producers, consumers and LMPs to make a decision. To clarify, ISO tries to maximize the social welfare which is described below:

$$\text{Social Welfare}=\sum B(P) - C(P) \qquad (1)$$

B(P) and C(P) are consumers' benefit and cost of generation, respectively. B(P) has complex equation and usually is neglected; as a result, the ISO tries to minimize the above equation:

$$\min\left(\sum_{i=1}^{n} C_i(P)\right) \qquad (2)$$

In which $C_i(P)$ is the cost of generation at Bus (i):

$$C_i = aP^2 + bP + c \qquad (3)$$

Constraints:

- Power flow equations:

$$P_i - PD_i = \sum_j |V_i||V_j| Y_{ij} \cos(\theta_{ij} + \delta_j - \delta_i) \qquad (4)$$

$$Q_i - QD_i = -\sum_j |V_i||V_j| Y_{ij} \sin(\theta_{ij} + \delta_j - \delta_i) \qquad (5)$$

- Constraints of generators:

$$P_i^{min} \le P_i \le P_i^{max} \qquad (6)$$

$$Q_i^{min} \le Q_i \le Q_i^{max} \qquad (7)$$

- Voltage's constraint:

$$\begin{aligned} &V_j^{min} \le V_j \le V_j^{max} && j = 1, \ldots, N_L \\ &V_i = Const && i = 1, \ldots, N_G \end{aligned} \qquad (8)$$

N_G is the number of PV buses.

- Thermal and insulation constraints at lines:

$$P_{ij} \le P_{ij}^{\max} \quad (9)$$

- Constraints of losses:

$$\sum_{j=1}^{n} P_i - PD_i = \sum_{j=1}^{n} I_i = L(I_1, I_2, ..., I_n) \quad i = 1, ..., n \quad (10)$$

In which L, I_i are losses and pure imposed real power at bus (i), respectively.

The ACOPF or DCOPF can solve the above equations. In this paper, DCOPF is used to calculate the LMPs. In DCOPF:

$$Cos(\theta_i - \theta_j) \approx 1$$
$$Sin(\theta_i - \theta_j) \approx \theta_i - \theta_j \quad (11)$$

$$P_i - PD_i = \sum_{j=1}^{n} Y_{ij}(\theta_i - \theta_j) \quad j = 1, ..., n \quad (12)$$

$$P_{ij} = Y_{ij}(\theta_i - \theta_j) \quad j, i = 1, ..., n \quad (13)$$

$$Y_{ij}(\theta_i - \theta_j) \le P_{ij}^{\max} \quad j, i = 1, ..., n \quad (14)$$

The Lagrangian function is derived as follow:

$$l = \sum_{i=1}^{n} C(I_i) + \sum_{i=1}^{n} \pi_i \left[I_i - \sum_{j=1}^{n} Y_{ij}(\theta_i - \theta_j) \right] + \sum_{i=1}^{n}\sum_{j=1}^{n} \mu_{ij} \left[P_{ij}^{\max} - Y_{ij}(\theta_i - \theta_j) \right] \quad (15)$$

Y_{ij}, θ_i, μ_{ij}, π_i are admittance between i-j, bus angle, coefficient of voltage's constraints and coefficient related to the constraints of losses, respectively. If a partial derivative with respect to the I_i is implemented on equation (15), the π_i will be the LMP buses.

3. SIMULATION AND RESULTS

The 8 bus system which is shown in figure 1 is used to show the impact of uncertainties. Information about the generators and system data can be found in table I and table II.

From equation (15) and running a DCOPF, the LMPs are calculated. Figure 2 shows the LMP at buses. It can be easily understood that the bus 2, 3 and 8 are more expensive than the others. For more information, owners benefit can be calculated by the following equations:

$$Cost_{G_j} = aP_j^2 + bP_j + c \quad j = 1, ..., 6 \quad (16)$$

$$Revenue_{G_j} = \pi_i \times P_j - Cost_{G_j} \quad i=1,.....,8 \quad j=1,.....,6 \quad (17)$$

As shown in figure 3, just 2 Gencos (2 and 6) benefit and the others have roughly zero or negative profit. It's recommended that the Gencos with the low profits don't contribute at the electricity market on that time. If these Gencos have to stay at the system due to limits of generators in turn off and start up or system stability, they tolerate the losses.

