Assessment of Wind Energy Technology Potential in Indian Context

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Abstract- Wind energy is highly preferred alternative as compared to conventional sources of power. India plays a leading role in the global wind energy market, but it is still not use its full wind potential, which is far from the exhausted condition. Moreover, these resources can lead to growth in Indian power sector. In this paper, the assessment of wind technology is explored for Indian context vis-a-vis indices related to wind technology. The state wise status, challenges, development of wind power; and market for small wind turbine system are discussed in detail. Moreover, the issues related to wind turbine capacity and installation are elaborated for wind technology in India.

Keywords- Pitch systems, renewable energy, wind electric system, wind energy, wind turbine.

1. Introduction

The shortage of energy resources is experienced globally, due to exponential increase in the rate of energy consumption. An urgent need is felt to explore more sustainable energy system. The use of renewable energy (RE) sources is one of the best available options [1]. As a result of these actions, India is in leading position and as one of the 'emerging economies' in broad sense at present. Wind has served the mankind as a source of power for ages. Before the development of the steam engine, conventionally wind power was primarily used for applications like sailing ships etc. [2]. With the advent of wind mills, wind energy was being converted to mechanical energy through wind mills. Later in nineteenth century, thermal and hydro power plants became the new source of electric power generation. Every country could not maintain the pace of development due to place bound availability of fossil fuel or other resources [3]. The development of RE in India is attributed because of the factors such as power shortage, continuously rising prices of oil and gases, ecological hazards, availability of ample RE resources sites, abundant sunshine, government incentive policy etc.

In this paper the endeavour has been made to assess the wind energy technology potential in India. The development stages, issues and challenges of wind energy based small wind turbine systems. Furthermore state wise aspects of installation, production utilization of turbine capacity of wind power in India have been discussed. Appropriate case studies of small wind power station have been made to highlight the development in this field. In addition to above, the current status of renewable power and scope of work is also summarized.

2. Wind resources and development stages in India

Nationwide wind resource assessment programme is implemented in the country, which is sponsored by the Govt. of India in association with state nodal agencies. The ministry of new and renewable energy (MNRE) has been sponsoring the programmes to measure, analyse and publish wind data in our country since last two decades. In 2009-2010, the details of total 37 wind stations in the country, are given in the Table 1 as,

Table 1. Status of wind monitoring stations (2009-2010) [3-5]

S. No	State / Union Territory	Number of Stations	
		Established Till 31.03.2010	Installed (New) during 2009-2010
1	ANDAMAN & NICOBAR ISLANDS	14	-
2	ANDHRA PRADESH	64	-
3	ARUNACHAL PRADESH	9	-
4	ASSAM	8	-
5	BIHAR	3	-
6	CHATTISGARH	7	1
7	GOA	3	2
8	GUJARAT	64	-
9	HARYANA	8	-
10	HIMACHAL PRADESH	10	-
11	JAMMU & KASHMIR	11	-
12	KARNATAKA	48	-
13	KERALA	27	-
14	LAKSHADWEEP	11	1
15	NAGALAND	3	3
16	MADHYA PRADESH	38	4
17	MAHARASHTRA	118	18
18	MANIPUR	8	3
19	MEGHALAYA	2	2
20	MIZORAM	5	-
21	ORISSA	10	-
22	PONDICHERRY	4	-
23	PUNJAB	13	-
24	RAJASTHAN	38	-
25	TAMIL NADU	69	-
26	TRIPURA	5	-
27	UTTARAKHAND	11	-
28	UTTAR PRADESH	12	3
29	WEST BENGAL	10	-
30	SIKKIM	3	-
31	JHARKHAND	4	-
	Total	**640**	**37**

Till 31[st] march 2010, approximate 640 stations were established, 216 stations have been found to have wind power density (WPD) in excess of 200 W/m2 at 50 m average height. The WPD ranges (W/m2) of these 216 stations are given in the following Table 2 as,

Table 2. WPD distribution at 216 stations in India [4-5]

WPD Range (W/ m^2)	Number of wind power stations
200- 250	82
250-300	62
300- 350	31
350- 400	14
>400	27

The wind power station ranges are existed approximately. According to the Table 2, at 82 wind power station as mentioned, the WPD is in range of 200-250 W/m^2, at 62 wind power station WPD is in range of 250-300 W/m^2 and at 27 wind power station, WPD is more than 400 W/m^2.

