World Academy of Science, Engineering and Technology
International Journal of Electrical and Computer Engineering
Vol:6, No:8, 2012

Variation of Spot Price and Profits of Andhra Pradesh State Grid in Deregulated Environment

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***Abstract*—**In this paper variation of spot price and total profits of the generating companies' through wholesale electricity trading are discussed with and without Central Generating Stations (CGS) share and seasonal variations are also considered. It demonstrates how proper analysis of generators' efficiencies and capabilities, types of generators owned, fuel costs, transmission losses and settling price variation using the solutions of Optimal Power Flow (OPF), can allow companies to maximize overall revenue. It illustrates how solutions of OPF can be used to maximize companies' revenue under different scenarios. And is also extended to computation of Available Transfer Capability (ATC) is very important to the transmission system security and market forecasting. From these results it is observed that how crucial it is for companies to plan their daily operations and is certainly useful in an online environment of deregulated power system. In this paper above tasks are demonstrated on 124 bus real-life Indian utility power system of Andhra Pradesh State Grid and results have been presented and analyzed.

***Keywords*—**OPF, ATC, Electricity Market, Bid, Spot Price

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I. INTRODUCTION

RESTRUCTURING of the power industry aims at abolishing the monopoly in the generation and trading sectors, thereby, introducing competition at various levels wherever it is possible. Generating companies may enter into contracts to supply the generated power to the power dealers/distributors or bulk consumers or sell the power in a pool in which the power brokers and customers also participate. In a power-exchange, the buyers can bid for their demands along with their willingness to pay. Power generation and trading will, thus, become free from the conventional regulations and become competitive. Electricity sector restructuring, also popularly known as deregulation is expected to draw private investment, increase efficiency, promote technical growth and improve customer satisfaction as different parties compete with each other to win their market share and remain in business.

Open access is the key to a free and fair electricity market. Power producers (sellers) and dealers/customers (buyers) have to share a common transmission network for wheeling the power from the point of generation to the point of consumption. Thus, interconnected transmission system is considered to be a natural monopoly so as to avoid the duplicity, the problem of right-of-the-way, and huge investment for new infrastructure and to take the advantage of the interconnected network viz. reduced installed capacity, increased system reliability and improved system performance.

Managing risk is primary tasks of any trading system [1]. This task is perceived harder for electricity being a non-storable commodity. In competitive environment, the price is determined by stochastic supply and demand functions. The price can change at any time. As a consequence of increased volatility, a market participant could make trading contracts with other parties to hedge possible risks and get better returns. Congestion occurs when transmission lines or transformers are overloaded and this prevents the system operators from dispatching additional power from a specific generator. This may be prevented to some extent by means of reservations or rights. These rights are used to guarantee an efficient use of transmission system capacity and to allocate transmission capacity to users who value it most [2].

Optimal power flow is one of the most useful tools in the simulation of power systems. The idea of optimal power flow is to rearrange the system to minimize or maximize a set function, known as the objective function. The general way this is achieved is by modifying the output power of the system's generators. For most cases, the optimal power flow attempts to minimize the sum of the operating costs of the system. Other than those mentioned above, one of the most important factors is the operating cost. Generation and distribution of power must be accomplished at minimum cost but with maximum efficiency. This involves the real and reactive power scheduling of each power plant in such a way as to minimize the total operating cost of the entire network [3]. In other words, the generator's real and reactive powers are allowed to vary within certain limits so as to meet a particular load demand with minimum fuel cost. This is called the Optimal Power Flow (OPF) or sometimes known as the Optimal Power Dispatch or Economic Dispatch (ED) problem [3]-[5].

Transfer capability is described as the amount electric power that can be passed through a transmission network from one place to another [5]. Physically, this involves the re-dispatching of generator real power outputs. One of the major purposes of transfer capability is to determine a power system's security, and through this to compare various system designs. The reason for this is that the larger the available transfer capability of a system, the easier it can handle changes in the system configuration. This is obvious when considering an interconnected system. If generation at one point fails, this can be compensated for by another generator in the system, provided that the transfer capability is greater than the required real power to be transferred.

In this paper, financial issues like spot price, total cost of Generation and total profits of a real-life utility power system of Andhra Pradesh Grid at 220kV using OPF Analysis and is extended to the calculation of ATC between the different Areas.