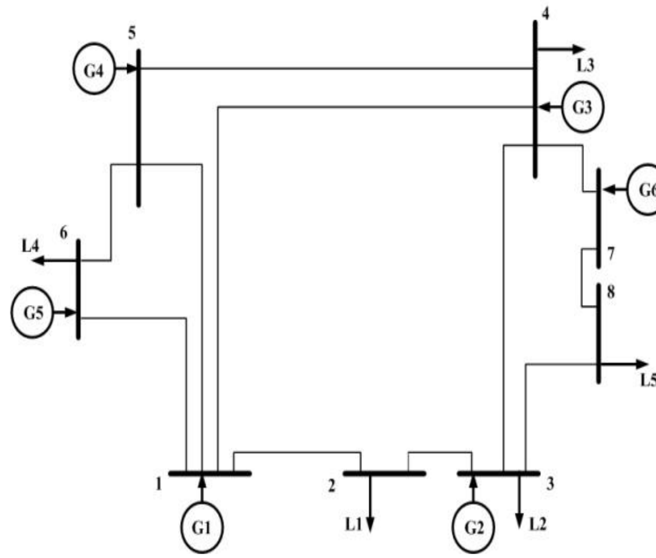

Figure 1 Schema of power system.

TABLE I
INFORMATION OF GENERATORS

Bus	a ($/MWh^2)	b ($/MWh)	C ($/h)	P_{min} (MW)	P_{max}(MW)	Pd (MW)
1	0.0048193	14.37181	89.62	0	35	0
2	0	0	0	0	0	15
3	0.0245283	37.60189	17.64	0	20	11
4	0.0730337	26.34562	31.60	0	32	15
5	0.002	13.39	79.78	0	40	0
6	0.01	13.47	49.75	0	20	15
7	0.05	25.47	24.05	0	12	0
8	0	0	0	0	0	15

TABLE II
INFORMATION OF TRANSMISSION LINES

Line	From Bus	To Bus	Reactance (p.u.)	Limit (MW)
1	1	2	0.03	9
2	1	4	0.03	15
3	1	5	0.0065	20
5	2	3	0.011	10
6	3	4	0.03	10
7	4	5	0.03	20
8	5	6	0.02	10
9	6	1	0.025	19
10	7	4	0.015	19
11	7	8	0.022	20
12	8	3	0.018	15

By assumption of uncertainty of generation at bus 2, 7 and the load at bus 2, the impact of uncertainties will be investigated. In terms of generation, Gencos adjusts their productions in several situations. As shown in figure 4, when G2 has an error in its generation (10%), the amount of produced energy at G4 and G5 decreases. In contrary, G3 increases its production. Similar attitudes occur when there is 10% error at G6. Also, lack of demand at bus 2 causes to decrease the production in all Gencos. When L1 has positive error all generation except G4 remain constant.

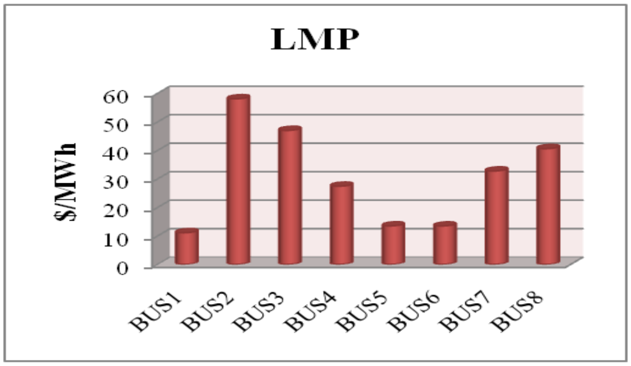

Figure 2 LMP.

