Trading Opportunities for Wind Generators in Indian Electricity Market

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Abstract: ***In many countries wind generation is now treated at par with other forms of generation and is traded in power exchanges. In the Indian market, the wind generators still rely on preferential tariffs and risk free bilateral agreements. However, well organized market structure is already in place to ensure efficient trading of wind electricity through power exchange. There is also a renewable energy certificate mechanism, also traded through power exchange to promote the renewable energy generators. An unscheduled interchange mechanism is in place to ensure appropriate handling of imbalances due to unpredictable and intermittent nature of wind generators. The analysis done in this paper shows that in India, trading of wind electricity through the power exchange would be a better option in most scenarios.***

Keywords: Bilateral Trading, Power Exchange, Renewable Energy Certificates, Unscheduled Interchange, Wind power.

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1. Introduction

In recent times there has been a great concern among people and governments regarding the environmental impact of emissions coming from fossil fuel based power generation sources. This has led many countries to set ambitious targets for replacing fossil fuel based generation by renewable and pollution free generation technologies. On the forefront of such technologies is wind power generation. Due to intense research in wind power generation in recent years, the cost of wind turbine generators has come down and their efficiency has improved considerably. However, integration of wind power into electric grid at a large scale imposes many technical and economic challenges. Wind power generation itself is uncertain and intermittent in nature. Its unpredictable nature makes wind power non-dispatchable from system operations point of view. Intermittency imposes high ramping requirements on other power plants [1]. Increasing wind power portfolio imposes extra cost due to increase in additional reserve capacity requirements and results in inefficient operation of conventional power plants.

Until penetration of wind power was low, there were no major problems in accommodating wind power generation into grid dispatch on as and when available basis. However, in most countries with high level of wind power penetration, wind power now is treated at par with other forms of generations. A number of studies have been carried out recently in relation to the bidding strategies of wind power plant in day-ahead markets [2]-[4]. However, before framing bidding strategies for wind generators it is necessary to evaluate the other options apart from trading on exchange. In many countries there are preferential tariffs for wind generators and these generators also benefit from other schemes for selling their electricity. In this paper various methods of selling wind electricity in Indian electricity sector have been evaluated. The analysis is carried assuming various scenarios faced by wind generators returns corresponding to each trading option for all scenarios are compared to derive conclusions.

The next section outlines the wind power generation scenario in India and lists the steps taken by Indian government to promote wind energy generation. In Section 3, an overview of Indian electricity market has been presented. Section 4 explains the Renewable Energy Certificate mechanism operating in India. In Section 5, mathematical model for calculation of revenues of wind generators three trading options considered in this paper is presented. In Section 6 these trading options are analysed for a number of scenarios by varying the system load conditions and actual generation of wind generator vis-à-vis its scheduled generation. The conclusion of this study is presented in Section 7.

2. Wind Power Generation in India

Wind energy is the fastest growing renewable energy sector in the India. With a cumulative deployment of over 13,000 MW capacity, it accounts for nearly 70% of the installed capacity in the renewable energy sector in the country. The sector is growing rapidly and India is likely to achieve, for the first time in the country, a capacity addition of 2000 MW in a year, in 2011 [5].

The Indian wind energy sector has an installed capacity of 14158.00 MW (as on March 31, 2011). In terms of wind power installed capacity, India is ranked 5th in the World. Today India is a major player in the global wind energy market.

Indian Govt. has been at the forefront of providing all out support for the accelerated development of wind energy through proactive policy and regulatory interventions. Govt. policies provide for a host of fiscal incentives, feed-in-tariffs as a recently activated Renewable Energy Certificate regime. Govt. has also recently introduced a Generation Based Incentive (GBI) Scheme to help more Independent Power Producers (IPPs) enter the arena.

3. Indian Electricity Markets

The bulk electricity supply in India is tied in long-term contracts. The bulk electricity suppliers are mainly central or state owned generating stations or the IPPs and the bulk buyers are mainly SEBs/Discos. An appropriate commission regulates the price of bulk power supply based on Terms and Conditions of Tariff or as per the Power Purchase Agreements (PPAs). Thus, most of the existing bulk supply is locked up in long-term contracts having station wise tariff. This tariff is usually in two parts:

(i) capacity charge
(ii) energy charge

The SEBs/Discos rely mainly on these long-term contracts to serve their customers, however it is neither feasible nor economical to meet the short-term peaking demand through long-term contracts. Power trading is essential for meeting short-term demands at an optimum cost. It also facilitates the sale of short-term surpluses of distribution utilities so as to optimize their cost of procurement. The Open Access in Inter State Transmission Regulations of CERC [6] have facilitated power trading in India in an organized manner.