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II. MODELLING OF OPF PROBLEM

Newton’s method is well-known in the area of power systems. It has been the standard solution algorithm for the power flow problem for decades [6]. A good reference for the theory of Newton’s method is a book by Luenberger [7], which describes Newton’s method as well as its quadratic convergence properties. The detailed explanation in [7] is left to the interested reader. This thesis will only cover the process of applying Newton’s method to a minimization problem such as the OPF.

Newton’s method is a very powerful solution algorithm because of its rapid convergence near the solution. This property is especially useful for power system applications because an initial guess near the solution is easily attained. System voltages will be near rated system values, generator outputs can be estimated from historical data, and transformer tap ratios will be near 1.0 p.u.

In the solution of OPF, the main objective is to minimize total operating costs of the system. In OPF, when the load is light, the cheapest generators are always the ones chosen to run first. As the load increases, more and more expensive generators will then be brought in. Thus, the operating cost plays a very important role in the solution of OPF [8], [9].

In all practical cases, the cost of generator i can be represented as a cubic function of real power generation expressed in \$/hr,

$$C_i = (\alpha_i + \beta P_i + \gamma_i P_i^2 + \xi_i P_i^3) * \text{fuel cost} \tag{1}$$

Where Pi is the real power output of generator i, and α, β, γ and ξ are the cost coefficients. Normally, the cost coefficients remain constant for a generator. The last term in the equation is the fuel cost, expressed in \$/MBtu [10].

Another important characteristic of a generator is the incremental cost, also known as marginal cost. It is a measure of how costly it will be to produce the next increment of power. The incremental cost can be obtained from the derivative of C_i of equation (1) with respect to P_i,

$$\frac{\partial C_i}{\partial P_i} = (\beta_i + 2\gamma_i P_i + 3\xi_i P_i^2) * \text{fuel cost} \tag{2}$$

Which is expressed in \$/MWhr.

The transmission losses become a major factor in a large interconnected network whereby power is being transmitted over long distances. A common function to represent total system real power losses in terms of the total real power output is the Kron’s loss formula,

$$P_L = \sum_{i=1}^{ng}\sum_{j=1}^{ng} P_i B_{ij} P_j + \sum_{i=1}^{ng} B_{oi} P_i + B_{oo} \tag{3}$$

Where P_L is the total real power losses, and B_{ij} are the loss coefficients or B coefficients [11].

Optimal dispatch can be seen generally as a constrained optimization problem. When solving a constrained optimization problem, there are two general types of constraints, which are equality and inequality constraints. Equality constraints are constraints that always need to be enforced.

The constrained optimization problem can be solved using the Lagrange Multiplier method, and for simplicity, only the maximum and minimum real power limits are included as the inequality constraints.

The total operating cost of all generators in a system is given by,

$$C_i = \sum_{i=1}^{ng} C_i \tag{4}$$

Where n_g is the number of generator buses.
The total real power generation is then given by,

$$\sum_{i=1}^{ng} P_i = P_D + P_L \tag{5}$$

Where $P_{i(min)} \leq P_i \leq P_{i(man)}$, P_D is the total real power demand, and P_L is the total system real power loss [12].
The Lagrange Multiplier can then be expressed as,

$$\ell = C_t + \lambda\left(P_D + P_L - \sum_{i=1}^{ng} P_i\right) + \sum_{i=1}^{ng} \mu_{i(max)} (P_i - P_{i(max)}) + \sum_{i=1}^{ng} \mu_{i(min)} (P_i - P_{i(min)}) \tag{6}$$

Where the term second term is the equality constraint, while the last two terms are inequality constraints in equation (6) [13].

Note that both $\mu_{i(max)}$ and $\mu_{i(min)}$ are equal to zero if $P_{i(min)} \leq P_i \geq P_{i(max)}$, which means that the inequality constraints are inactive. The constraints will only be active when violated, which means $P_i > P_{i(max)}$ or $P_i < P_{i(min)}$. This is known as the Kuhn-Tucker necessary conditions of optimality, following the conditions below,

$$\frac{\partial \ell}{\partial P_i} = 0 \tag{7}$$

$$\frac{\partial \ell}{\partial \lambda} = 0 \tag{8}$$

$$\frac{\partial \ell}{\partial \mu_{i(min)}} = P_i - P_{i(min)} = 0 \tag{9}$$

$$\frac{\partial \ell}{\partial \mu_{i(max)}} = P_i - P_{i(max)} = 0 \tag{10}$$

The optimal solution can then be obtained by solving for the condition, $\frac{\partial \ell}{\partial P_i} = 0$ [14]-[16].