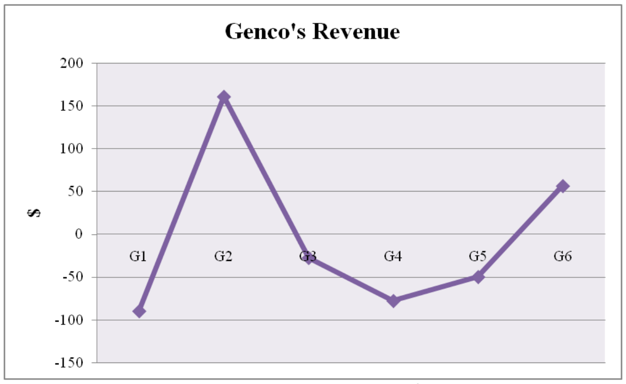

Figure 3 Genco's benefit.

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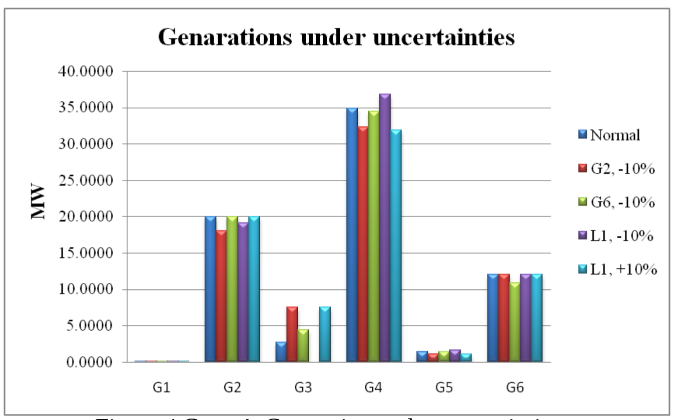

Figure 4 Genco's Generation under uncertainties.

Total cost used to produce the energy in several uncertainties has been shown in figure 5. Lack of energy at bus 2 or 6 causes the increase of the amount of total cost. Indeed, uncertainty in generation increases the LMP of the buses and decreases the amount of profits. G2 is more expensive than G6; thus, the increase of the total cost in case 2 is more than case 3. +10% error of load L1 has the biggest effect on the total cost.

These differences between total costs can be found in figure 5. Cost variation must be provided with the Gencos and consumers. In some cases, the uncertainty causes to win some Gencos and lose other ones. Consumers who contribute in electricity market tend to buy the energy with the less cost as much as possible. Being these fluctuations causes some consumers to hesitate to buy the energy and encourage some others to buy the energy in low cost.

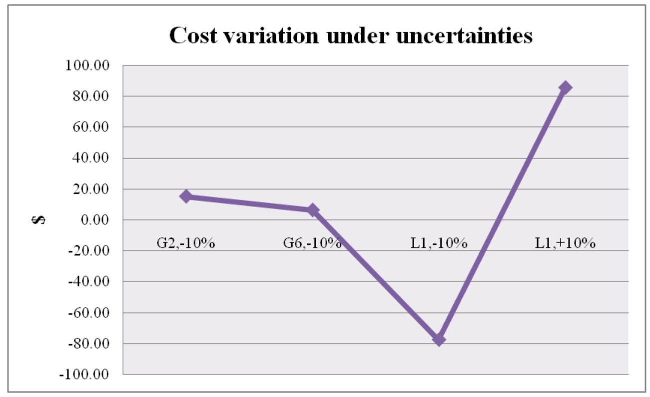

Figure 5 Total cost differece under uncertaities.

4. CONCLUSION

To sum up, in this paper, the impact of uncertainties on electricity market has been studied. The studies show that uncertainties at generation cause the increase of the total cost of generation and decrease the social welfare. Also, uncertainties affect the generations of Gencos and some of them tolerate a big loss. Uncertainty at the loads has the biggest effects on LMPs and total cost. Uncertainties lead to increase the profits of some unit and consumers and on the other hand decrease the profits of other groups; as a consequence, every owner or consumer who contributes in electricity market has to have a special strategy which considers the uncertainty to maximize their profits. This can be the subject of the future works.

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