Status of wind energy in India

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Abstract *— Energy is a significant factor in socio-economic development of nation's growth. Conventional energy sources based on hydrocarbon oil, coal, and natural gas have proven to be highly effective tools of economic progress, but at the same time causes huge carbon emissions, which leads to harm the environment and to human health. Renewable sources of energy such as solar, wind etc. are very noteworthy in the context of growing concern about sustainable energy supplies and protection of the environment from adverse effect of fossil fuel. Wind energy is a clean, non- polluting, environmental friendly renewable resource. In India, the wind power generation has gained a high level of attention and acceptability. This paper presents the ways in which India has already supported the growth of wind energy, its current status and achievements. The diffusion of wind energy generation in the potential states of India is also analysed.*

Keywords — *Wind, government, capacity, energy.*

I. INTRODUCTION

Energy is an essential factor for economic growth and improvement to quality of life in society. Every sector of economy like agriculture, industry, transport, commercial, and domestic needs energy. Conventional energy sources based on hydrocarbon oil, coal, and natural gas have proven to be highly effective tools of economic progress, but at the same time causes huge carbon emissions, which leads to harm the environment and to human health. Fossil fuels, though cost effective and efficient, are depleting. They pollute the environment and contribute to the greenhouse effect and global warming. Growing concern for the rise in fossil fuel prices, environmental degradation, emission of greenhouse gases, limited coal availability, Global warming, erratic weather patterns have cast a shadow over the future of coal, oil and other conventional sources of energy and it has led to the world's interest in renewable energy sources.

As per International Energy Agency, more than 28 percent of the world's total energy will be consumed in India and China by the year 2030[2]. Therefore a significant amount of energy must come from renewable sources. Renewable sources of energyare very noteworthy in the context of growing concern about sustainable energy supplies and protection of the environment from adverse effect of fossil fuel .This energy is derived from natural processes that are replenished constantly. There is enormous potential of renewable energy sources as they can meet the world's energy demand. Renewable energy sources like wind, solar, hydropower, biomass and geothermal can provide sustainable energy services, based on the use of routinely available, indigenous resources. Wind is commercially and operationally the most doable renewable energy resource and emerging as one of the largest source in renewable energy sector. It is a renewable energy source that meets the energy demand in the direct, grid connected modes as well as stand alone.

Wind has considerable potential as a global clean energy source, being widely available, and producing no pollution during power generation. Wind energy has been one of primary energy sources for milling grain, and pumping water for several millennia. Over 2000 years ago windmills used in China, India and Persia.

Technology of wind energy made its first actual steps with the simple vertical axis windmills found at the Persian-Afghan borders around 200 BC and the horizontal-axis windmills of the Netherlands and the Mediterranean following much later (1875 AD). Further advancement and excellence of these systems was performed in the USA during the 19th century, i.e. when over 6 million of small machines were used for water pumping between 1850 and 1970[1]. The first large wind machine to generate electricity (a low speed and of 12 kW) was installed in Cleveland, Ohio, in 1888, while during the late stages of World War I, use of 25 kW machines throughout Denmark was widespread.

Between 1935 and 1970 efforts in USA, Denmark, France, Germany, and the UK showed that large-scale wind turbine could work. European developments continued after World War II. A series of advanced horizontal-axis designs were developed in Germany, with both of the aforementioned concepts dictating the future horizontal- axis design approaches later emerging in the 70s.

The first large-scale wind energy occurrence was encountered in California [1], where over 16,000 machines(ranging from 20 to 350 kW , total of 1.7 GW) were installed between 1981 and 1990, as a result of the incentives (such as the federal investment and energy credits) given by the USA government. After 1990 most market action shifted to Europe bringing wind energy at the front line of the global scene with major players from all world regions.

In the early 20th century wind energy has played an important part in generation of electricity in Europe and North America. Wind power generation declined as industrialization took place in Europe and then in America, first gradually as the use of petroleum and coal, both cheaper and more reliable energy sources, became widespread, and then more sharply as power transmission lines were extended into most rural areas of industrialized countries. The oil crises of the 70's, however, caused the interest in wind energy technology for grid connected electricity production and power supply in remote areas, promoting the industry's rebirth.

