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Wind Energy in India: Current Status and Potential

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Abstract : Wind energy sources and technologies have potential to provide solutions to the long-standing energy problems being faced by the developing countries. The renewable energy sources like wind energy can be used to overcome energy shortage in India. To meet the energy requirement for such a fast growing economy, India will require an assured supply of 3–4 times more energy than the total energy consumed today. The renewable energy is one of the options to meet this requirement. In this paper, efforts have been made to summarize the availability, current status of wind energy, wind power potential, wind power growth, repowering wind farms in India and future potentials of renewable energy options in India. This paper also discusses the wind real contribution to electricity demand of India and aspects for improvement of wind technology. This paper also assesses specific policy interventions for overcoming the barriers and enhancing deployment of renewable for the future.

Keywords: Wind energy; repowering wind farms; wind technology; wind potential.

I. INTRODUCTION

Wind energy is the fastest growing sources of energy in the world. Developing countries have witnessed huge gap between demand and supply of the electricity. The socio-economic development of the nation depends on availability of electricity infrastructure, as electricity is the key in development of industrial and commercial establishments. Renewable energy sources such as wind, hydro, solar, biomass are interesting attractive to meet the challenges of growing electricity demand in India. With recent development in wind energy technologies for power generation, wind energy has emerged as a viable and cost effective option for electricity. India is the fifth largest energy producer globally after China, USA, Germany and Spain. But due to lack adequate planning resource crunch the country has only 17.35 GW of installed wind energy.

However during past few decades the Ministry of New and Renewable Energy (MNRE) has taken important steps to accelerate the growth of wind energy installed in India. Wind energy programme have been launched for comprehensive wind resources assessment, R&D works and implemented of new wind energy technologies. The MNRE has announced several fiscal and promotional incentives at the Central Government and State Government levels to encourage private wind energy developers to take-up large commercial projects on wind mills.

II. WORLDWIDE STATUS OF WIND ENERGY

Wind is the key of the energy economy. It is redundant, low cost, and widely distributed; it scales up easily and can be developed quickly. Oil wells go dry and coal seams run out, but the earth's wind resources cannot be depleted. China overtook U.S. as the world leader in wind power in 2011 and 2010 according to a new annual report by the Global Wind Energy Council. Table 1 shows the cumulative installed capacity of top ten countries [1] in the world. Cumulative capacity of U.S.A. is 46.919 GW, Germany having 29.06 GW, Spain have a cumulative capacity of 21.674 GW. India in the world is at fifth position with capacity of 16.084 GW in 2011.

III. INDIA WIND POWER GROWTH

Wind energy in India has emerged sources available in the country. The large numbers of wind energy projects have been started during past few decades. With recent development of the wind turbine technology and continuous improvement in the reliability and conversion efficiency of the wind energy conversion system, the wind energy installation is growing at faster rate than other alternatives. Presently, India [9] has the fifth largest installed capacity of 14158 MW till the end of March 2011. Starting from about 1350 MW in 2001, this figure has been achieved at a CAGR (Compound Annual Growth Rate) of 26 percent for the period 2001-2011.

The estimated wind energy potential in India by wind energy technology (C-WET) and world Institute for the sustainable energy (WISE) are 48.5GW and 100 GW respectively. Recently, the Energy Alternatives India (EAI) has estimated total offshore wind energy in the country to 120 GW, which is about 68 percent of the presently total installed capacity of the country. Therefore such a huge potential if truly exploited through indigenous technology may help in reducing the existing demand and supply gap of the nation.