2.1. Indian Wind Atlas

An important aim of the wind atlas is to give suitable data of wind power for determining the potential sites for large electricity production after the wind turbine installations. This wind atlas has been prepared with the help of national laboratory for sustainable energy. Wind atlas as shown in Fig. 1, gives an updated wind status of different locations in India [5-6].

In the wind atlas, state wise WPD is shown clearly. The actual WPD of 0 to 100 W/m^2, is found mostly in northern and eastern India i.e. Punjab, Haryana, Himachal Pradesh, West Bengal, etc. The WPD range of 200- 250 W/m^2 is generally found in Uttar Pradesh, Madhya Pradesh, Andhra Pradesh and central of India. The WPD range 250-300 W/m^2 is observed in Jammu & Kashmir, Tamil Nadu and Gujarat. Higher range 400- 500 W/m^2 of WPD is found in some critical areas of Jammu & Kashmir State only. Therefore wind atlas is helpful in finding the sites for the wind power station.

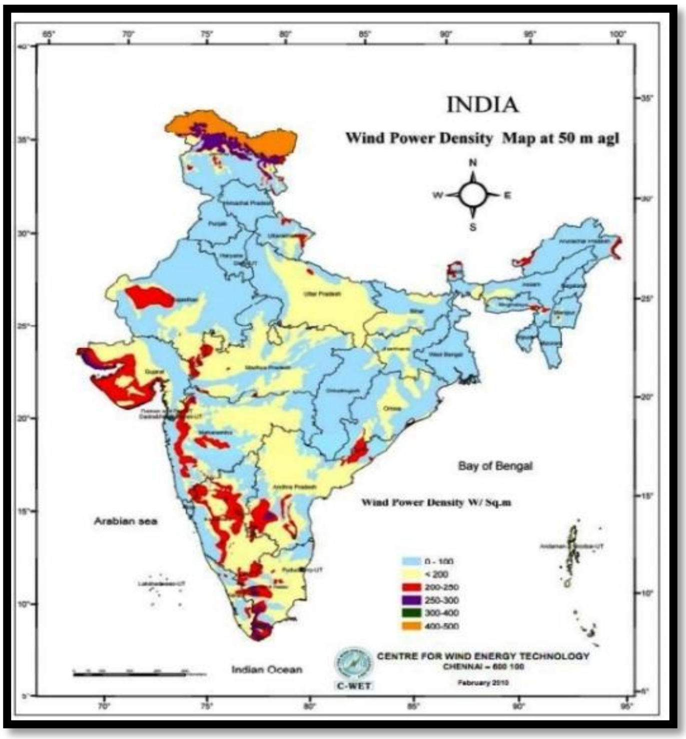

Fig. 1. Wind power density map not to scale from Indian wind Atlas [5, 6].

2.2. Issues and Challenges: Wind Energy in India

There are several challenges in the development of wind power. The challenges of financial and technical aspects need to be addressed on priority basis [1, 7].

2.3. Financial Challenges

At present, a number of green energy projects are under planning and implementation stage with the government. As the success of a new technology is always associated with question mark, which creates some obstacles that can prevent its growth and development. This uncertainty results in high financial burden for further research and development work for that technology.

2.4. Technical Barriers

Firstly, there is a state of uncertainty in some technologies due to unavailability of reliable power supply in developing countries. Secondly, it may not be able to serve competitively with more established options.Following issues may be considered as technical barriers that can prevent the growth as,

- Optimal power pricing produced from the wind energy sources.
- Quality and the state of being consistent issues.
- Cost of improvement in existing technology.
- Current production level needs to be changed significantly.
- Availability of financial schemes for wind energy based projects.