3.1 Bilateral Trading

Open Access as stated in Electricity Act 2003 means, “the non-discriminatory provision for the use of transmission lines or distribution system or associated facilities with such lines or system by a licensee or consumer or a person engaged in generation in accordance with the regulations specified by the Appropriate Commission”. As per the latest CERC regulations [7], [8], Open Access can be granted under these three categories:

(i) long term
(ii) medium term
(iii) short term

Long-term access is granted for usage of inter-state transmission system for a period exceeding 12 years but not exceeding 25 years. Medium term access is granted for a period exceeding 3 months but not exceeding 3 years. Short-term access is granted for the usage of inter-state transmission system for a period up to one month at one time. For short-term open access, the grid operator declares the anticipated power transfer capability available in the transmission system during the forthcoming three months. Within the short-term category, reservations on transmission corridors may be made under any of the following categories:

(i) advance
(ii) first-come first-served
(iii) day-ahead

3.2 The Day Ahead Market

In order to promote power trading in a free power market, CERC has allowed setting up of energy exchanges. The two energy exchanges operating in India at present are:

(i) Indian Energy Exchange (IEX)
(ii) Power Exchange of India Limited (PXIL)

These exchanges have been developed as market based institutions for providing efficient price discovery and price risk management to the generators, distribution licensees, traders, consumers, and other stakeholders. These exchanges coordinate with NLDC, RLDCs, and SLDCs for scheduling of traded contracts to get up-to-date network conditions. The participation in exchange operations is voluntary. On daily basis, the exchange offers a double-sided closed auction for delivery on the following day, which is termed as day-ahead market. Network constraints are considered in deriving the market-clearing price and market-splitting approach is used in case of congestion. CERC revised the regulations for open access in inter-state transmission [7], [8] to include collective transactions made on a power exchange. These transactions result in a transparent price discovery and present a balanced portfolio to the system operator through anonymous bids on a neutral platform. These transactions are processed before the processing of day-ahead category of bilateral transactions. The total available margins for short-term open access are assessed by the RLDCs in advance through simulation studies and made available transparently to the stakeholders through their respective websites. The balance margin after permitting advance and first-come-first-serve bilateral transactions is the margin available for scheduling of collective transactions.

3.3 Unscheduled Interchange Mechanism

The UI mechanism of ABT scheme provides a simple and transparent balancing mechanism for all type of power transactions in India. Whether they are long-term contracts, short-term bilateral trades, or collective trades through energy exchange, all of them rely on UI mechanism for settlement of deviations from scheduled transactions. The primary purpose of introducing ABT in Indian system in the year 2002 was to deal with grid indiscipline prevailing at that time and to ensure grid security through regulatory measures [9]. Under ABT, each state and each central generating station connected to regional grid is designated as a control area with schedules of demand and generation issued one day in advance. These schedules consider central allocation, bilateral trades, and collective trades through exchange. Deviations from schedules are termed as UI and charged at a frequency-linked price. They are determined in 15-minute time blocks through special metering and priced according to the system condition prevailing at that time. If the frequency is high, UI charge is small and if the frequency is low, UI charge is high. The introduction of ABT in all regional grids in the country has enabled the exchange of unscheduled power without any commercial problems. ABT is serving the dual purpose of providing frequency control service and enabling unscheduled interchange of surplus power, as and when available in the grid [10].

The shape of UI price vs. frequency curve has been a subject of much debate among the sector participants. Regular modifications have been done in the shape of UI curve since it was introduced in the year 2000. The modifications have been ordered by CERC, so as to meet the stated objectives of ABT mechanism. Initially, the frequency range in which UI prices vary was set between 49.0 and 50.5 Hz. In 2010, CERC has come up latest regulations [11], which set the frequency range between 49.5 and 50.2 Hz. The UI price – frequency relation as per this regulation is shown in Figure 1.