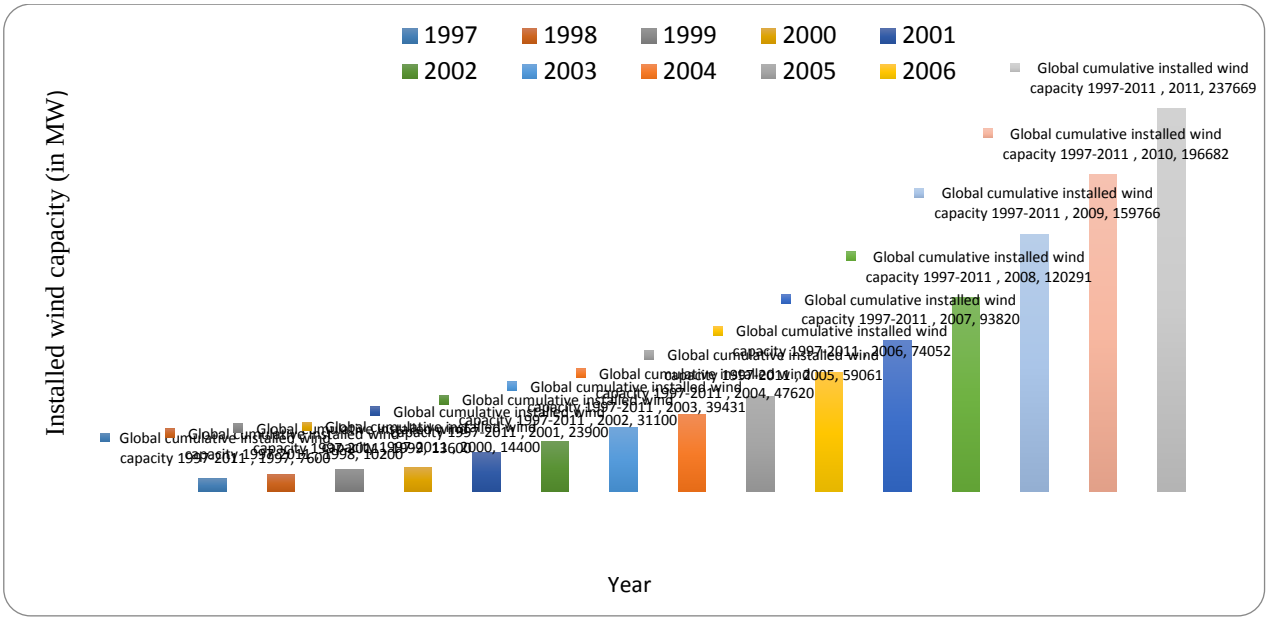

Fig.1 Global cumulative installed wind capacity 1997-2011 [1]

Table 1 Top 10 cumulative installed capacity up to December 2011 [1, 2]

Position	Country	Total Capacity 2011 [GW]	Total Capacity 2010 [GW]	Total Capacity 2009 [GW]
1	**China**	62.364	44.733	25.81
2	**USA**	46.919	40.18	35.159
3	**Germany**	29.06	27.215	25.777
4	**Spain**	21.674	20.676	19.149
5	**India**	16.084	13.065	11.807
6	**Italy**	6.8	5.797	4.85
7	**France**	6.737	5.66	4.754
8	**United Kingdom**	6.54	5.203	4.092
9	**Canada**	5.265	4.008	3.319
10	**Portugal**	4.083	3.702	3.357
12	**Rest of the World**	32.143	26.441	21.872
	Total	**237.669**	**196.682**	**159.766**

IV. REPOWERING WIND FARMS IN INDIA

Replacing old, underperforming wind turbines with modern ones that could offer better returns and more power than before opens up a lucrative opportunity in wind power-that of Repowering. For close to 2 decades the sector has witnessed a number of challenges, opportunities and changes. Over this time, the industry has made path breaking enhancement in turbine efficiency and reliability. Today we have turbines that offer a viable investment in low wind sites while also ensuring improved reliability. This advancement in technology also offers another lucrative opportunity. Repowering wind turbines that are over 15 years old cover a landscape that could easily be called the "Gulf of Wind Energy in India." These turbines hardly do justice to the potential that this region houses. The performance has been below par, and it has been found that most of the turbines that are underperforming are in wind sites which have much lower speeds. It is therefore natural to explore the option of replacing these with modern turbines that could offer better returns and more power than before. In Tamil Nadu, about 60 percent of small wind turbines (<400kW) installed before the year 2000 are operating with plant load factor (PLF) ranging from 10 to 15

percent, where as the new technology wind turbines can operate at a PLF range of 27 to 32 percent in the same sites.

It is also important to plan the project well in advance to ensure that access roads, platforms, storage area and removal /rerouting of the existing lines the wind farms is smooth and does not affect any wind turbines in vicinity.

The challenges include securing necessary approvals and licenses from authorities as well as ensuring a favorable policy and maintaining regulatory transparency and support. It would benefit the industry to replace the inflexible, arbitrary and bureaucratic spacing requirements with a more flexible, fact based regulations. The Government should also encourage Re Powering through various forms of incentives for capacity addition, increase in tariff, etc.

Installation of suitable turbines for a specific site , replacing obsolete technology with technologically advanced variable drive, thereby increasing the average PLF to 27 percent. This will Improve overall performance and hence power generation from 12.5 million units to 30.0 million units, for the same capacity and with existing evacuation infrastructure.