3. Comparision of State Level Wind Power

There is no specific reason for state level wind power improvement in India. As shown in Table 3, state wise data are given, which show that maximum 45 sites are recognized in Tamil Nadu for wind power development. However maximum numbers of potential districts are located in Maharashtra with 13 numbers. Maximum installable wind potential of 10,609 MW is available in Gujarat. Present installed capacity in ready to use position till December 2010 is 5,502.90 MW in Tamil Nadu. Apart from this, the data of other leading states are also given in Table 3. [3, 5, 6]

Table 3. Comparison of wind power development of leading states in India [5, 8]

S. No.		STATES							
		Andhra Pradesh	Gujarat	Karnataka	Kerala	Madhya Pradesh	Maharashtra	Rajasthan	Tamilnadu
1	Total number of identified sites	32	40	26	17	7	39	8	45
2	Identified number of potential districts	7	9	9	3	5	13	5	11
3	Annual mean wind speed (m/sec) at 50 m mast height	4.86-6.61	4.33-6.97	5.19- 8.37	4.41-8.12	5.0- 6.25	4.31- 6.58	4.02- 5.73	4.47- 7.32
4	Number of wind monitoring stations established till October 2010.	63	69	49	27	37	112	36	68
5	Installable wind potential (MW)	5,394	10,609	8,591	790	920	5,439	5,005	5,374
6	Presently installed capacity (MW) till Dec. 2010	176.8	2,005.30	1,576.20	28	230.8	2,201.60	1,353.40	5,502.90
7	Untapped installable potential (MW) as on Dec. 2010	5,217.20	8,603.80	7,014.90	762	6892	3,237.40	3,671.70	128.9

The renewable energy capacity additions during $10^{th}/11^{th}$ five year plan are shown in Table 4, which also shows the target for 2008-12. It is evident from Table 4 that the wind power target is 10,500 MW for block year of 2008-12. The status of other renewable technology is also briefed in Table 4. The total target for 2008-12 year is around double to actual power for 2003-07 year block.

Table 4. Renewable energy capacity additions during 10th/ 11th five year plan [5, 10]

Technology	Target 2003-2007 (MW)	Actual 2003- 2007 (MW)	Target 2008-2012 (MW)
Wind power	2,200	5,426	10,500
Small Hydro (< 25 MW)	550	537	1,400
Biomass Power/ generation	725	759	1,700
Biomass Gasifier	37	26	--
Solar PV	2	1	--
Waste to energy Programme	70	47	400
	3,584	**6,795**	**14,000**

3.1. Strategic Road Map for Developing Small Wind Turbine (SWT) Systems

Energy is the lifeline for the improvement of world's economic scenario. In recent years, there is paucity of conventional energy resources and it is severely restricting the activities of rapid economic development [9]. A status survey project was carried out through world institute of sustainable energy (WISE), Pune, to organize and carry out an in depth study to estimate the potential market and involvement of the small wind turbine systems in India. The percentage share of different states generating power using SWT and hybrid system is shown in Fig. 2, which shows that Maharashtra state shares a big portion of 47.1%, followed by west Bengal, Manipur, etc. Furthermore, Sikkim share is ground 1% in SWT system.

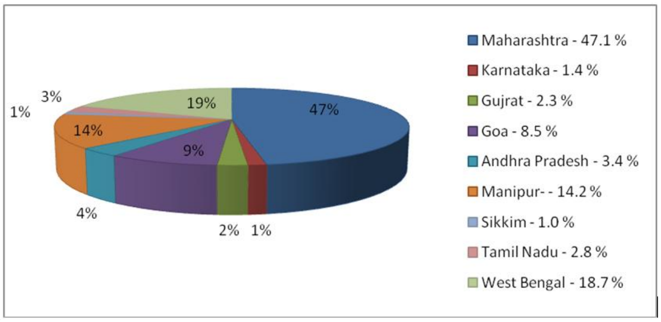

Fig. 2. Share of different states generating power using of SWT and hybrid system [5, 9, 10].