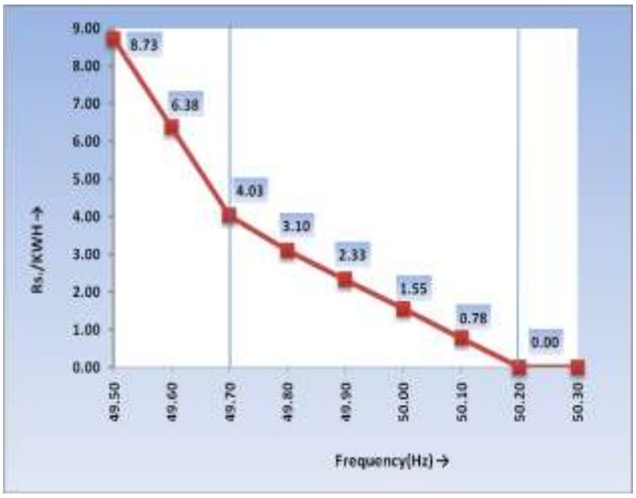

Figure1: UI price vs. Frequency

4. Renewable Electricity Certificate Mechanism

A large part of India's renewable energy potential is concentrated in few states in the country and some of these states have already achieved comparatively high levels of renewable electricity purchase as share of their total electricity consumption. After having met their Renewable Purchase Obligation (RPO), these states are now mostly reluctant to buy energy from renewable sources after having met their RPO as mandated by the State Electricity Regulatory Commission (SERC). This is hampering the growth of the renewable sector in an upward manner since the electricity from renewable energy is at present more expensive than conventional electricity. States that have already fulfilled the required RPO mandate are therefore not willing to invest more in renewable based electricity any further. For example, some states have more than 10% of total electricity from renewable sources of energy but still have untapped wind energy potential. On the other hand, some states have very little RPO but are required, by the National Electricity Policy (NEP), to enhance the share of renewable electricity in their total electricity consumption. To address this mismatch, the Electricity Regulatory Commissions have collectively evolved a Renewable Energy Certificate (REC) mechanism under which the green electricity is to be split into two components, i.e. electricity and the green attribute [12]. The electricity component can be sold to local distribution utilities at a price of conventional electricity and the green attribute is converted into REC which the generator can sell to the utilities of states like Delhi. Such a utility can help a state with little RPO to fulfill its renewable purchase obligations by purchasing RECs, and simultaneously will help states with more RPOs to realize it to the maximum potential in an economical manner.

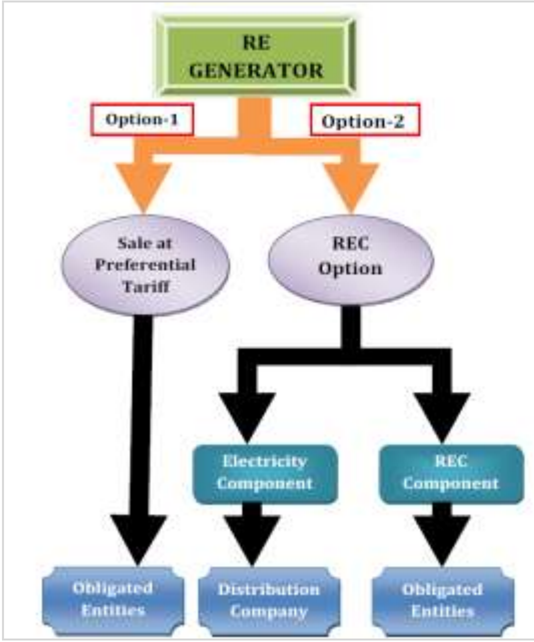

Figure2: Trading Options under REC Mechanism

Salient features of the REC mechanism are as follows:

- The RE generators will have two options as shown in Figure 2 – either to sell the renewable energy at preferential tariff fixed by the concerned Electricity Regulatory Commission or to sell the electricity component and environmental attributes separately.
- On choosing the second option, the generator can sell the 'electricity component' to either the local distribution company at its average power purchase cost (APPC), the traders, open consumers or to the power exchanges at a mutually agreed/market determined price. In addition, the 'environmental attributes' can be exchanged in the form of the REC.

A Renewable Energy Certificate (REC) is a tradable certificate of proof that one MWh of electricity has been generated by a RE plant in the state. Under this framework, RE generators can trade RECs through a power exchange platform that will allow market based price discovery, within a price range determined by the CERC. The respective price limits are called forbearance price and floor price and their values are calculated separately for solar and all non-solar energy sources (wind, biomass, small hydro). While the CERC has stipulated floor and forbearance price for non-solar RECs and for solar RECs, respectively, the real price of an REC would be determined at the power exchanges. RECs will be traded in the power exchange within the boundary set by the forbearance price and floor price, determined by the CERC from time to time. For wind power generation, this range is Rs 1,500 to Rs 3,900 per REC.

The only requirement for a RE generator to be eligible for trading RECs is that the power generator must sell its power to the host distribution utility or licensee at Average Power Procurement Cost (APPC). APPC is the weighted average cost of power purchase for the utility and is usually lower than the preferential tariff for the RE sources available in the state.

