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Bidding and Generation Strategy for Hybrid System in Electricity Market

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ABSTRACT Generation is an important and challenging optimization problem which involves efficient generation among the interconnected or hybrid system which satisfies the demand and provides economical operation. An optimization model is developed using GAMS modeling technique. The paper proposes a method to hybrid system comprising of thermal, hydro and wind generating units. The paper work proposes and formulates an algorithm that optimize the generation schedule of the thermal generating units on modified IEEE 24/30 bus system data for a predicted load demand with a motive to minimize the overall operating cost of the hybrid system. The operating cost includes the fuel cost of the thermal power plant, as the operating costs of the hydro and wind plants are insignificant. It determines the MCP for the generating units which participate in the electricity market. The model also considers the system comparison containing wind system and without wind system. This model helps in scheduling of conventional generators in the presence of renewable like wind and hydro units. The algorithm used for determining is modest and easy which will provide optimal solutions for a hybrid system. The work can be further extended by using real time variations in load and wind power that can be incorporated through stochastic modeling in GAMS.

Keywords- Hybrid system, bidding strategy, deregulation, incremental cost

INTRODUCTION

An electricity market is a system for effecting purchases, through offers and bids. The market operation is implemented competitively based on auctions. In a single-sided electricity auction the autonomous framework administrator (ISO) acquires the vitality and hold in the interest of the vitality and save clients. The ISO aggregates the generation bids and clears the auction based on Age Companies offers and the framework necessities, for example, stack level, asked for hold and so forth. In this structure, the competition is established between Generation Companies [1].

HYBRID POWER SYSTEM

Hybrid power system can be a combination of various generation technologies such as thermal, hydro, wind and solar etc. In order to compensate the variations of wind speed and load demand, the best option is to combine generation of wind units with other units which have instant availability and least start up costs. Due to this reason hydro and power system units are the best options which can be considered [2]. The second option is to use thermal plants with wind as they supply the major portion of energy demand worldwide despite high operational and maintenance cost and large emission of harmful gases. These are few factors which must be considered while deciding the operational strategy for the generating units. The power framework units in these circumstances can abstain from beginning of extra units as well as can deal with high slope rate required to meet the framework volatilities. Thus, the combination of thermal, wind, and pumped storage units are the most preferable option and work successfully under real operating conditions.

TERMINOLOGIES USED IN ELECTRICITY MARKET

Transmission System Operator (TSO) Body responsible for vitality adjust (structure operation) and transmission line up process. The Electricity Commission utilizes the phrasing Transmission System Operator (TSO) and Independent System Operator (ISO), together have a similar part however they contrast in the responsibility for organize. While TSO is completely unbundled from focused exercises being the proprietor of the system, the ISO deals with operational part of the system without own the system.

Makers: performers in control to create power. Their readiness is spoken to by an offered to the TSO.

Client: on-screen characters who request and expend power. This incorporates local, business and mechanical customer.

Capacity: most extreme capacity of a maker to produce power in a given time. Measured in power, kW or MW. The real vitality created relies upon the heap factor.

Load factor: Ratio of real vitality yield over some stretch of time and its vitality yield in the event that it had worked at full limit over some undefined time frame.

Bid: generation offer as far as amount of power and the cost at which they will create it. On account of uniform sale, just the providers offer into the market.

Pool showcase: unified market plan in which no physical, respective exchanges are permitted other than the required pool.

Age Companies takes an interest in the market through offering age limits and relating costs. From Generation Companies perspective, planning appropriate offer capacities is monetarily a testing assignment to make more benefit. In a joint vitality and save advertise the communication amongst vitality and save costs powers the Generation Companies to bargain between their offers in the submarket. In the simultaneous markets, Age Companies must offer in all submarkets in the meantime [4]. Subsequently, the offering issue is imperative and unsafe for Generation Companies in vitality markets. Offering parameters of the opponents are estimated. The offering parameters of the Generation Companies are ascertained utilizing the transformative programming approach. The advancement of here and now age planning is directly a region of profundity concentrated research; principally with the propensity towards privatization and deregulation of the power business. It is a testing improvement issue as a result of the mind boggling exchange among numerous factors. The age planning is the assurance of the producing unit with the end goal that the aggregate framework age cost is least while fulfilling the framework requirements. The cost of generation depends upon the operating cost, start up and shut down cost.

PROBLEM FORMULATION

The enhancement issue goes for minimization of working expense and the amplification of the money saving advantages gave by the buyers amid stack planning. A power structure has a few power plants. Each power set has a few producing units. Anytime of point, the collective load in the structure is met by the creating units in various power plants [6]. Monetary dispatch control chooses the power yield of each power plant, and power yield of each making unit inside a power plant, which will restrain the general cost of fuel, anticipated that would serve the structure stack.