3.2. Leading Manufacturers of Wind Turbine Systems in India

Table 5. Leading wind turbine manufacturers in India [10-13]

Wind turbines manufacturers	Model specifications Rotor diameter (RD) m, Hub height (HH) m, Tower type	Capacity
Chiranjjeevi wind Energy Limited. Coimbatore	CWEL C-30 RD: 29.8 m, HH: 50 m, Tower type : Lattice	250 kW
Enercon (India) Ltd. Mumbai	E-48 RD: 48 m, HH : 50/56/57/65/75/76 m, Tower type :Tabular steel	800 kW
Gamesa Wind Turbines Pvt. Limited, Chennai	AE – 59 RD:59 m, HH:60.6 m, Tower type: Tabular steel	800 kW
GE India Industrial Private Limited, Bangaluru	GE RD: 82.5 m, HH: 80 m, Tower type: Tabular steel	1600 kW
Global Wind Power Limited Mumbai.	NORWIN RD : 47 m, HH: 65 m, Tower type: Tabular steel	750 kW
Inox Wind Limited, Noida.	WT 2000 DF RD: 93.3 m, HH: 80 m, Tower type: Tabular steel	2000 kW
Kenersys India Private Limited. Pune	K-82 RD: 82 m, HH: 80 m, Tower type: Tabular steel	2000 kW
Pioneer Wincon Private Ltd. Chennai	Pioneer P-29 RD: 29.6 m, HH: 50 m, Tower type: Lattice	250 kW
Regan Powertech Pvt. Ltd. Chennai	VEN SYS-77 RD: 76.84 m, HH: 75/85 m, Tower type: Tabular steel	1500 kW
RRB Energy Limited. Chennai	V-39 RD: 47 m, HH: 50 m, Tower type : Tabular steel & Lattice	500 kW
Shriram EPC Limited. Chennai	SEPC-250 T RD: 28.5 m, HH: 41.2 m, Tower type : Lattice	250 kW
Suzlon Energy Ltd. Pune	Suzlon S-52 RD: 52 m, HH: 75 m, Tower type: Lattice	600 kW
	Suzlon S-64 RD: 64 m, HH: 56/65/74 m, Tower type: Tabular	1250 kW
	Suzlon S-66 RD: 66 m, HH: 65/74 m, Tower type : Tabular steel	1250 kW
	Suzlon S-88 RD: 88 m, HH: 80 m, Tower type: Tabular steel	2100 kW

With the help of an formation provided by important organisations such as Centre for Wind Energy Technology (CWET) [10], World Institute of Sustainable Energy (WISE), Global Wind Energy Council (GWEC) and Indian Wind Turbine Manufacturers Association (IWTMA) [11], the leading Indian wind turbine manufacturers are given in Table 5 along with their important wind turbine system specifications such as rotor diameter (RD), hub height (HH) and turbine capacity in kW. For example Suzlon is the leading company for designing the wind turbines with various capacities for power generation, e. g. - 250 kW, 600 kW, 1250 kW and 2100 kW.

4. Installation, Production & Utilization and Turbine Capacity of Wind Power

In this section, the issues related to the wind power installation; production and utilization status and turbine capacity of wind power system in India are discussed.

4.1. Installation of Wind Turbines

An addition of 24.67% capacity of wind turbine generator (WTG) has taken place in India in the period 1992-2010. From 1992 to December 2010, the installed capacity increased from 41.3 MW to 13,065.78 MW [3, 5]. Tamil Nadu has highest rank in both areas as installed capacity and in terms of wind energy generation, with the shares of 41.8% and 53.4% respectively. The other states like Gujarat, Maharashtra and Rajasthan have witnessed important growth in wind capacity over the last few years due to stable policy and regulatory schemes. The Table 6 presents the share of different states in installed capacity (MW) and cumulative energy generation.

4.2. Wind Power Production Capacity

Wind power production capacity in key consideration for the assessment of wind energy level in order to achieve the next targeted wind power generation. Actually, utilization of wind power capacity came into real fact in 1997 with 940 MW capacities. An increment of 5.6% was obtained in the following year 1998. As shown in Table 7, the increase in power generation on the basis of annual average data is observed [17]. Clearly, it is a sign of improvement in the wind energy system for future. In the Table 7, annual average data has been taken by power production capacities and corresponding graph is shown in Fig. 3. On the observation of increase in annual production capacity in overall period from 1997 to 2011, maximum increase of 47.7% is observed.

