Impact of Renewable Energy Availability on Load Serving Entity’s Sale Price and Procurement Decisions

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Introduction

➢ Retail Electricity Market – Second stage of trading take place
➢ Load serving entity (Retailer and Distribution Company) and consumers (End user) take part

*[Source - https://learn.pjm.com]*

Fig. 1. Electricity Market
LSE’s Decision-Making Problem

LSE’s Objectives

- Profit Maximization
- Risk Minimization

Procurement Cost Minimization

Optimal Procurement Decision

Revenue Maximization

Sale Price Decision

Consumer Demand

Wholesale Market Prices

Price Sensitive Consumer Behavior
Procurement Side

➢ Wholesale electricity market (WEM) - Prices are volatile
➢ Bilateral contracts- Fixed price fixed power contract
➢ Self-generation facility
  ➢ Thermal generating unit
  ➢ Renewable sources: Solar and Wind
Uncertainty Involved

➢ Wholesale electricity market (WEM) price uncertainty
➢ Renewable Uncertainty
Sale Side

➢ LSE can offers electricity under
➢ Fixed Pricing
  ▪ Price is kept fixed for several months
  ▪ Do not reflect actual wholesale electricity prices
  ▪ Consumers are not exposed to wholesale price volatility
    ▪ Example - Flat Rate
➢ Dynamic or Time-varying Pricing
  ▪ Price changes over the period of time
  ▪ Significantly reflect actual wholesale prices.
  ▪ Consumers has exposure to wholesale price uncertainty
    ▪ Example - Time of Use Price, and Real Time Price
Problem

➢ LSE’s Decision-making problem in the presence of RE sources
  ➢ Determine optimal procurement decisions
  ➢ Determine dynamic prices
➢ Procurement sources
  ➢ WEM
  ➢ Bilateral contracts
  ➢ Thermal Generation
  ➢ Renewable generation: Solar and wind
➢ Consumer behavior
  ➢ Price sensitivity is considered through price elasticity
➢ Uncertainty
  ➢ WEM – mean variance criterion
  ➢ RE – aggregated form
Mathematical Model

Objective Function

Max Obj = \sum_{t} Prof_{t} - \beta \sum_{t} var_{t}^{WEM} \tag{1}

Profit

Prof_{t} = R_{t} - C_{t}^{tot} \tag{2}

Cost

C_{t}^{tot} = C_{t}^{B} + C_{t}^{SG} + C_{t}^{WEM} \tag{3}

Revenue

R_{t} = D_{t}^{act} \lambda_{t}^{sale} \tag{4}

Demand function

D_{t}^{act} = D_{t} (1 + \varepsilon_{t} \frac{\lambda_{t}^{sale} - \lambda_{t}^{nsale}}{\lambda_{t}^{nsale}}) \tag{5}

Variance (Risk)

var_{t}^{WEM} = \left(P_{t}^{WEM}\right)^{2} \cdot \text{var} (\lambda_{t}^{WEM}) \tag{6}

Demand shifting

\sum_{t} D_{t}^{act} = \sum_{t} D_{t} \tag{7}
Constraints

LSE’s Objective function is subjected to following constraints

• **Bilateral contracts constraints**
  • Limits on minimum and maximum purchase

• **Wholesale electricity market constraints**
  • LSE can procure from WSE

• **Thermal-generating unit constraints**
  • Start up and shut down cost limits
  • Ramping up and ramping down limits
  • Minimum up time and down time limits
  • Minimum and maximum generation limits

• **Sale price constraints**
  • Upper and lower bound on sale prices

• **Energy balance constraint**
Renewable Generation

**RE Sources:** PV and Wind based self-generation

**Procurement cost:** Total cost from PV and wind is

\[ C_t^{RE} = P_t^{PV} \lambda_t^{PV} + P_t^{W} \lambda_t^{W} \]

**RE Uncertainty Consideration:**
Energy from RE sources are considered in aggregated form
Case Study

• The proposed model is illustrated via a case study of a LSE in PJM market.
• Planning period - 24 hours of a day
• One bilateral contract is considered for 24 hours of a day
  • Price - 34$/MWh.
  • Minimum power procurement limit - 30 MW
  • Maximum power procurement limit - 350 MW
• A thermal self-generation unit - 130 MW
• Consumers elastic behavior in response to LES’s selling price with hourly varying rate is considered equal to -0.4.
• RE Price - 28$/MWh
• Flat rate - 35 $/MWh
• Nominal sale price = Flat rate
• Min. and max. variation on sale price=18% of flat rate
Considered Cases

Case-1: PV: 15% of total LSE’s demand.
Case-2: PV: 20% of total LSE’s demand.

Case-3: Wind: 15% of total LSE’s demand.
Case-4: Wind: 20% of total LSE’s demand.

Case-5: PV and Wind: 15% from PV and 15% from Wind
Case-6: PV and Wind: 20% from PV and 20% from wind.
Fig. 1. PV and Wind profile for different cases

Fig. 2. Demand Profile.

Fig. 3. WEM prices, and standard deviation of WEM Prices.
Simulation Results for Case-1 and 2 (with PV)

Fig. 4. Dynamic sale prices for (a). Case-1 and (b) Case-2.

Fig. 5. LSE demand for (a). Case-1 and (b) Case-2.
Simulation Results for Case-3 and 4 (with Wind)

Fig. 6. Dynamic sale prices for (a). Case-3 and (b) Case-4

Fig. 7. LSE demand for (a). Case-3 and (b) Case-4.
Simulation Results for Case-5 and 6 (with PV+Wind)

Fig. 8. Dynamic sale prices for (a). Case-5 and (b) Case-6.

Fig. 9. LSE demand for (a). Case-5 and (b) Case-6
Fig. 10. Procurement from various sources for
(a). Case 1 and 2 (PV)
(b). Case 3 and 4 (Wind) and
(c). Case 5 and 6.
Fig. 11. Efficient frontier for case-1 to case-6.
Conclusion

- This paper proposed a decision-making model for setting dynamic sale prices and determination of LSE’s modified demand for optimal energy procurement.
- Impact of RE availability from PV and Wind are analyzed individually and simultaneously.
- Results show that LSE’s offers lower prices during RE availability periods.
- High RE procurement leads to further decreases sale prices to increase demand by shifting from other hours.
- LSE’s expected profit decreases with risk weight, i.e. with risk-averse behavior.
- Considering the risk averse nature of an LSE, this work highlighted the impact of demand behavior on LSE’s decision-making.
References


References


References


• The GAMS Website, 2019. [Online]. Available; http://www.gams.com/

Thank You