Reliance on renewable energy systems is looking increasingly as in the past 30 years the costs of solar and wind power systems have dropped substantially, and continue to decline, while the price of oil and gas continue to increase. It is obvious that future growth in the energy sector is primarily in the new regime of renewable and not in conventional oil and coal sources. Financial markets are awakening to the future growth potential of wind and other renewable new energy technologies.

II. WIND ENERGY IN INDIA

A. Overview

India is blessed with plenty of renewable energy sources such as wind, solar, hydro and biomass, tidal due to its geographic conditions. There is good potential of wind throughout the country. India occupies the fourth place in the world in installing wind energy, after China, U.S. and Germany [12]. In India winds are affected by the strong south-west summer monsoon, when humid winds blow towards the land in May to August and the weaker north-east winter monsoon, which starts in October, when cool dry winds blow towards the ocean. During the period of March–August, the winds are uniformly strong over the Indian Peninsula, except the eastern peninsular coast. Winds during the period from November to March are relatively weak in India, though higher winds are available during a part of the period on the coastline of the state of Tamil Nadu.

As a result of social, economical and industrial development of country, the demand for electricity grows rapidly in India. Almost all types of oil and natural gas are imported from neighbouring countries. Rapidly growing demand of energy forces India to search for renewable energy sources such as wind energy. As a result of scientific evaluation of wind resources [1–4] throughout the country, wind power has emerged as a feasible and cost effective option for power generation.

B. Wind potential in India

India had mere 1350 MW generation capacity at the time of independence in 1947 and in 2016 India has 305554.25 MW generation capacities [8]. About 14.48% of this is the contribution of renewable energy. The Ministry of New and Renewable Energy (MNRE) is the nodal ministry of Government of India for all matters related to renewable energy. Centre for Wind Energy Technology (C-WET) is responsible for wind resource assessment in the country.

The total wind potential in India was first estimated by the Centre for Wind Energy Technology (C-WET) at around 49.13 GW, and was recently increased to 102 GW at 80 meter hub height. Country has 790 wind monitoring stations in 31 states and union territories for wind resource mapping, established by the C-WET. Gujarat, Karnataka, Andhra Pradesh, Tamil Nadu, Rajasthan and Maharashtra are leading states in wind energy potential [10]. Wind resource assessment done by C-WET has made a crucial contribution to wind energy generation as it identified suitable sites for commercial use. State wise potential and installation till 31st March 2016 has been provided in Table I and Table II respectively.

III. WIND ENERGY PROGRAMME IN INDIA

The significance of renewable energy was accepted in the country in the early 1970s due to oil shock & sudden increase in the price of oil. Indian wind energy programme was initiated in 1984. The objective of this national programme includes resource assessment, provide help to wind projects, to create awareness among people, implementation of demonstration wind projects, involvement of industry, development of infrastructure and capacity for manufacture, installation, operation and maintenance of wind electric generators and policy support.

The Commission for Additional Sources of Energy (CASE) was set up by Indian government in 1981with the intention of formulation and implementation of policies for development of new and renewable energy [12]. Department of Non-Conventional Energy was formed in 1982 and given the responsibility of taking care of CASE. In 1992, this department was altered into the separate ministry, Ministry of Non-Conventional Energy Sources (MNES) and became world's first ministry dedicated to renewable energy [3]. This ministry has been re-named to Ministry of New and Renewable Energy (MNRE) in October 2006. MNRE is dedicated to increase the contribution of all grid connected renewable energy sources in the energy mix of India. MNRE supervises independent energy development institutes like National institute of solar energy for solar energy, Centre for Wind Energy Technology (C-WET) for wind energy, SSS NIRE

for biomass energy, AHEC for hydropower and Renewable Energy Development Agency (IREDA) for financial support and lending to renewable energy projects [14]. The wind programme is being implemented through the State Nodal Agencies, Research Unit of Indian Institute of Tropical Meteorology (IITM-FRU) and Centre for Wind Energy Technology (C-WET). Other departments under various ministries such as Ministry of Power, Planning commission and Prime Minister Council for Climate Change also supervise renewable energy projects. Wind energy has received maximum investment among all the renewable energy technologies due to its lower investment and better commercial feasibility of the projects. As a result, wind energy has largest share in the total renewable energy installation in India with 57.4%.