4.3. Utilization Status of Wind Energy

In order to make availability for sustainable energy supply and subsequent economic growth of the country, it is required to intensify renewable energy and energy efficiency programme [15-16].

After analysing the number of successful countries in promoting wind energy such as China, USA, Germany, Spain, India, Italy, France, etc., India is ranked at fifth position in wind energy among the leading countries [17], and their position in Table 8.

Table 6. Wind power generation and installed capacity of states [3,5] during 1992-2010

State	Cumulative generation (MW)	Cumulative installed capacity (MW)
Andhra Pradesh	1,451	138.4
Gujarat	8,016	1,934.6
Karnataka	9,991	1,517.2
Madhya Pradesh	554	230.8
Maharashtra	11,790	2,308.1
Rajasthan	3,938	1,095.5
Tamil Nadu	41,100	5,079.4
Kerala	110	28
Total	**7,6950**	**12,125.8**

Table 7. Percentage increment in production capacities [17]

Year	Annual production capacity (MW)	Annual % increment in production capacities
1997	940	--
1998	992	5.60%
1999	1035	4.40%
2000	1267	22.50%
2001	1507	19.00%
2002	1702	13.00%
2003	2110	24.00%
2004	3000	42.20%
2005	4430	47.70%
5006	6270	41.60%
2007	7850	25.20%
2008	9587	22.20%
2009	10926	14.00%
2010	13065	19.60%
2011	14158	8.30%

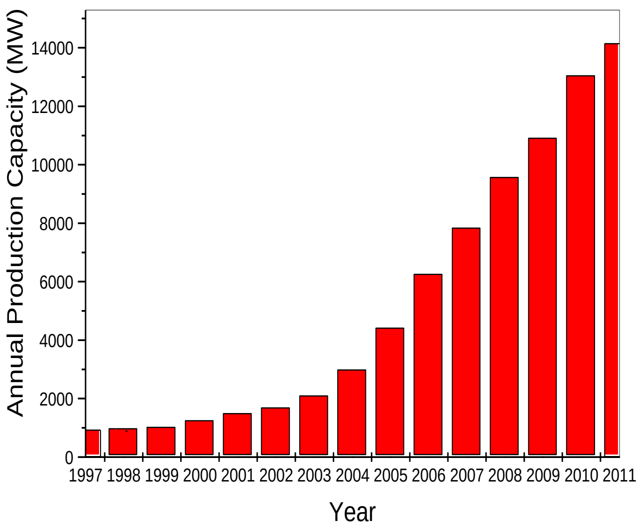

Fig. 3. Annual power production capacity.

Table 8. Global wind energy status [17]

Country	Position	Total capacity by June 2011(MW)
China	1	52,800
USA	2	42,432
Germany	3	27,981
Spain	4	21,150
India	5	14,550
Italy	6	6,200
France	7	6,060
United Kingdom	8	5,707
Canada	9	4,611
Portugal	10	3,960
Rest of the world		29,500
Total		**215,000**

4.4. Turbine Capacity

The growth rate in the present scenario is based on the information obtained from the analysis of the wind turbine market. In recent years, the wind industry has experienced much higher growth rate. Since last five years, the average annual increment and cumulative installed wind power capacity were more than 35% in India. It should also be kept in mind that growth rate comprises a smaller proportion of total wind scenario. Another aspect of wind scenario is re-powering, which encompasses replacing old turbines by latest technology based and more powerful turbine. The average capacity of wind turbines installed has been 1MW in 2008 in India, up from just 400 kW in 2000. Globally, the largest turbines now available for commercial use are up to 6 MW in capacity. In a conservative prediction for India, the average turbine installation will gradually increase from current figure to 1.5 MW in 2013, further increasing to 2 MW by 2030. It is also assumed that each turbine will have an operational life time of 20 years.