Super Sales India, a part of the Lakshmi Machine Works (LMW) Group joined hands with Gamesa in implementing the first Re-powering project in India named "Project Avatar". At the selected site, the existing wind farm consisted of 29 units of 300 kW turbines and 2 units of 500kW turbines at Kethanur village in Tirupur district, Tamil Nadu. Gamesa undertook a detailed study of the site and surrounding area and recommended that the 11x300 kW turbines could be replaced with 4 units of Gamesa. Wind power generation is multiplied without the need for additional land, efficient use of potential land and more capacity addition per unit of land area .A typical example comparing existing scenario and Re-powering proposal for a wind farm in Coimbatore is given in Table 2.

Table 2 Comparison of existing scenario and Re-Powering proposal [10]

Parameter	**Wind Farm**	
Capacity	8.1 MW	8.5MW
Annual estimated generation	104 Lakh kW	220 Lakh kW
PLF	14.70 percent	29.50 percent

V. WIND POWER POTENTIAL IN INDIA

Wind availability in India is influenced by the monsoon circulations. The Southwest summer monsoon in India starts usually in May-June month when cool and humid air starts moving towards the land also the weaker Northeast monsoon when cool air moves towards the ocean. The wind potential in India is mainly available in the coastal areas of Gujarat, Karnataka and Maharashtra. In addition to these the states of Andhra Pradesh, Tamil Nadu and Madhya Pradesh, Telangana and Kerala have also significant potential of wind energy. Table 3 shows the state wise wind power potential in India. Gujarat having highest wind potential with 84431 MW, Karnataka is on second with 55857 MW, Maharashtra is on third position with a potential of 45394 MW power potential and Andhra Pradesh having wind power potential 44229 MW.

Table 3. State wise % of Wind Potential Utilized (As on 31.03.2016)

S.No	**State**	**Cumulative Wind Power Installed Capacity operational at the end of FY 2016 (MW)**	**Total Wind power potential at 100 meter above ground level (MW)**	**Percentage of Wind Power potential utilized**
1.	Andhra Pradesh	1431.45	44229	3.24%
2.	Gujarat	3948.61	84431	4.68%
3.	Karnataka	2869.15	55857	5.14%
4.	Kerala	43.5	1700	2.56%
5.	Madhya Pradesh	2141.1	10484	20.42%
6.	Maharashtra	4653.83	45394	10.25%
7.	Rajasthan	3993.95	18770	21.28%
8.	Tamil Nadu	7613.86	33800	22.53%
9.	Telangana	77.7	4244	1.83%
10.	Others	4.3	3342	0.13%
Total		**26777.45**	**302251**	**8.86%**

VI. ROLE OF WIND ENERGY IN INDIA

Currently, wind power accounts for about 8 percent of India total installed power capacity, but actual wind energy is about 2 percent of the total generation. This is mainly due to lower capacity utilization factors (CUFs) than do fossil fuel power plants. It is a matter of great concern, that in spite of huge potential of wind energy available in the country, due to unavailability of efficient and reliable energy conversion of systems, the utilisation of wind energy is poor. Table 4

provides insights on possible contributions by wind energy to the total electricity produced in India by 2020.

A. Challenges in Global Positioning

India is finding difficulty in global positioning mainly due to its conservative approach with wind energy density estimation. The ministry of New and Renewable Energy (MNRE) is addressing these issues in the upcoming 12th five year plan by revaluating wind energy potential at higher hub heights and by proposing local content requirements.

Also, the use of indigenous technology in WECs are still not aggressive enough since most of the manufacturing bases in India are merely assembly units which import most the components /subcomponents. It has become essentials to develop indigenous technology in WEC through R&D works and implementation of pilot projects.

Table 4 Summary of wind energy outlook scenario for 2020- India [5]

Growth Scenario	Cumulative Wind Power Capacity (MW)	Electricity Output (GWh)	Share of electricity demand (%)	Output (GWh)
Reference	20332	40665	2.6-2.8	610
Moderate	63230	126459	8.1-8.7	8247
Advanced	134828	269656	17.3-18.6	9438

B. Challenges in Transmission

The intermittent nature of wind has an adverse impact on the grid stability. The wind energy sites are mainly located in coastal area of the country, when the grid stability is not very good. The interconnection of wind farms/mills to the causes the voltage fluctuation and also increases the stress on existing transmission infrastructure. Since the transmission networks maintenance is the responsibility of the state transmission utilities, which are not upgraded during recent past due to lack of resources in the state utilities. Wind energy utilization need upgraded transmission infrastructure in especially coastal areas for effective power evacuation. Presently, the India has no grid codes that include standard for wind integrates and specific the tolerable limit of grid parameters due variable elements products for grid. It is worth to mention that existing grid codes also needed necessary modifications to ensure system operational stability and reliability.