III. SPOT PRICE

Some industrial customers, for example metal industry, can bear with a reduction in their power supply [17]. This may give rise to numerous interruptible contracts individually negotiated with various industrial customers [18]. Power Exchange (PX) develops a demand curve from aggregated demand bids for each hour, on a day-ahead basis, starting with the highest priced bids and ending at the lowest ones. This gives rise to a set of hourly demand curves for next day each resembling a descending staircase - see Fig. 1. Demand curve starts with highest price for un-interruptible power supply. It is followed by different reduced prices for different levels of acceptable interruptions.

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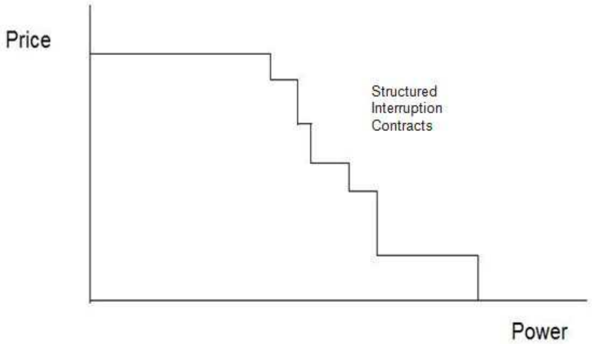

Fig. 1 A typical demand curve showing interruptible contracts

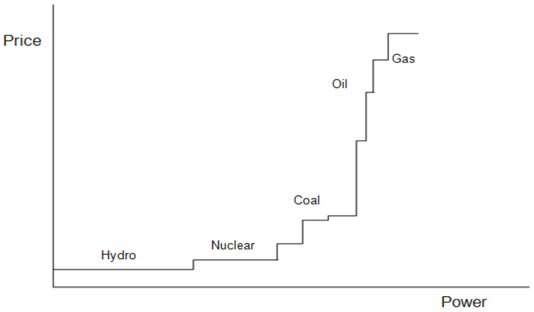

Fig. 2 A supply curve showing change in price due to production method

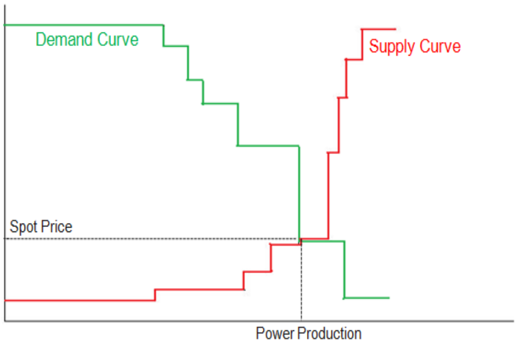

Fig. 3 Determination of Spot Price and required Power Production

Similarly a supply curve is established for each hour of the next day by aggregating supply bids in opposite order to the demand bids i.e. starting with the lowest priced bids from plants such as hydro or nuclear and ending at the highest ones from plants operating on gas and oil [19]. It leads to a supply curve, for every hour of the next day, as an ascending staircase pattern - see Fig. 2. Hourly spot price of electricity is determined on a day-ahead basis by intersection of the respective demand and supply curves as shown in Fig. 3. The point of intersection determines the hourly spot price and required power generation.

IV. AVAILABLE TRANSFER CAPABILITY

Available transfer capability (ATC) is a measure of the transfer capability remaining in the physical transmission network for further commercial activity over and above committed uses [20]. ATC can be expressed as:

$$ATC = TTC - \text{existing transmission commitments} \qquad (11)$$

Where, Total Transfer Capability (TTC) is defined as the amount of electric power that can be transferred over the interconnected transmission network or particular path or interface in a reliable manner while meeting all of a specific set of defined pre and post contingency conditions. Existing transactions is the power flow over the transmission paths at the desired time at which ATC should be calculated. This is the already committed used power on the transmission path. Utilities would have to determine adequately their ATC's to insure that system reliability is maintained while serving a wide range of transmission transactions. ATC between and within areas of the interconnected power system and ATC for critical transmission paths between these areas would be continuously updated and posted changes in scheduled power transfers between the areas.