Under the REC framework, a RE generator will have the option to sell two products through the power Exchange:

- Generated electricity (not at preferential tariff but at APPC)
- Renewable Energy Certificate (one REC equivalent to one MWh of electricity generation)

On the demand side, the REC framework allows the utilities with purchase obligations to buy RECs through the national exchange irrespective of state potential and installed capacity. On the supply side, the REC mechanism allows the RE generators to get a base revenue income by selling power at the APPC and an additional market determined revenue stream through the REC trading platform.

5. Modelling of Trading Options

The trading environment for a wind electricity generator I Indian market has become very complex. Although the regulatory environment in India is itself very complex, some special measures for promoting renewable energy e.g. GBI, RPS, and REC Mechanism etc. have further added to the complexity. In order to devise appropriated strategies for selling wind energy, generators must have a clear understanding of various options of trading available to them. In this section a mathematical model of wind generator's revenue under all trading options is presented. The receivables of wind generators are classified into four components:

(i) Contractual payment
(ii) UI payment
(iii) REC payment
(iv) GBI payment.

Depending on the trading option exercised, they would be eligible for a few or all of these components. The trading options are described as follows:

5.1 Option I: Long-term PPA

Power Purchase Agreements are contracts between two parties, one who generates electricity for the purpose of sale (the seller) and one who is looking to purchase electricity (the buyer). There are various forms of Power Purchase Agreements; these are differentiated by the source of energy harnessed (solar, wind, etc.). Financing for the project is delineated in the contract, which also specifies relevant dates of the project coming into effect, when the project will begin commercial operation, and a termination date for which the contract may be renewed or abandoned. All sales of electricity are metered to provide both seller and buyer with the most accurate information about the amount of electricity generated and bought. CERC New Delhi has announced new regulations in 2009 [13] for determination of preferential feed-in tariffs for renewable energy, including both wind and solar energy. Therefore, under this option the wind generator is eligible for receiving a contractual payment component as per the scheduled generation and preferential feed-in tariff given by (1)

$$R_{cI} = C_{pft} * P_{sch} \tag{1}$$

If there are deviation from schedule the wind generator is eligible to pay/receive UI payment component given by (2):

$$R_{uiI} = C_{ui} * \left(P_{act} - P_{sch}\right) \tag{2}$$

The total revenue of wind generator under option I is given by (3)

$$R_I = R_{cI} + R_{uiI} \tag{3}$$

5.2 Option II: Bilateral Trading (with REC Mechanism)

Under this option, the wind generator may sell its electricity bilaterally to the host state utility or any other state at APPC cost of that state. In this case the payment received as per APPC also becomes the contractual payment component.

$$R_{cII} = C_{appc} * P_{act} \tag{4}$$

Additionally, the wind generator also becomes eligible for REC payment component and GBI payment component.

$$R_{recII} = C_{rec} * P_{act} \tag{5}$$

$$R_{gbiII} = C_{gbi} * P_{act} \tag{6}$$

Under this option, the wind generators shall be responsible for forecasting their generation up to an accuracy of 70%. Therefore, if the actual generation is beyond +/- 30% of the schedule, UI charges would be applicable to the wind generator. For actual generation within +/- 30% of the schedule, no UI would be payable/receivable by Generator.

If the actual generation is beyond 30% less than schedule generation, the UI payment component is given by (7)

$$R_{uiII} = \left(C_{ui} - C_{appc}\right) * \left(P_{act} - 0.7 * P_{sch}\right) \tag{7}$$

If the actual generation is beyond 30% more than schedule generation, the UI payment component is given by (8)

$$R_{uiII} = \left(C_{ui} - C_{appc}\right) * \left(P_{act} - 1.3 * P_{sch}\right) \tag{8}$$

The total revenue of wind generator under Option II is given by (9)

$$R_{II} = R_{cII} + R_{recII} + R_{gbiII} + R_{uiII} \tag{9}$$

5.3 Option III: Power Exchange

Wind generators presently do not come on exchange as renewable generators prefer preferential tariff. We shall investigate this option to sell wind energy in Power exchange at the same tariff as the conventional electricity, but REC payment included. However wind power projects selling power to third party/merchant power plant are excluded from the GBI incentives. For this 3rd Option, prices for Indian Energy Exchange Limited, New Delhi (IEX) [14] are taken as references, i.e., we shall investigate the receivable amount by the WG if it sell its generated energy through Indian Energy Exchange Limited at Day Ahead Unconstrained Market Clearing Price as the conventional electricity. The contractual, REC and UI components under this option are given by (10), (11) and (12) respectively.

