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Modelling renewable energy impact on the electricity market in India

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ABSTRACT

Renewable power generation development, most notably for wind and solar, has taken off at a rapid pace in India especially in the last 4 years. While these developments have many positive aspects, a rapid shift in balance of baseload and intermittent generation must be assessed carefully to ensure the share of renewable power generation increases without compromising system security and economics. Seasonal and spatial variability of wind, and to a lesser extent that of solar, can render these resources to have low availability for a significant part of the year leading to an increase in unserved energy, i.e., deteriorate system reliability. The intermittency of generation also impacts on inter-state power flows and lead to higher congestion in the grid. Climate model results provide a rich set of information on the nature of solar/wind variability that can be embedded in an electricity market simulation tool to assess these impacts on prices, generation dispatch and power flows. We have developed a modelling analysis for the Indian national electricity market informed by CSIRO climate model results. We have assessed the added costs arising from intermittency to put in perspective the true costs and benefits of renewable power. We have focused on the near-term developments in 2017 to show how some of the high renewable growth scenarios included in the Indian National Electricity Plan may imply significant pressure on inter-state/region transfer capability, and lead to a significant worsening of system reliability. The outcome of our modelling analysis suggests that a more orderly and balanced development of renewable and conventional power generation capacity is needed with a stronger focus on system economics and security.

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Table 1
Installed renewable capacity and short/medium/long term target (MW).

	Total installed capacity (MW)	Targeted for next year (2012/13)	Target for next five years (2017)	Target for next decade (2022)	Long term potential
Wind	18,192	2500	11,000–15,000	50,000	Wide range: 48,000 [4] to >2,000,000 [5]
Solar	1045	800	4000–10,000	20,000	200,000 (by 2050) [6]
Other	6806	805	3000–5000	15,000	88,000 [6]

1. Introduction

1.1. Electricity market in India

The electricity market in India catered for 123 Giga Watt (GW) of peak demand and 911 Terra Watt hour (TWh) energy in 2012/13. The generation capacity in India is 225 GW including 153 GW (or 68 per cent, including 132 GW of coal) thermal, 39.6 GW of hydro, 27.5 GW of other renewables and 4.8 GW of nuclear [1]. Despite a significant growth in capacity over the years, especially that of wind and solar in recent years, supply has perpetually lagged behind demand. As a result, in 2012/13 financial year, the country still faced a peak and energy shortage of 9 and 8.7 per cent, respectively. A move towards competitive electricity markets began in the nineties when the peak/energy shortages were in fact far greater. A number of regulatory developments starting with the Electricity Act in 2003 facilitated the di-licensing generation to allow multiple buyers and sellers in the market, followed by the Open Access Regulation in 2008 that formed the backbone of electricity markets.

Since 2008, there are two Power Exchanges in India, namely, the Indian Energy Exchange (IEX) and the Power Exchange India Limited (PXIL), that operate a range of intra-day, daily and weekly markets. The electricity market in India is, however, primarily structured around long-term Power Purchase Agreements (PPA) that account for 90 per cent of the 876 TWh electricity bought and sold in 2011/12. The volume of trade through the Power Exchanges is still relatively small at around 24 TWh year^{-1} in 2012/13. i.e., only 2.8 per cent of the total energy requirements. However, the volume of trade in the short-term market has grown significantly 7 TWh in 2009/10 and the number of participants in IEX, which has 97 per cent of the market share, has grown from 175 in 2009 to over 2000 in 2013 [2]. Trading of Renewable Energy Certificates (REC) commenced via Power Exchanges in February 2011. IEX also holds the major market share of 77 per cent for the REC market and has posted a trading volume of 2.9 million renewable MWh.

Power Exchanges operate a Day Ahead Market (DAM) on a 15-min basis and a Term Ahead Market (TAM) for daily/weekly trading. Spot prices are set in the market clearing prices for 12 market zones across the country covering the five sub-regions in India (namely, North, West, South, East and North-East). There are effectively two separate grids in India namely North-East-West (N.E.W.) Grid and the South Grid. These two grids are interconnected asynchronously through HVDC links. Spot prices in recent years have exhibited significant temporal and spatial volatility that serves an important purpose of indicating the need for new investments. Although the Power Exchanges serve a small part of the energy, an efficient and transparent price discovery process has already been a major aid in pricing long term contracts and signalling the location and type of capacity needed in the market.

1.2. Renewable energy in India: present status and future targets

Grid-connected renewable power generation in India has seen a spectacular growth in recent years – most notably since the beginning of 2010. Starting with a very low base of renewables in 2000, the installed capacity of grid-connected renewables has reached 27.5 GW in June 2013 – more than 33 per cent of it has come about in last five years and over 7 GW of this is in the form of wind in the Southern state of Tamil Nadu. The major impetus of this development comes from the National Action Plan on Climate Change that promises to deliver 15 per cent of the total electricity energy from renewables by 2020. Table 1 shows the composition of grid-connected installed capacity of renewable generators, along with the short/medium term target and the estimated long term resource potential. Wind dominates the share of renewable at present, although solar power is also adding to the mix of renewables at a faster rate driven mostly by the 20 GW National Solar Mission. A state-based Renewable Purchase Obligation (RPO) is the cornerstone of the renewable policy in India that sets the target by geography and year for each state, determined by the respective state commission. In addition, there are federal/national targets that are overlaid to include a separate solar energy target [3]. The National Solar Mission i.e., the 20 GW solar target, is applied uniformly across all states – there is no differentiation in solar tariff across the states. Most states currently have a solar target of 0.25 per cent of total energy that is expected to rise to 3 per cent by 2020 in line with the national target.

The absolute dominance of wind and solar over other forms of renewable resources is evident from the medium term target (over the next 10 years), and also the long term potentials that are available from different sources. It is estimated that that over the next two 5-year plans, a total wind capacity addition of ~50 GW will be achieved. A significant part of the future wind capacity addition is being planned in the Southern Indian state of Tamil Nadu. There is however significant confusion on the long term potential of wind. The original estimate from the Ministry of Power/C-WET [4] had estimated it around 48 GW, but a more recent study by Phadke et al. [5] has estimated a wind potential in excess of 2000 GW, i.e., a 42-fold increase in the original estimate. The solar power potential reported in Central Electricity Authority's National Electricity Plan (NEP) for 2050 is projected to be 200 GW [6]. The long term potential of all other renewable resources including biomass is likely to grow from 6.8 GW in 2012 to just over 15 GW over the next decade, i.e., an addition of ~8 GW, in comparison to 19 GW of solar and over 30 GW of wind.

The capital cost for adding renewable especially solar is significant. It has been estimated that the National Solar Mission would cost around INR 3 trillion or USD 60 billion [6] covering all three phases up to 2020.

1.2.1. High renewable target, variability of wind/solar and their ramifications

Addition of renewable to the coal-dominated generation system in India is clearly a welcome development to boost production, especially during periods of constrained coal supply [7]. Indeed, it helps to contain carbon emissions. Apart from these two benefits, it has a number of other ancillary benefits to scale up the renewable industry and bring down the cost of production of solar panels and wind turbines. However, it is also important to keep in mind the cost and power system impact of these resources,