The information of ATC, as an important indicator of the system performance, is useful in restructured energy market in the following ways:

- It provides the knowledge of power system capability about the present system condition.
- The ATC is required in making decisions for the transactions between the market participants. The market participants check for the power contracts between themselves.
- The ATC is also useful in enhancing system capability. With the knowledge of the limiting condition for the ATC, the system operator can take some operating or planning decision to avoid this limiting condition and thus enhance the system capability.
- The ATC value can also serve as an indicator of power congestion through transmission lines.
- The ATC is useful in transmission costing function. The ISO can put more transmission cost for the transaction through transmission path having low value of ATC. Transmission cost can be allocated in proportion to the ratio of the power transfer and the ATC of the transmission path. This extra transmission cost can be used in increasing the transmission capabilities for the transmission path.

V. CASE STUDY

A. *124-Bus Indian Utility system*

In a competitive electricity market, there will be many market players such as generating companies (GENCOs), transmission companies (TRANSCOs), distribution companies (DISCOs), and system operator (SO). Similarly Andhra Pradesh State Electricity Board (APSEB) is divided into Andhra Pradesh Generating Company (APGENCO), Andhra Pradesh Transmission Company (APTRANCO) and Andhra Pradesh Distribution Company (APDISCO). All are operating as independent companies under the government of Andhra Pradesh. APDISCO is again divided into four companies as Northern Power Distribution Company Limited (NPDCL), Central Power Distribution Company Limited (CPDCL), Eastern Power Distribution Company Limited (EPDCL), and

Sothern Power Distribution Company Limited (SPDCL). Each Distribution Company is considered as one area for this analysis. Details of Area wise buses are given in Table 1.

At present APGENCO is operating with Installed Capacity of 8923.86 MW (Thermal 5092.50MW and 3831.36MW) along with Private sector of 3286.30MW and Central Generating Stations (CGS) share of 3209.15MW. A 124-bus Indian utility real-life power system at 220kV is used for portfolio analysis in different operating scenarios. The generators' bids are assumed to be 10% higher than the generators' costs and the spot price is determined by the highest generator's bid. Simulations are done with and without CGS Share and in the case of summer on with varying load conditions from 50% to 125% load for this system.

Case 1 : All the generators are committed to dispatch with 100% load.

Case 2 : Some of Generators with more expensive are shut down with 125% load.

Case 3 : Some more Generators with more expensive are shut down with 100% load.

Case 4 : Some more Generators with more expensive are shut down with 75% load.

Case 5 : Some more Generators with more expensive are shut down with 50% load.

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TABLE I
DETAILS OF AREA WISE BUSES

Area No.	Area Name	Buses Number (Total No. of Buses)
1	NPDCL	1-5,12,24,26,27,29,30-35,37,38,129 **(19)**
2	CPDCL	6-11,13,15-23,25,28,36,39-54,56-65,121,124,128 **(48)**
3	EPDCL	93,95-118,123 **(26)**
4	SPDCL	55,66-75,77-92,94,120,125,126 **(31)**

B. *Case Study A (With Zero Interstate Power)*

For this case total APGENCO, Private sector and CGS Share of Two Generating stations (bus 1 (2600MW), bus 115 (1500MW)) are located within the Andhra Pradesh State itself. But the total generation of these two plants is not belongs to Andhra Pradesh State only.

Dispatch of generators for variation of the load is given in table II. Details of Total Generation, Load, Losses, Cost of Generation, Spot price and Total Profit are given in Table 3. In all the Cases Profits are varying linearly with respect to the spot price. Case 1 gives more profits to the sellers by operating more costly generators. In Case 3, by turning off the more costly generators that are not required, spot price is reduced will give more benefits to the buyers. Variation of ATC for each case is given in Table IV.