5. Case Study: C-WET Tamil Nadu - 2.0 MW Wind Power Station

A study has been carried out for C-WET wind turbine installed in Tamilnadu. The salient points are as follows [19]-

Location : Kayathar, District - Tuticorin, Tamil Nadu, India
Customer: C-WET (Centre for Wind Energy Technology), Chennai
Total power installed : 2.0MW
Turbine type : KENERSYS K-82, 80 m hub height
Number of turbine : 1
Commissioning date : July 2010

Best possible component reliability that is crucial for the stable operation of wind turbine generator system is the wind energy conversion system (WECS) consisting of wind turbine, generator, interconnection apparatus and control systems [19, 20]. The various components/ parts of the above wind installation are described as, *5.1. Rotor*

Swept area	:5281 m²
Number of blades	:3
Blade length	:40 m
Rotor diameter	:82 m
Blade material	:GFRP (Glass fibre reinforced plastic)
Tilt angle	:5°
Cone angle	:2°
Rated speed	:17.1 rpm

5.2. Pitch System

Pitch bearing	:Ball bearing slewing ring, externally geared
Pitch drives	:AC motors, angular gearboxes

5.3. Drive Train

Principle	:3-point-support
Main bearing	:2-rows spherical roller
Gearbox type	:Planetary / spur comb.
Rated torque	:1200 kNm (approx.)

5.4. Yaw System

Type	:Active orientation
Yaw drives	:4 motors with planetary gearboxes
Yaw brake	:Hydraulic callipers with brake disk

5.5. Generator-Converter System

Electrical system	:Full conversion, electrically excited synchronous generator
Protection class	:IP 54
Converter output voltage	:600 V
Frequency	:50 / 60 Hz
Rated power	:2000 kW
Rated speed	:1440 rpm

5.6. Operational Data

Power control	: Pitch control
Operational mode	: Variable speed
Presumed design life	:20 years
Ambient operation temperature	:-20 °C / +50 °C
Noise power level	:104 dB (A) ±2 dB (A)
Cut in wind speed	:3.5 m/s (60 seconds average)
Cut out wind speed	:25 m/s (10 minutes average)
Re-cut in wind speed	:22 m/s (10 minutes average)

5.7. Tower Weight and Height

Height	:80 m hub height
Type	:Tubular conical steel segments
Access	:Internal climbing system
Rotor including hub	:38000 kg (approx.)
Nacelle	:60000 kg (approx.)
Tower	:Depending on hub height

Table 9. Generated power on 50 m hub height [19]

Wind speed at hub height of 50 m (m/s)	Estimated power (kW)	Wind speed at hub height of 50 m (m/s)	Estimated power (kW)
1	0	14	1600
2	0	15	1800
3	50	16	1900
4	75	17	1950
5	200	18	2000
6	400	19	2000
7	500	21	2000
8	700	22	2000
9	900	24	2000
10	1000	25	2000
12	1400	26	2000
13	1500	27	2000

The estimated power for different wind speeds at hub height of 50 m is given in Table 9 and corresponding chart is shown in Fig. 4, which shows that up to 2 m/sec there is no electrical power output. Then electric power gradually increases with wind speed of 18 m/sec. Beyond 18 m/sec, the electrical power output remains constant at 2000 kW.

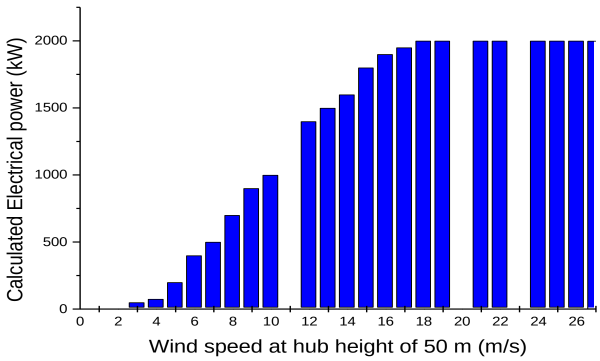

Fig. 4. Graph between generated power and wind speed on defined hub height (50 meter).

This site of wind turbine power generation is managed by the C-WET, which is credited to bring technological advancements in India. C-WET was established in 1998 in Chennai as an autonomous research & development institution in the ministry of new and renewable energy (MNRE), Govt. of India to assist technically for wind power development, promotion and utilization in the country. The leading state Tamil Nadu has installed over 5 GW of wind power, and is predicted to be a power surplus state by 2012.