The first commercial venture was commissioned on 28 March 1990 at Kattadimalai, Muppandal, Tamil Nadu. At first, wind farms in India were installed in the coastal areas of Tamil Nadu, Gujarat, Maharashtra and Orissa. Now wind farms have been installed in more than nine states of India. India now ranks fourth in the global wind power installed capacity index after China, USA and Germany as per global wind energy council in the third week of December 2016 [10]. Table II shows the global wind power installed capacity of top five countries.

Currently, India has over 50017 MW of installed renewable power generating capacity (up to December 16) out of which wind energy accounts 28700 MW which counts 57.4% of total renewable energy. The total capacity added during year 2016 was around 3612 MW with a growth rate of 14.4%. From 2002 to 2016, the average growth rate of wind energy was 26.87%.

TABLE I

State wise potential and installation till 31st March 2016

States / UTs	Estimated potential (MW)	
	@ 50 m ($)	@ 80 m (* #$)
Andaman & Nicobar	2	365
Andhra Pradesh	5394	14497
Arunachal Pradesh	201	236
Assam	53	112
Bihar	-	144
Chhattisgarh	23	314
Dieu Damn	-	4
Gujarat	10609	35071
Haryana	-	93
Himachal Pradesh	20	64
Jharkhand	-	91
Jammu & Kashmir	5311	5685
Karnataka	8591	13593
Kerala	790	837
Lakshadweep	16	16
Madhya Pradesh	920	2931
Maharashtra	5439	5961
Manipur	7	56
Meghalaya	44	82
Nagaland	3	16
Orissa	910	1384
Pondicherry	-	120
Rajasthan	5005	5050
Sikkim	98	98
Tamil Nadu	5374	14152
Uttarakhand	161	534
Uttar Pradesh	137	1260
West Bengal	22	22
Total	49130	102788

TABLE III

Global wind power installed capacity of top five countries

S.No.	country	Comm.(end 2015)MW	New installed(2016)MW	Comm.(end 2016)MW
1	China	145362	23328	168690
2	USA	73991	8203	82184
3	Germany	44941	5443	50018
4	India	25088	3612	28700
5	Spain	23025	49	23074

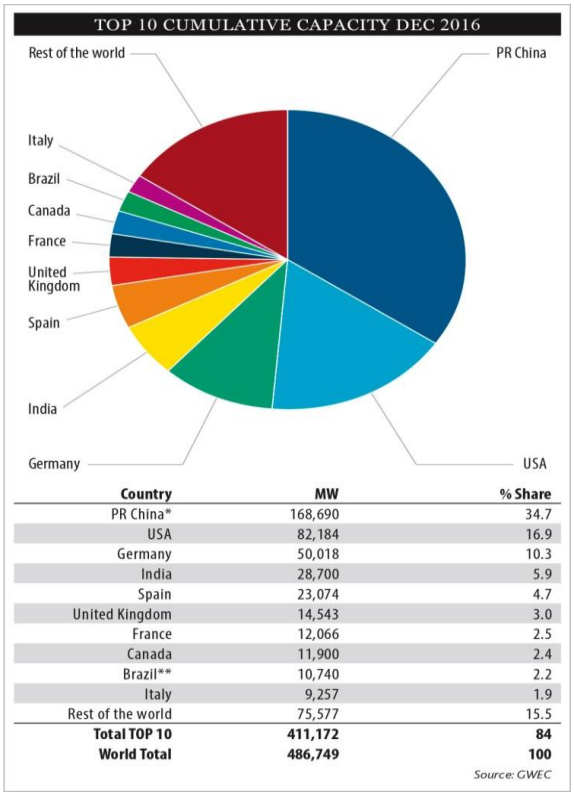

Fig I- Global wind power installed capacity of top ten countries.

IV. STATES WISE WIND ENERGY GROWTH IN INDIA

A. *Rajasthan*

Rajasthan is rising as a significant destination for wind energy generation. Wind energy development programme in Rajasthan was begun in 1999, when MNRE launched a

scheme to install 2 MW demonstration projects. In 2004 the first commercial project of the state of 25 MW Wind energy developed by Rajasthan Renewable Energy Corporation Limited (RRECL). The state has reached to installation of 4006 MW on March 2016 from just 16.1 MW in 2002. In the financial year 2015-16, the desert state raced past Gujarat adding a record 685 MW wind power to reach a cumulative operational capacity of 4,006 MW and become the third largest producer in the country after Tamil Nadu and Maharashtra [13].