TABLE II
DISPATCH OF GENERATORS FOR DIFFERENT CASES

Area	Generators	Generators committed to Dispatch				
		Case 1	Case 2	Case 3	Case 4	Case 5
1	1-10	All	1-10	2,3,5-8	3,6-8	7,8
2	11-16,34	All	11-16,34	11-16,34	11-16,34	11-16,34
3	20-33	All	20,21,24-27,29-33	26,27,29-32	30-32	30-32
4	17-19	All	17,18,19	17,18,19	18	18

TABLE III
DETAILS OF TOTAL GENERATION, LOAD, LOSSES, COST OF GENERATION, SPOT PRICE AND TOTAL PROFIT

	Case 1	Case 2	Case 3	Case 4	Case 5
Total Generation (MW)	10644.20	13064.60	10663.20	7969.80	5345.10
Total Load(MW)	10366.00	12757.50	10366.00	7775.00	5183.50
Total Losses(MW)	297.19	307.19	297.18	194.77	161.60
Cost of Generation (Rs./Hr)	22378,601.70	23605080.75	17871964.00	12352748.26	8282243.00
Spot Price (Rs./MWHr)	6385.69	3992.51	3833.23	2533.65	2435.37
Total Profit (Rs./Hr)	45591832.09	28555585.17	23002210.16	7839935.50	4734980.07

TABLE IV
VARIATION OF ATC BETWEEN THE AREAS FOR DIFFERENT CASES

Transfer Areas	Case 1	Case 2	Case 3	Case 4	Case 5					
	ATC (MW)	Limiting Area/Line	ATC (MW)	Limiting Area/Line	ATC (MW)	Limiting Area/Line	ATC (MW)	Limiting Area/Line	ATC (MW)	Limiting Area/Line
1-2	1019	Area 2	1944	Area 2	1941	101-31	1160	Area 2	353	Area 1
1-3	1199	Area 3	1503	101-31	1436	101-31	1247	Area 1	353	Area 1
1-4	1520	Area 4	1790	30-87	537	Area 4	1057	Area 4	353	Area 1
2-1	528	Area 1	101	Area 2	36	Area 2	913	Area 2	28	Area 1
2-3	748	40-84	101	Area 2	36	Area 2	881	Area 2	1211	Area 3
2-4	801	82-46	101	Area 2	36	Area 2	473	Area 4	673	Area 4
3-1	734	Area 1	620	Area 3	541	Area 3	458	Area 3	28	Area 3
3-2	1019	Area 2	1428	Area 3	941	Area 3	485	Area 3	358	Area 3
3-4	795	Area 4	1359	Area 3	545	Area 3	480	Area 3	368	Area 3
4-1	607	Area 1	21	Area 1	411	Area 1	224	Area 1	11	Area 4
4-2	636	Area 4	23	Area 4	1668	Area 2/4	216	Area 4	11	Area 4
4-3	610	Area 4	228	Area 4	1515	95-85	1042	Area 4	111	Area 4/3

C. Case Study B (With CGS Share)

For this case total APGENCO, Private sector and CGS Share of Two Generating stations from Andhra Pradesh (bus 1 (913.55MW), bus 115 (1168.4MW)) and Four Generating stations located in the other states (bus 45 (146.69MW), bus 68 (210.19MW), (bus 77 (175.97MW), bus 115 (22.69MW)) as a Andhra Pradesh State share is considered.

Dispatch of generators for variation of the load is given in table V. Details of Total Generation, Load, Losses, Cost of Generation, Spot price and Total Profit are given in Table VI. In this Case Study also Profits are varying linearly with respect to the spot price. By operating the power system with CGS share spot price is reduced, and the get benefited. In spite of operating more costly generating stations and constructing of new power plant with in the state, using of CGS share and purchangeing the power from National Thermal Power Corporation (NTPC) in cheaper. Variation of ATC for each case is given in Table 7.