C. Regulatory Challenges

The existing regulation on renewable energy generation, grid connected and transmission changes are not uniform. A national policy on generation, grid connection and transmission of energy produced through Renewable source should be framed to achieve the mission of wind and solar energy set by the Government. Also effort should be made to enhance proactive co-operation between state transmission utilities, and power producers and power purchasers.

D. Technological Challenges

Development of high capacity turbines in recent past has given significant important to the wind energy conversion system. The continuous improvement in the turbine technology has developed confidence among the manufacturers and they are willing to give a guarantee on performance.

The power of wind turbine has a cubic relation with wind speed and hence the interconnection of turbine to grid affects the grid parameters such as power outrages primary fluctuations and voltage fluctuation etc. seems to be an interesting alternative. Utilization of wind energy in low wind speed region is another grey area, where no effects have been made so far. Development of low speed turbine to meant this challenge.

Table 5 Potential areas for generating wind energy (in MW)

S.No.	**States**	**Power generated (in MW)**
1.	Tamil Nadu	6987.60
2.	Maharashtra	2733.30
3.	Gujarat	2966.30
4.	Karnataka	1933.50
5.	Rajasthan	2070.70
6.	Madhya Pradesh	376.40
7.	Andhra Pradesh	245.50
8.	Kerala	35.10
9.	West Bengal	1.1

VII. WIND ENERGY STATUS IN INDIA

India's rapidly growing economy and population leads to relentlessly increasing electricity demand. The IEA predicts that by 2020, 327 GW of power generation capacity will be needed, which would imply an addition of 16 GW per year. This urgent need is reflected in the target the Indian government has set in its 11th Five Year Plan (2007-2012), which envisages an addition of 78.7 GW in this period, 50.5 GW of which is coal. The potential areas for generating power through wind mills are in the states of Tamil Nadu, Karnataka, Kerala, Gujarat, Andhra Pradesh, Maharashtra, Rajasthan and Madhya Pradesh. As of 31st March 2012 the installed capacity of wind power in India was 17.351 GW mainly spread across Tamil Nadu (6987.60 MW), Maharashtra (2733.30 MW), Gujarat (2966.30 MW), Karnataka (1933.50 MW), Rajasthan (2070.70 MW), Madhya Pradesh (376.40MW), Andhra Pradesh (245.50 MW), Kerala (35.10 MW), West Bengal (1.1 MW) as shown in Table 5.

VIII. TRENDS IN WIND TECHNOLOGY

A major trend in wind turbine technologies, observed consistently since early eighties, is to build larger and larger wind turbines. The wind turbine ratings have changed from 25-40 kW to 7 MW and now 10 MW wind turbines are under development. One can make out the immense technological transition that has taken place in wind turbines and engineering of wind turbines in the installation in India. Trends in India mirror international trends except for the fact that there been a lag of about 2 years. This is due to technology transfer issues often related to individual wind turbine suppliers.

Profiles of blades used in earlier turbines are based on National Advisory Committee for Aeronautics (NACA) profiles that result in maximum coefficient of performance of 0.3 to 0.4. Efforts are on to develop blade aerodynamic profiles that are better at harnessing wind energy. Lightness and strength of the materials is important for blades of large wind turbines with a rating of 5 MW, 7MW or 10 MW. A blade is composite material, therefore the properties and interaction between materials during processing need to be well understood to produce high quality components. Materials used while manufacturing blades are birch plywood sticks, core material fiber rods, and fiberglass and epoxy resin. In some designs, carbon epoxy is also used. Traditionally, the wind turbines used to be fixed speed, running at fixed revolutions per