- The enhancement issue goes for minimization of working expense and the amplification of the money saving advantages gave by the buyers amid stack planning.
- The target work is contained aggregate vitality hold cost and the cost acquired because of the heap lessening of different purchasers.
- To find out unit commitment scheduling for a hydro system.
- To obtain wind power variations using Monte Carlo simulation.
- To optimize the bidding and generation strategy by using MINLP (Mixed Integer Non Linear Programming) technique through GAMS (General Algebraic Modeling System) software.

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INPUT-OUTPUT CURVE OF UNIT GENERATION

Influence plants comprising of a few producing units are built contributing enormous measure of cash. Fuel cost, staff pay, intrigue and devaluation charges and upkeep cost are a portion of the segments of working expense. Fuel cost is the real bit of working expense and it can be controlled. Hence, we take the fuel cost alone for encourage thought.

To get diverse yield control, we have to change the fuel input. Fuel information can be measured in Tons/hour or Millions of Btu/hour. Knowing the cost of the fuel, as far as Rs. /Ton or Rs. /Millions of Btu, contribution to the producing unit can be communicated as Rs/hour. Let Ci Rs/h be the information cost to create energy of Pi MW in unit I. Fig.. For each creating unit there is a base and a greatest power produced as Pi_{min} and Pi_{max}. The Fig.1 shows the typical input-output characteristics.

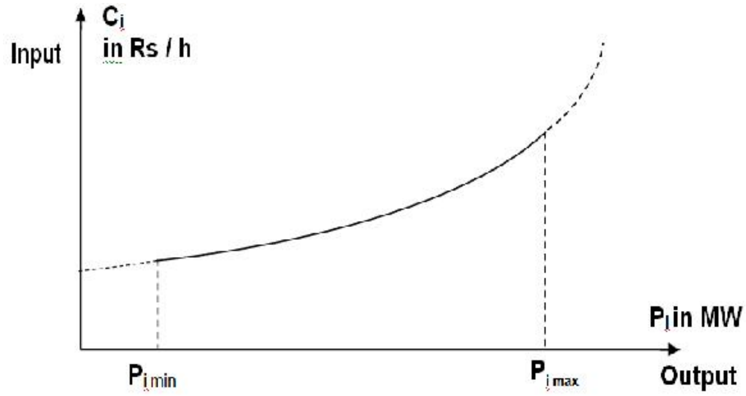

Fig.1 Input-Output Curve of a Generating Unit

If the input-output curve of unit i is quadratic, we can write

$C_i=\alpha_i P_i^2+\beta_i P_i+\gamma_i$ Rs/h (1)

A power plant may have a couple of generator units. If the data yield typical for different generator units is unclear, by then the delivering units can be comparably stacked. Be that as it may, making units will all things considered have different data yield trademark. This infers, for particular information cost, the generator control Pi will be unmistakable for different delivering units in a plant.

INCREMENTAL COST CURVE

The measure for appropriation of the heap between any two units depends on in the case of expanding the age of one unit, and diminishing the age of the other unit by a similar sum brings about an expansion or abatement in all out cost.

$\Delta Ci=dCi/dPi * \Delta Pi$ (2)

This can be gotten on the off chance that we can compute the adjustment in input cost ΔCi for a little change in control ΔPi.

Accordingly while choosing the ideal scheduling, we are pertained with dCi/dPi Incremental cost (IC) is controlled by the slants of the info yield bends. In this way the incremental cost bend is the plot of dCi/dPi versus Pi. The measurement of dCi/dPi in Rs/MWh.

The unit has the information yield as $C_i=\alpha_i P_i^2+\beta_i P_i+\gamma_i$ Rs/h (3)

Have the incremental cost as

$IC_i=dCi/dPi=2\alpha_i P_i+\beta_i$ (4)

Where, α_i ,β_i and γ_i are constants.

The aggregate cost will be least when the Incremental expenses are equivalent. in the event that any two units have diverse incremental costs, at that point to diminish the aggregate cost of age, decrease the output power in unit having higher IC and increment the yield control in unit having lower Incremental Cost .A phase will reach wherein incremental expenses of the considerable number of units will be equivalent. By and by the total cost of age will be minimum. Subsequently the judicious division of load between units is that all units must work at the same incremental cost.

