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Review

Opportunities and key challenges for wind energy trading with high penetration in Indian power market

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ABSTRACT

This paper briefly discusses the present framework and status of Indian power market and guides through the possible adaptations to accommodate the growing renewable energy (RE) integration into the grid. The participation of RE generators in the wholesale energy market would provide them a platform to optimally manage their generation portfolio which would help them in compensating the high investment cost. The increased competition in the market would eventually bring down the electricity price. The objective of this paper is to identify an ideal framework and optimal bidding mechanism for RE generators (wind energy in particular) to maximize the overall capital gain (social welfare) in the Indian power market. The inputs from various foreign electricity markets having high wind energy penetration have been considered. Recent studies suggest that battery energy storage system (BESS) can play a significant role in handling risks associated with the uncertainties in wind power generation and thus can help in maximizing the revenue for wind farm owners. It can also be instrumental in active/reactive power balancing which will further help in the frequency regulation. The paper probes into the combined wind and battery energy trading, and various bidding strategies in the day-ahead market (DAM), intraday energy market, real-time balancing, and other ancillary markets.

Contents

Introduction . . . 54
Overview of electricity markets . . . 54
Institutional market agents . . . 54
Market players . . . 54
Pricing mechanism and market settlement . . . 55
Major electricity markets-RE trading perspective . . . 55
Indian power market: present status . . . 55
Power exchanges in India . . . 55
RE Trading in Indian power market . . . 56
Literature review on electricity market for wind farms integrated with energy storage . . . 57
Short-term electricity market . . . 57
Reserve market and regulation market . . . 58
Demand Response . . . 58
Major challenges in trading of large-scale wind energy . . . 58
Key findings and future directions . . . 59
Future directives for the framework of Indian power market . . . 60
Conclusion . . . 60
References . . . 60

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Introduction

Renewable energy (RE) resources, primarily wind and solar energy are expanding at a significant pace in India to support the growing energy requirements of the country. Indian power grid is one of the largest synchronized network in the world with more than 330 GW of installed capacity (Installed Capacity, 2017). Presently, the fossil fuels based generators comprise around 67% of the total installed capacity while RE resources account for 17% with wind and solar contribution at 32 GW and 13 GW respectively. Over the last decade, the economy and the electricity demand of India has grown at an annual average of 7.5% (Economic Survey of India, 2017). The energy demand is expected to escalate further to support India's growing manufacturing sector and improved standard of living. In order to cater the augmenting energy needs with a commitment of providing clean and green energy, the Government of India under its ministry of new and renewable energy (MNRE) has established a target of installing 175 GW of RE by the year 2022 which would include 100 GW of solar energy and 65 GW of wind energy (Ministry of New and Renewable Energy, Government of India, 2017). As RE sources are intermittent in nature, such a large-scale integration of solar and wind power may result in load-generation imbalance. This may jeopardize the stability and reliability of whole power system if the situation is not addressed aptly. Thus, the Indian power system has to progressively evolve to absorb the impacts of increased variability and uncertainty of such a large-scale RE expansion.

The majority of Indian generation capacity is bound to long-term power purchase agreements (PPAs) of 12–25 years which results in entire demand-risk being transferred to distribution companies (DISCOMs) (Try short-term power trading, IEX article, 2017). Heavy reliance on long-term contracts has led to multiple issues faced by both DISCOMs and generators. DISCOMs are losing money due to the higher cost of power procurement in long-term contracts and lower realization of AT&C losses (aggregated transmission and commercial losses). This, in turn, results in delayed payments to the generator, idle capacities, stranded plants with no PPA and hence no means to achieve financial closure. However, with the advent of short-term open access and power exchange platform, it is possible to balance long-term PPAs with short-term power procurements.

RE sources are characterized by high installment cost with return on investment (ROI) of several years. Allowing RE generators to participate in wholesale market will help them to increase their profit and overcome the high investment cost. Since the objective of a market is always to maximize the social welfare, it will also bring down the price of electricity generated from renewable resources. However, the high risk associated with the uncertain power output from RE sources deter the RE producers to participate in the short-term market. Further, lack of suitable market framework and attractive incentives restrict RE trading. Recent literature (Xie et al., 2011) suggest that the battery energy storage system (BESS) integrated with RE generators can provide a smooth power output. The charging and discharging rates of BESS are pretty much fast so it can be used to address sudden load changes, reducing the reliance on fast ramping but costly generators. Further, BESS can also be instrumental in providing frequency regulation, power quality improvement, voltage stabilization, demand response activities like peak load shaving and load shifting and energy management in microgrids etc.

This paper gives a brief overview of basic electricity market (interchangeably used with power market) and explores the several global electricity markets where trading of either RE or its products is prominent. It highlights the key features of existing power market in India wherein the current and future scenarios for RE trading under high renewable energy integration is examined. The emphasis is made to explore the possibility of wind energy trading in Indian power exchanges. A thorough literature survey on various market options and bidding strategies for efficient wind energy trading is presented which investigates the role of BESS for profit maximization of wind farm owners. It identifies the major challenges in the way of successful integration of large-scale wind energy resources and its trading in the market. Further, it suggests the future directives for the framework of the Indian power market to accommodate the impending growth of wind energy.

Overview of electricity markets

The basic architecture of the electricity market is more or less the same around the world. Fig. 1 shows the structure of a typical market with its constituent agents and players (Conejo, Carrión, & Morales, 2010). In general, the electricity trading involves three types of markets based on different trading horizons:

- Day-ahead Market (DAM): It operates in one day advance and the market clears about 8 to 12 h ahead of actual power delivery. DAM accounts for most of the volume trading in the short-term market.
- Intra-day Market (IDM) or adjustment markets: It is sequentially arranged throughout the delivery horizons and clears a few hours before the actual power delivery.
- Real-time market (RTM) or balancing market: It clears a few minutes before the actual power delivery and intends to maintain the system balance in real-time.

Apart from these, an electricity market may also provide various ancillary services like reserve market (RM), regulation market (RGM) and demand response market (DRM).

Institutional market agents

The institutional market agents are authoritative for the technical and the financial aspects of the market. They include:

- Market Operator (MO): It is accountable for managing the financial affairs of the market. It governs the trading rules, decides the market price and determines the volume of energy to be traded.
- Independent System Operator (ISO): It controls the technical aspects of the electricity network and ensures the system reliability, stability and security through smooth power flow.
- Market regulator (MR): It ensures the competitive and adequate functioning of the market, enforces orders and regulations, and increases the utilization of RE resources by introducing various policies.

Market players

Market players mainly comprise of producers, retailers, and consumers which are discussed below:

- Producers: These entities own the generating units and are accountable for electricity production. There may be dispatchable as well as non-dispatchable producers. A producer seeks to maximize its profit

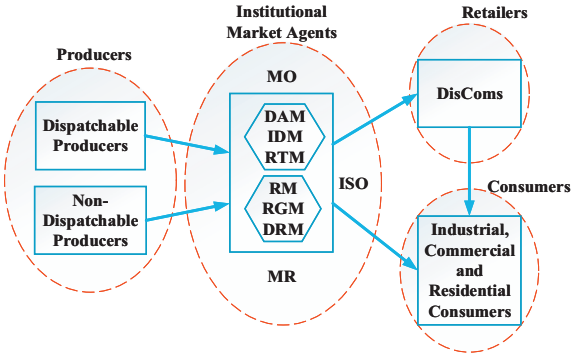

Fig. 1. Basic market architecture, institutional market agents, and market players.