TABLE V
DISPATCH OF GENERATORS FOR DIFFERENT CASES

Area	Generators	Generators committed to Dispatch				
		Case 1	Case 2	Case 3	Case 4	Case 5
1	1-10	All	1-8	2,3,5-8	2,3,6-8	7,8
2	11-16,34,**35**	All	11-16,34	11-16,34	11-16,34	11-16,34
3	20-33,**38**	All	20-27,29-33	26,27,29-32	26,27,30-32	30,31,38
4	17-19,**36, 37**	All	17,18.36,37	17,18,36,37	18,36,37	18,36,37

TABLE VI
DETAILS OF TOTAL GENERATION, LOAD, LOSSES, COST OF GENERATION, SPOT PRICE AND TOTAL PROFIT

	Case 1	Case 2	Case 3	Case 4	Case 5
Total Generation (MW)	10587.61	13291.5	10630.7	7906.5	5399.1
Total Load(MW)	10366	12957.5	10366	7774.5	5184
Total Losses(MW)	221.60	334.00	264.71	132.15	215.15
Cost of Generation (Rs./Hr.)	20701659.61	23196628.7	16795680.72	11839945.38	5883134.5
Spot Price (Rs./MWHr)	6385.69	3436.09	3224.77	2624.51	2518.30
Total Profit (Rs./Hr)	46907535.69	22474195.90	17485752.73	8910769.18	7713494.58

TABLE VII
VARIATION OF ATC BETWEEN THE AREAS FOR DIFFERENT CASES

Transfer Areas	Case 1		Case 2		Case 3		Case 4		Case 5	
	ATC (MW)	Limiting Area/Line	ATC (MW)	Limiting Area/Line	ATC (MW)	Limiting Area/Line	ATC (MW)	Limiting Area/Line	ATC (MW)	Limiting Area/Line
1-2	2061	30-87	483	Area 1	1674	Area 1	999	Area 1	486	Area 1
1-3	1040	Area 3	483	Area 1	1531	101-31	991	Area 1	204	Area 1
1-4	838	Area 4	483	Area 1	1572	101-31	638	Area 4	450	Area 1
2-1	681	Area 2	491	Area 2	258	Area 2	56	Area 1	427	Area 1
2-3	1355	Area 2	692	Area 2	457	Area 2	607	Area 2	612	Area 2
2-4	1408	Area 4	610	Area 2	1018	Area 2	607	Area 2	606	Area 2
3-1	1146	Area 3	413	Area 3/1	553	Area 3	54	Area 3	381	Area 3
3-2	1299	Area 3	1573	Area 3	1435	Area 3	979	Area 3	697	Area 3
3-4	869	Area 3	610	Area 3	1018	Area 3	647	Area 3	510	Area 3
4-1	676	Area 1	413	Area 1	314	Area 1	56	Area 1	426	Area 1
4-2	2576	Area 4	2174	Area 4	901	Area 4	363	Area 4	513	Area 2
4-3	675	Area 3	1168	Area 4	1155	Area 4	363	Area 4	1403	Area 3

D. Case Study C (In Summer)

For this case total APGENCO, Private sector and CGS Share as in case B is considered and in the summer season most of the Hydro power plants (generators at buses 2, 8,11,12,15,16,30,31, and 34) will not generate power due to the shortage of the water. In this case if load is 125%, Generation is not sufficient leads to load shedding and this case does Not Exist (NE).

Dispatch of generators for variation of the load is given in table 8. Details of Total Generation, Load, Losses, Cost of Generation, Spot price and Total Profit are given in Table 9. In this Case Study also Profits are varying linearly with respect to the spot price. In the summer spot price is more as compared to that of previous case because Generation cost for hydro power plants is less. Variation of ATC for each case is given in Table 10.

TABLE VIII
DISPATCH OF GENERATORS FOR DIFFERENT CASES

Area	Generators	Generators committed to Dispatch				
		Case 1	Case 2	Case 3	Case 4	Case 5
1	1-10	1,3-7,9,10	NE	1,3-7,9,10	3,5,6,7	3,5,6,7
2	11-16,34,**35**	13,14,35		13,14,35	13,14,35	13,14,35

3	20-33,**38**	20-29,32,33,38		21-27,29,32,33,38	22,29,32,33,38	38
4	17-19,**36, 37**	17-19,36,37		17,18,36,37	17,18,36,37	18,36,37

TABLE IX
DETAILS OF TOTAL GENERATION, LOAD, LOSSES, COST OF GENERATION, SPOT PRICE AND TOTAL PROFIT

	Case 1	Case 2	Case 3	Case 4	Case 5
Total Generation (MW)	10648.40	**NE**	10648.60	7959.90	5353.00
Total Load(MW)	10366.00		10366.00	7774.50	5183.00
Total Losses(MW)	282.41		282.59	185.38	170.01
Cost of Generation (Rs./Hr.)	24141581.83		23288479.32	16631619.88	9313848.39
Spot Price (Rs./MWHr)	6385.69		4252.00	3267.36	2432.21
Total Profit (Rs./Hr)	43855544.14		21989282.84	9376337.00	3705796.06