OPTIMAL SCHEDULING OF HYDRO-THERMAL SYSTEM

Static optimization problem is stated as

$$C_T=\int_0^T C'(P_{GT}(t))dt \quad (5)$$

Under the constraint

i. Meeting load demand- $P_{GT}(t) + P_{GH}(t) – P_L(t) – P_D(t) = 0$ (6)

Power balance equation
P_{GT} (t) = Thermal generation
P_{GH} (t) = Hydro generation
P_L (t) = Total system transmission losses
P_D (t) = Sum of load demand at all buses

i. Water availability

$$X'(t)-X'(o)-\int_0^T J(t)dt+\int_0^T q(t)dt =0 \quad (7)$$

J (t) – water inflow (rate)
X' (t) – water storage
X' (o) – specified water storage at beginning
q (t) – water storage (head)

ii. Hydro generation PGH(t) is a purpose of hydro release and water storage (head)

$$P_{GH}(t)=f\{x'(t),q(t)\} \quad (8)$$

On the off chance that the arrangement acquired without thinking about the disparity requirements, at that point got arrangement will be ideal. If for no less than one generator units, the imbalance requirements are not fulfilled, the perfect method is gotten by keeping these generator units in their nearest limits and making the other generator units to supply whatever is left of the power as indicated by level with incremental cost run the show.

METHODOLOGY

The normal of offering parameter is computed to be the ideal methodology. Fortification Learning is utilized to locate the ideal offering methodology. In this technique, manufactured specialist will choose what cost ought to be bidden in the following round of sale comparing to stack conjecture and past experience. The optimal bidding strategy problem is formulated as a mixed- integer nonlinear problem and is solved under GAMS.

i. The profit maximization problem is simulated and constraints by considering the forecasted market price data.
ii. Market Clearing Price (MCP) is characterized as the working capacity that expands the social welfare work where both the creating organizations and the purchasers are at favorable circumstances. The proposed strategy is inferred utilizing settled request and just considering the generator offer capacities. Wind power variation calculation using Monte Carlo simulation.
iii. Calculation of Market Clearing Price (MCP) prices depending upon the equations.
iv. Bidding amount will be calculated depending upon the prices being offered.

The target work is included aggregate vitality and save cost and the cost brought about because of the heap diminishment of different shoppers as communicated by condition (1) beneath.

$$\text{Tcost} = \sum_{k=1}^{K}\Big[P_g\ (k) \times C_g(k) + \sum_{d=1}^{d}\{\text{Cost}_G(d,k) + RP_g(d,k)\ \times \text{Cost}_g^R(d,k) + SUC(d,k)\} + \sum_C\ C_C^E\ (cc,k) + \sum_r\ C_r^E\ (rc,k)\Big] \quad (9)$$

(3.1)

The cost function $C_g(j, t)$ can be given by a quadratic cost curve as shown in equation (10) below.

$$Cost_g(d,k) = (a_d + b_d \times Po_g(d,k)) \times u(d,k) \quad (10)$$

where, a_d and b_d are respectively cost coefficients of Generators.

Total power generation = power demand + total transmission losses

(b) The wind power depends upon the speed and density of the air at the corresponding time interval and is given as,

$$P_{wk}=1/2\rho AV^3 \quad (11)$$

where, P_{wk} is the wind power at time k, ρ is the air density, A is the area of the wind blade, and V is the wind speed in m/sec.

GENERATORS AND RESERVE POWER CONSTRAINTS

The thermal generator units have maximum and minimum limits which must be adhered during load scheduling.

$$Po_g(d,k) + RP_g(d,k) \le P_g^m \;. u(d,k) \quad (12)$$

$$P_g(d,k) \ge P_g^m \;. u(d,k) \quad (13)$$

The startup cost $SUC(d,k)$ of generator units is as follows,

$$SUC(d,k) \ge Suc \times \left(u(d,k) - u(d,k-1)\right) \quad (14)$$

$$SUC(d,k) \ge 0 \quad (15)$$

GENERATION LIMITS CONSTRAINTS OF WIND

$$P_w \quad (w,k) \le P_w(w,k) \le P_w \quad (w,k) \quad (16)$$

POWER FLOW CONSTRAINTS

It is important to have the line flows within the limits during system operation. The equations (17) and (18) give the real and reactive power limits restriction on power flow.

$$P_i(s,k) = \sum_{r=1}^{s} |V(s,k)||V(r,k)||Y_{s,r}|\cos\left(\delta_{r,k} - \delta_{s,k} + \theta_{s,r}\right) \quad (17)$$

$$Q_i(s,k) = -\sum_{r=1}^{s} |V(s,k)||V(r,k)||Y_{s,r}|\sin\left(\delta_{r,k} - \delta_{s,k} + \theta_{s,r}\right) \quad (18)$$

PUMPED STORAGE HYDRO UNIT

Pumped hydro operates in two modes, generation mode and pump mode.