$$R_{cIII} = C_{mcp} * P_{sch} \tag{10}$$

$$R_{recIII} = C_{rec} * P_{act} \tag{11}$$

$$R_{uiIII} = C_{ui} * \left(P_{act} - P_{sch}\right) \quad (12)$$

The total revenue of wind generator under Option III is given by (13)

$$R_{III} = R_{cIII} + R_{recIII} + R_{uiIII} \quad (13)$$

I. **Table 1**: Assumed system loading, frequency and price conditions for case study

Cases	*System Condition*	*Assumed frequency condition*	*UI price (in Rs/kWh)*	*Assumed MCP (in Rs/MWh)*
Case 1	Non-Peak Load	50.2 Hz	0	2608.40
Case 2	Day Load	50 Hz	1.55	3269.98
Case 3	Peak Load	49.5 Hz	8.43	3903.82

II. **Table 2**: Revenues of wind generators for various trading options under study

Cases		*Actual Generation (MW)*	*Total Receivable (Rs./Hr)*			*Comments*
			Option 1	**Option 2**	**Option 3**	
1.1	Non-Peak Load	100	339000.00	437000.00	410840.00	Opt 1<Opt 3<Opt 2
1.2		80	339000.00	349600.00	380840.00	**Opt 1<Opt 2<Opt 3**
1.3		120	339000.00	524400.00	440840.00	Opt 1<Opt 3<Opt 2
1.4		60	339000.00	285900.00	350840.00	**Opt 2< Opt 1<Opt 3**
1.5		140	339000.00	588100.00	470840.00	Opt 1<Opt 3<Opt 2
1.6		160	339000.00	667300.00	500840.00	Opt 1<Opt 3<Opt 2
2.1	Day Load	100	339000.00	437000.00	476998.00	**Opt 1<Opt 2<Opt 3**
2.2		80	308000.00	349600.00	415998.00	**Opt 1<Opt 2<Opt 3**
2.3		120	370000.00	524400.00	537998.00	**Opt 1<Opt 2<Opt 3**
2.4		60	277000.00	270400.00	354998.00	**Opt 2< Opt 1<Opt 3**
2.5		140	401000.00	603600.00	598998.00	Opt 1<Opt 3<Opt 2
2.6		160	432000.00	698300.00	659998.00	Opt 1<Opt 3<Opt 2
3.1	Peak Load	100	339000.00	437000.00	540382.00	**Opt 1<Opt 2<Opt 3**
3.2		80	164400.00	349600.00	335782.00	Opt 1<Opt 3<Opt 2
3.3		120	513600.00	524400.00	744982.00	**Opt 1<Opt 2<Opt 3**
3.4		60	-10200.00	198600.00	131182.00	Opt 1<Opt 3<Opt 2
3.5		140	688200.00	675400.00	949582.00	**Opt 2< Opt 1<Opt 3**
3.6		160	862800.00	841900.00	1154182.00	**Opt 2< Opt 1<Opt 3**

6. Results

The revenues collected by wind generator under the three trading options described in previous section are calculated for various system conditions and forecast error scenarios. Three main cases are taken for representing the variation in system conditions:

Case1: Peak load
Case2: Non-peak load
Case3: Day load

These cases were selected on the basis of unconstrained market price reports at IEX. The factor C_{mcp} corresponding to these the cases is shown in Table 1. These prices are assumed by considering the average MCP at IEX from January to May 2011. Corresponding to these three cases the system frequency conditions have also been assumed as indicated in Table 1. Further six sub-cases have been selected for representing the various forecast error scenario. We have assumed that forecast errors result in an actual wind generator different from its scheduled output. These six sub-cases are listed in Table 2. The revenue calculation for all three trading option have also been summarised in Table 2. Following important observations can be made from this table: Currently, Option II has been promoted as the best proposition for wind generators which can guarantee better and risk free returns to wind generators. However our analysis shows that returns under Option II are best only in 8 out of 18 cases. Additionally, Option II gives worst return in four cases. In comparison, Option III gives best returns in 10 cases and worst in none. This shows that despite the risk, trading energy through power exchange would still be the best option for wind generators. Principally, there would be no harm in extending the GBI to wind generators selling electricity through power exchange which would further boost the trading option III.

7. Conclusion

The analysis done in this paper suggests that selling electricity through power exchange is a viable option in Indian electricity market scenario. The revenues of wind generator depend on system load conditions, prevailing grid frequency, and forecast errors of wind generators If the wind generators take stock of energy market conditions and frequency conditions, they can take appropriate decisions regarding the sale of their electricity. This study can be used as a reference while devising the bidding strategies of wind generator in Indian electricity markets.

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