TABLE X
VARIATION OF ATC BETWEEN THE AREAS FOR DIFFERENT CASES

Transfer Areas	Case 1		Case 2		Case 3		Case 4		Case 5	
	ATC (MW)	Limiting Area/Line	ATC (MW)	Limiting Area/Line	ATC (MW)	Limiting Area/Line	ATC (MW)	Limiting Area/Line	ATC (MW)	Limiting Area/Line
1-2	226	Area 2		NE	226	Area 2	739	29-35	1066	29-35
1-3	1660	Area 1			1660	Area 1	1087	Area 1	206	Area 3
1-4	1660	Area 1			1660	Area 1	235	29-35	1281	Area 1
2-1	00	Area 2			00	Area 2	297	Area 2	90	Area 2
2-3	359	40-84			355	40-84	981	Area 2	19	Area 2
2-4	788	40-84			893	40-84	1435	Area 2	1502	Area 2
3-1	626	Area 3			219	Area 3	297	Area 3	90	Area 3
3-2	226	Area 2			219	Area 3	226	Area 3	226	Area 3
3-4	631	Area 3			219	Area 3	717	Area 3	533	Area 3
4-1	677	Area 4			307	Area 4	08	Area 4	96	Area 1
4-2	226	Area 2			226	Area 2	08	Area 4	144	Area 4
4-3	441	85-86			448	85-86	08	Area 4	206	Area 3

Results showed that profits are positively-related to the spot price and the load demand. In other words, profits increase as the spot price increases with the load demand. This is because the spot price is determined from the highest generator's bid, and expensive generators are required when the load demand is high, which will set a high spot price.

It is also realized that cheaper generators will have higher profit margins regardless of the spot prices. Therefore, it is advantageous for companies to own a greater number of cheap generators along with a few expensive ones. Those expensive generators can be used as backup units for emergencies and perhaps also used to set high spot prices which are beneficial to the cheaper generators.

VI. CONCLUSION

Our results show that profits of industrial plants are maximized by participation in a de-centralized electricity market through a power exchange. At high spot price savings are increased that means each generating company should have the combination of both cheap and costly generators. The above results are more useful for Power Trading Corporation of India Ltd. (PTC), the leading provider of power trading services, in India is trading power on a sustained basis since June 2002 through purchase from surplus utilities and sales to deficit State Electricity Boards (SEBs) at an economical price, providing best value to both the buyers and sellers and ensuring that the resources are utilized optimally. Though the power-trading scenario in India is at a nascent stage, it is growing at a rapid pace. The power market in India has evolved over the last four years and it is expected that it is likely to grow at a faster pace – with the reforms of State Electricity board s and building up of transmission highways across the regions to increase Inter-regional power transfer capacity. These case studies are much useful for Energy Management System (EMS), Operating people of the Andhra Pradesh State Electricity board.

APPENDIX

TABLE XI
DETAILS OF GENERATORS AND THEIR COST FUNCTIONS

Gen. No.	Bus Number	Bus Name	Area Name	α_I (Rs. /Hr)	β_I (Rs. /MWHr.)	Min MW	Max MW
1	1	RSS	1	55639.27	1640	37.5	62.5
2	1	RSS	1	17968.04	0	8.1	27
3	1	RSS	1 (Total)	874531.90	1250	1560	2600
			1 (AP Share)	358744.29	1250	548.13	913.55