B. ***Gujarat***

The state of Gujarat is blessed with a long coastline where the wind speeds are adequate for conversion into electrical energy. To tackle the oil crisis of 1970s Government of Gujarat setup Gujarat Energy Development Agency (GEDA) in 1979. This is a state nodal agency to promote the development of sustainable energy systems. Due to government efforts, in 1985 India's first joint sector 1.10 MW wind farm came at Mandvi in Gujarat. Gujarat's wind power footprint rose by 392 MW to a cumulative operational capacity of 3948 MW at the end of March, 2016, a decommissioned capacity of 88 MW caused it fall from third to fourth position [13].

C. ***Maharashtra***

Maharashtra Energy Development Agency (MEDA) had been formed to undertake development of renewable energy as a state nodal agency under umbrella of MNRE in 1980s. Due to the long- term certainty provided by the regulatory framework and several other policy initiatives, there has been significant development of installed wind power capacity. Satara, Sangli, Dhule and Panchgani are places in Maharashtra those have a good number of wind power generating facilities. Maharashtra have largest installed capacity of wind energy after Tamil Nadu with 4654 MW.

D. ***Tamil Nadu***

Tamil Nadu is pioneer of wind energy in India. Wind farm developed by M/s. Pandian Chemicals at Kanyakumari on March 28, 1990 with 250 KW wind turbine, had been the first wind farm developed by any private company in India. As wind farm sites in Tamil Nadu are not located on complex terrain, it is easy to transport wind turbine equipment to the site that makes project development comparatively easy. Due to its encouraging policies for wind energy, this state has always been preferred by the wind energy industry for installing the projects since the commencement of Indian wind energy programme. The state has reached to installation of 7614 MW on March 2016 with 28.43% of India's total wind installations.

E. ***Andhra Pradesh***

According to the studies conducted by C-WET, Andhra Pradesh is having second highest potential for wind energy with 14.5 GW of generation potential at 80 meter hub height. Non Conventional Energy Development Corporation of Andhra Pradesh Ltd. (NEDCAP) is the single window clearance agency to sanction projects up to 20 MW capacities in the State. The total installed capacity in A.P. is 1431 MW as on 31st March, 2016.

TABLE II Cumulative wind potential installed in different states of India from yr 2002 to 2016

S.No.	Year	Cumulative installed capacity as on 31 march 2016			
		Rajasthan	Gujarat	Maharashtra	Karnataka
1	02-03	61.37	187.6	402.3	124.9
2	03-04	175.77	216.5	408.5	209.8
3	04-05	279.51	268	457.3	411.3
4	05-06	352.785	352.6	1002.4	555.1
5	06-07	464.535	636.6	1487.7	821.1
6	07-08	534.985	1253	1755.9	1011.4
7	08-09	734.585	1566.6	1938.9	1327.4
8	09-10	1084.585	1863.7	2077.8	1472.8
9	10-11	1521.285	2176.5	2316.9	1726.9
10	11-12	2066.935	2966.4	2733.4	1933.6
11	12-13	2698.935	3174.7	3022	2135.3
12	13-14	2796.935	3454.5	4096.5	2318.3
13	14-15	3320.435	3581.4	4369.95	2548.8
14	15-16	4005.935	3948.61	4653.83	2639.55

V. CONCLUSIONS

India is one of the leading countries in the world for the development and deployment of wind energy. Wind energy technology is currently making a significant contribution to the electric power generation systems in India. Government of India has been actively putting efforts to promote renewable energy. Wind energy has become more of business propositions for investors and contributing to development of economy as well. India's global position in wind energy can be bettered, since nature has provided it abundant resources of wind energy. Hence it is important for Indian government to introduce revolutionary changes in its wind energy programme to become global leader in wind energy. These changes can include starting offshore wind energy installation, repowering of old turbines with new higher capacity wind turbines, increasing R&D budget in wind energy technology and enhancing regulatory and tariff regime to bring wind energy into national power system.

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