Pump mode

$$P_{P} \quad (k) \le P_{p} \quad (k) \le P_{p} \quad (k) \quad (19)$$

$$PL_k \le PL_k \quad (20)$$

Generation mode

$$P_g \quad (k) \le P_g \quad (k) \le P_g \quad (k) \quad (21)$$

$$PL_k \ge PL_k \quad (22)$$

Pumped hydro capacity constraint

$$PL_2 - (W_2 \; * \Delta k) = PL_1 \quad (23)$$

$$PL(k+1) = PL(k) + M\left(E_P * P_{P} \quad (k) - P_g \quad (k)/E_g\right) \quad ` \quad (24)$$

Where M is duration of interval

BIDDING STRATEGIES

Consider the generation system with j resources participating in energy market. Generation system has a strategy set with N strategies to tackle with different scenarios arising in day to day market. In order to maximize its revenue in various scenarios, generation system can choose an appropriate strategy from N strategies without losing market share. If the generation system chooses i^th strategy, then corresponding strategy coefficient S_i is

$$S_i = S_m + \frac{i}{N-1}(S_m - S_m) \quad (25)$$

where, S_m and S_m are the minimum and maximum limit of this range.

The bidding price or Market clearing price (MCP) of generation system with its different resources $B_{j,k}$ is,

$$B_{j,k} = (b_j + S_i c_j P_{j,k}) \quad (26)$$

Where b_j and c_j are cost coefficient of different participating resources of generation system.

Average MCP over the specified time period B_a is,

$$B_a = \frac{\sum_k \sum_j (P_{j,k} * B_{j,k})}{\sum_k \sum_j P_{j,k}} \quad (27)$$

Average price of purchasing electricity over the specified time period C_e is,

$$C_e = \frac{\sum_k \sum_j (P_{j,k} * B_{j,k}) + \sum_k P_{r\epsilon\ ,k} * C_r}{\sum_k P_L(k)} \quad (28)$$

where, $P_{r\epsilon\ ,k}$ and C_r is the power generated from renewable energy and corresponding price.

Contribution of various participating resources of generation system in energy market Ø_j is

$$\text{Ø}_j = \frac{\sum_k P_{j,k}}{\sum_k \sum_j P_{j,k}} \quad (29)$$

CONCLUSION

The printed material proposes and details a calculation that advance the age calendar of the warm creating units on changed IEEE 24/30 transport framework information for an anticipated load request with a rationale to decrease the general working expense of the mixture framework. The operating price includes the fuel cost of the thermal power set, as the operating costs of the hydro and wind plants are insignificant. It determines the MCP for the generating units which participate in the electricity market and offer their bids in the form of quadratic cost curves. This model helps in scheduling of conventional generators in the presence of renewable like wind and hydro units. The proposed work for MCP has yielded tasteful outcomes for advertises clearing value assurance under various economic situations including emanation imperatives. The algorithm used for determining is modest and easy which will provide optimal solutions for a hybrid system. The work can be further extended by using real time variations in load and wind power that can be incorporated through stochastic modeling in GAMS.

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Appendix-A

Sets indexes

k	index of time period
cc	index of commercial customers
rc	index of residential customers (home)
r, s	index of buses
d	index of non-renewable generators
w	index of wind units

Binary variable

u (d, k)	start up/shut down status (1/0) of the generator d at time k

Continuous variable

Tcost	total operating cost
C_{cc}^{E}(cc, k)	price of load deduction offer of commercial consumer cc at time k (Rs)
P_{gd}(k)	energy purchased from the utility grid (MW)
$Cost_G$(d, k)	fuel cost of generator d at time k
Po_G(d, k)	scheduled output power of generator d at time k (MW)
RP_G(d, k)	scheduled operating reserve offered by generator d at time k (MW)
Pow(w, k)	scheduled output power of renewable wind unit w at time k (MW)
P_i(s, k)	net active power injected to bus s at time k
Q_i(s, k)	net reactive power injected to bus s at time k
$\delta_{s,k}$	angle of voltage at bus s at time k
V(s, k)	magnitude of voltage at bus s at time k
$P_{j,k}$	generated power of participating resource j at time k

Parameters

C_g (k)	cost of electricity from grid at time k (Rs/MW)
$Cost_G$ (d, k)	reserve price of generator d at time k Suc start up cost of generator d (Rs).
P_{wmin}(w,k)	lower limit of output generated power of wind plant w at time k (MW)
P_{wmax}(w,k)	upper limit of output generated power of wind plant w at time k (MW)
Pg_{max},Pg_{min}	upper and lower limit of power supplied by generator d (MW)
$\theta_{s,r}$	angle of admittance $Y_{s,r}$
$Y_{s,r}$	admittance magnitude of connection(s, r) in admittance matrix