4	27	OGLPRM	1	740867.60	1160	300	500
5	29	KTS-V	1	636061.60	1200	600	1000
6	30	KTS	1	402568.50	1280	432	720
7	31	LSL	1	93139.27	0	138	460
8	31	LSL	1	15410.96	0	25.2	84
9	32	SRP	1	114155.30	1900	68.4	114
10	34	HWP	1	34246.58	1800	21.6	36
11	46	SSM	2	179931.50	0	231	770
12	46	SSM	2	438618.70	0	270	900
13	54	NSR	2	11837.90	0	18	60
14	54	NSR	2	17751.14	0	27	90
15	54	NSR	2	160844.80	0	244.68	815.6
16	61	GTY	2	10559.36	0	17.28	57.6
17	72	RTP	4	1080297.00	1770	630	1050
18	85	VTS	4	1126256.00	1570	1056	1760
19	91	LNC	4	366016.00	1760	109.5	365
20	96	VG-I	3	108096.50	1830	30.6	102
21	97	VG-II	3	182280.80	1830	51.6	172
22	100	VMG	3	364143.80	1790	141.8	472.8
23	100	VMG	3	167374.40	1790	66	220
24	100	VMG	3	353881.30	2000	116.4	388
25	100	VMG	3	261929.20	2040	133.5	445
26	104	SPC	3	102237.40	1700	62.34	207.8
27	105	JGP	3	105593.60	1670	62.61	208.7
28	106	SMK	3	353881.30	2000	93	310
29	107	REL	3	184566.20	1650	66	220
30	111	USL	3	48595.89	0	72	240
31	113	DNK	3	9121.00	0	7.5	25
32	115	KLP	3 (Total) 3 (AP Share)	941632.40 824663.24	1580 1580	900 701.04	1500 1168.4
33	118	VSP	3	22831.05	1800	15	25
34	128	JURA	2	112716.90	0	70.2	234
35	45	MBN	2	270513.70	0	181.73	302.89
36	68	CDP	4	272819.63	820	260.4	434
37	77	NLR	4	91118.72	1400	218	363.34
38	115	KLP	3	47111.87	0	28.116	46.86

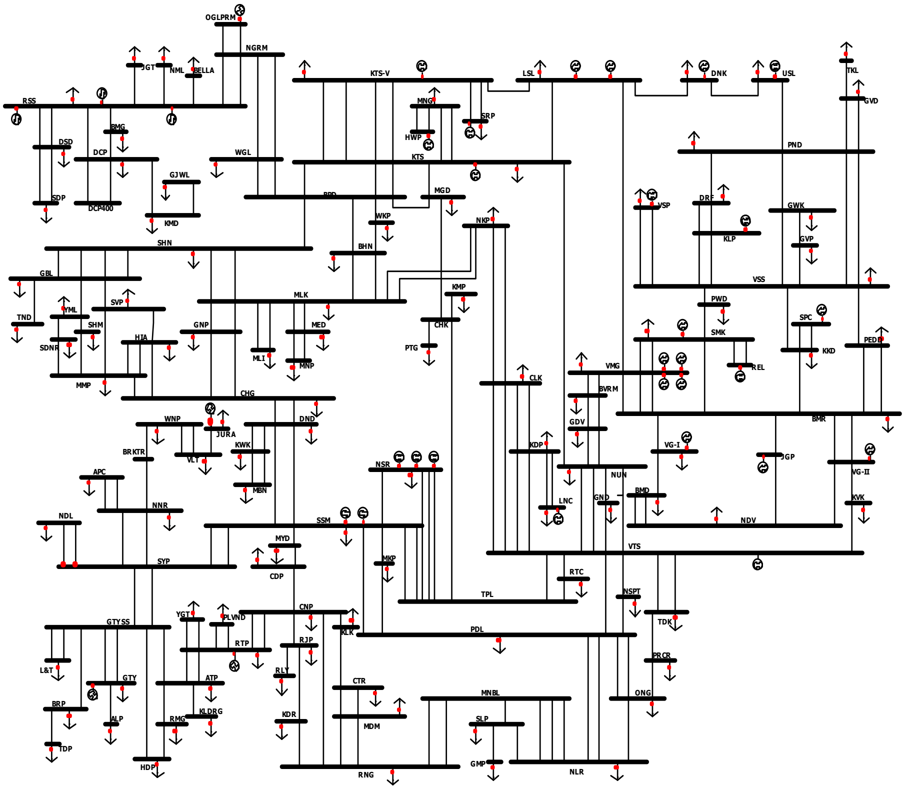

Fig. 4 124-Bus Indian utility real-life Power System of Andhra Pradesh State Grid

ACKNOWLEDGEMENT

The authors are thankful to the managements of CVR College of Engineering, R.R District. And JNT University, Hyderabad, for providing facilities and to publish this work.

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