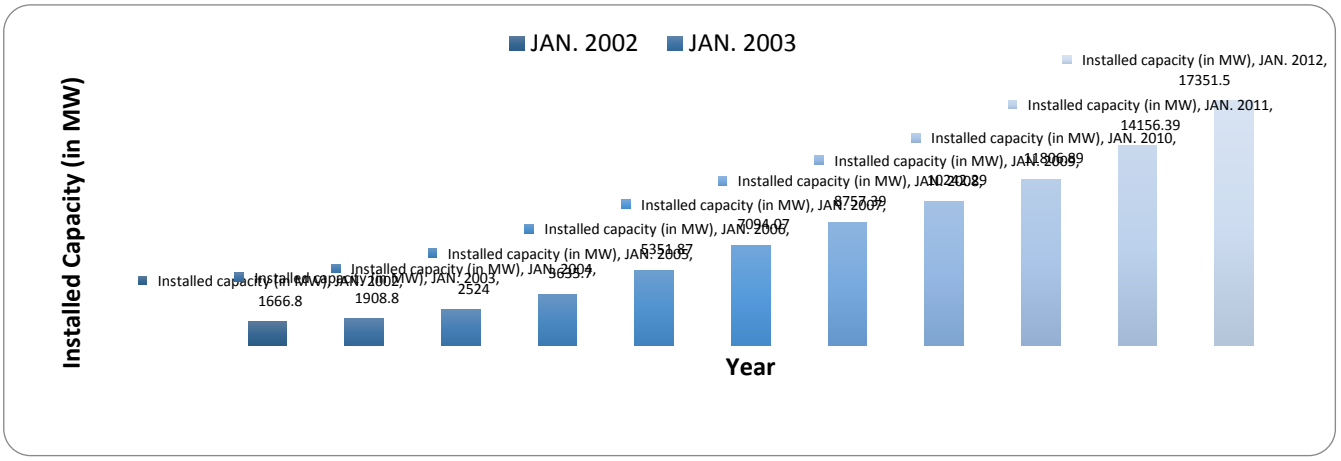

Fig.2 Wind power growth in India (MW) [7,8]

Table 5 Year wise installed capacity in India up to 31.03.2012 [6].

State	Andhra Pradesh	Gujarat	Karnataka	Kerala	Madhya Pradesh	Maharashtra	Rajasthan	Tamil Nadu	West Bengal	Others	Total
Up to March'2002	93.2	181.4	69.3	2.0	23.2	400.3	16.1	877.0	1.1	3.2	1666.8
2002-03	0.0	6.2	55.6	0.0	0.0	2.0	44.6	133.6	0.0	0.0	242.0
2003-04	6.2	28.9	84.9	0.0	0.0	6.2	117.8	371.2	0.0	0.0	615.2
2004-05	21.8	51.5	201.5	0.0	6.3	48.8	106.3	675.5	0.0	0.0	1111.7
2005-06	0.45	84.60	143.80	0.0	11.40	545.10	73.27	857.55	0.0	0.0	1716.17
2006-07	0.80	283.95	265.95	0.0	16.40	485.30	111.90	577.90	0.0	0.0	1742.05
2007-08	0.0	616.36	190.30	8.50	130.39	268.15	68.95	380.67	0.0	0.0	1663.32
2008-09	0.0	313.6	316.0	16.5	25.1	183.0	199.6	431.1	0.0	0.0	1484.9
2009-10	13.6	197.1	145.4	0.8	16.6	138.9	350.0	602.2	0.0	0.0	1564.6

2010-11	55.4	312.8	254.1	7.4	46.5	239.1	436.7	997.4	0.0	0.0	2349.2
2011-12	54.1	789.9	206.7	0.0	100.5	416.5	545.7	1083.5	0.0	0.0	3196.7
Total	**245.50**	**2966.30**	**1933.50**	**35.1**	**376.40**	**2733.30**	**2070.70**	**6987.60**	**1.10**	**3.20**	**17351.5**

per minute (RPM). However, a variable speed concept is considered more suitable because of the flexibility it offers in changing the rotor RPM. A variable speed wind turbine enables greater efficiency at wind speeds between cut-in and related wind speeds of the wind turbine (3-12 m per sec.). A variable speed turbine, due to the power electronics involved can also be grid friendly and minimize the reactive power requirements. Within the variable speed wind turbine category also we have geared and non-geared wind turbines and within the gearless category we can have wind turbines with permanent magnets and electromagnets.

Wind turbines with doubly fed induction generator (DFIG) enable operation of wind turbine in a quasi variable state. In about 10 years of implementation experience, wind turbine or wind power generation in grid connected mode as well as off grid mode has been firmly established as a resource and technology option. We have only harnessed 0.3 percent of the total potential and perhaps 2-3 percent of the electricity demand. From the power system view point there are many challenges associated with wind power that need to be addressed.

IX. CONCLUSION

This paper describes the wind energy potential and installed wind energy in India. The growth of wind energy technologies during last few decades has been summarised through various tables, and illustration in the form of bar charts. The Renewable energy scenario of the country the & also global trends are discussion in detail. The government of India very actively involved in promoting renewable energy. It has been observed that the size of wind turbine has increased and the cost of production has decreased. The future challenge is to bring down the cost further and make it more competitive. The wind turbine cost constitutes 68-84% cost of wind power. India has huge potential for producing wind energy too, but there are still some lacunas. Indian government has laid the foundation for a broad-based renewable energy program to fulfil energy shortage. Despite all its efforts, India is unsettled by China and has now slipped to the fifth rank in its contribution to global wind energy production. Analysis shows that the main factor behind China's lead is presence of a countywide renewable energy law. It may be concluded that India will have to improve in terms of incentives and regulations on renewable energy order to compete with other countries and become the leader in wind energy generation.

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