6. Current Renewable Power Status and Scope Of Work

The grid which is a source of electric power should be able to manage power flows from various geographically distributed generators to dispersed load centres. The five years span from 2011 to 2016 is used for developing strategic plans in terms of measurable, achievable, realistic, time-bound targets for various renewable resources and its applications. Target for year 2016-17 has been forecasted so that the exercise becomes co-terminus with the 12th five year plan for the period 2011-17 [9]. Moreover, the grid also integrates non- traditional sources. Resource- wise targets have been projected in Table 10, for the duration from year 2011 to 2017. The corresponding bar chart is shown in Fig. 5.

Table 10. Year wise targets for grid interactive RE power for the period 2011-17 [9]

Technologies/ Year	RE Power (MW)
Cumulative (anticipated up to 31.03.2011)	14158
2011-12	2400
2012-13	2200
2013-14	2200
2014-15	2200
2015-16	2200
2016-17	2200
Total target for the 6 year period (2011-17)	**13400**
Cumulative Total Target	**27558**

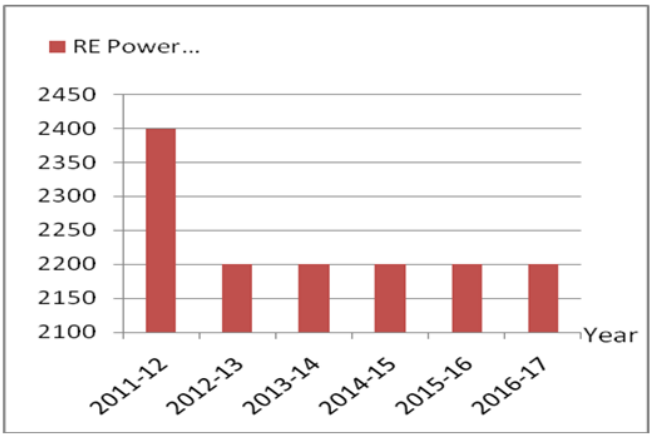

Fig. 5. Stastically data of RE power for the period 2011-17.

Fig. 5 shows the targets for the six year period (2011-17) and total target for the 6 years period is estimated as 13,400 MW. The cumulative power up to 31th March, 2011 is 14158 MW. In six year period (2011-17) cumulative total target of power is 27,558 MW.

Following areas may be considered as a future work for the development of wind power:

- Grid interactive renewable energy production systems [21].
- Cost effective renewable energy for urban, industrial and commercial utilities and rural applications for irrigation, home appliances as cooking, lighting etc.
- Improvements in renewable energy generation.
- Awareness about use of low power wind turbine for home electricity supply.
- Cost effective measures to overcome voltage fluctuation problem from wind generating stations.
- Improve the sensitivity of wind turbine for generating the power at very low wind speed.
- Optimal integration of wind energy conversion system (WECS)/ wind energy conversion storage system (WECSS) with a weak grid (generation and transmission system) associated with the addition of large-scale wind energy conversion systems [22, 23, 30-31].
- System stability, reliability and performance evaluation with various parameter variation.
- Use of different simulation studies as PSCAD, MATLAB for predicting the actual performance.

7. Conclusion

In this paper a study on the wind potential in India has been carried. The discussions have been made on issues and challenges of renewable energy in India particularly financial and technical context. Following are the salient points of the study,

- Till 31st March 2010, approximate 640 stations were established for wind energy in India.
- The highest range of wind power density (400-500 W/m^2) is found in some critical areas of Jammu & Kashmir state only.
- State wise comparision has been made for wind power development level. Maximum installed capacity of wind potential has been observed in Maharashtra and Gujarat.
- For development of wind energy the leading wind turbine manufacturers have been identified, which are dealing with the designing of the wind turbine with various capacities for power generation, for example- 250 kW, 600 kW, 1250 kW and 2100 kW as reported till June 2011.
- India was on 5th position on the basis of installed capacities (14,550 MW) among the leading countries utilizing renewable power.
- Detailed case study of 2.0 MW wind power station has been incorporated.
- Scope for research and development in the area of wind technology has also been identified for future work.

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