An Overview of Wind Power Development in India

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ABSTRACT
Climate change has become one of the biggest challenges of the global environment which is primarily caused by the emission of green house gases due to the burning of fossil fuels. It has compelled the world to explore renewable sources of energy for power generation which are environment friendly. Wind resource is one of the major renewable energy resources besides solar resource. The paper gives an overview of the wind power development in India including basic principle and technology. The policy and service supports are briefly explained. The trend for optimum use of location specific wind resource in the form of repowering, wind-solar hybrid and off-shore projects is also discussed.

Keywords: Wind resource, power curve, wind power consultancy, wind power directory, repowering, wind-solar hybrid power, offshore wind power

I INTRODUCTION

Due to rapid depletion of fossil fuel and the challenge of climate change, whole world is looking for environment friendly clean sources of Renewable Energy. Among various renewable energy sources, wind energy has been emerged as one of the most promising option for generation of electricity. For many centuries, globally, wind energy has been used for water lifting and grinding purposes but for its utilization towards generation of electricity started somewhere in the mid-20th century.

II WIND POWER DEVELOPMENT

Air in motion is wind. Kinetic energy available in wind is converted in to mechanical energy and then electrical energy using a wind machine which is called wind turbine generator or wind electric generator or wind energy conversion device.

(a) Wind turbine output - The kinetic energy of wind is utilized rotating the turbine shaft. The output of wind turbine (P) is given by the following equation.

$$P\ (Watts) = \tfrac{1}{2}\rho A V^3 \quad \ldots (1)$$

where,

ρ = air density, 1.225/m^3
A = swept area of turbine rotor, m^2
V = wind speed, m/s

A German physicist Albert Betz mathematically proved that no wind turbine can convert more than 59.3% of the kinetic energy of the wind into mechanical energy for turning a rotor.

(b) Main parts of wind turbine - The main parts of a turbine are shown in Figure 1.

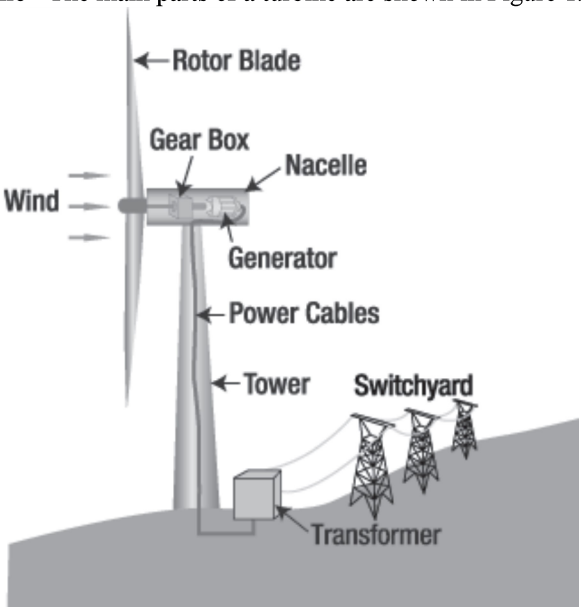

Fig. 1 Main parts of the horizontal axis wind turbine [1]

(c) Power curve - The power curve of a wind turbine drawn between wind speed (X-axis) and turbine output (Y-axis) is shown in Figure 2 along with wind power curve. In the region-I up to cut-in speed there is no power generation. With the increase in wind speed, turbine power also increases up to rated turbine output in region II. However, the turbine output is maintained constant in region III by regulating the pitch of the turbine blades. In case of stall regulated turbine, the output is restricted by the profile of the rotor blades.

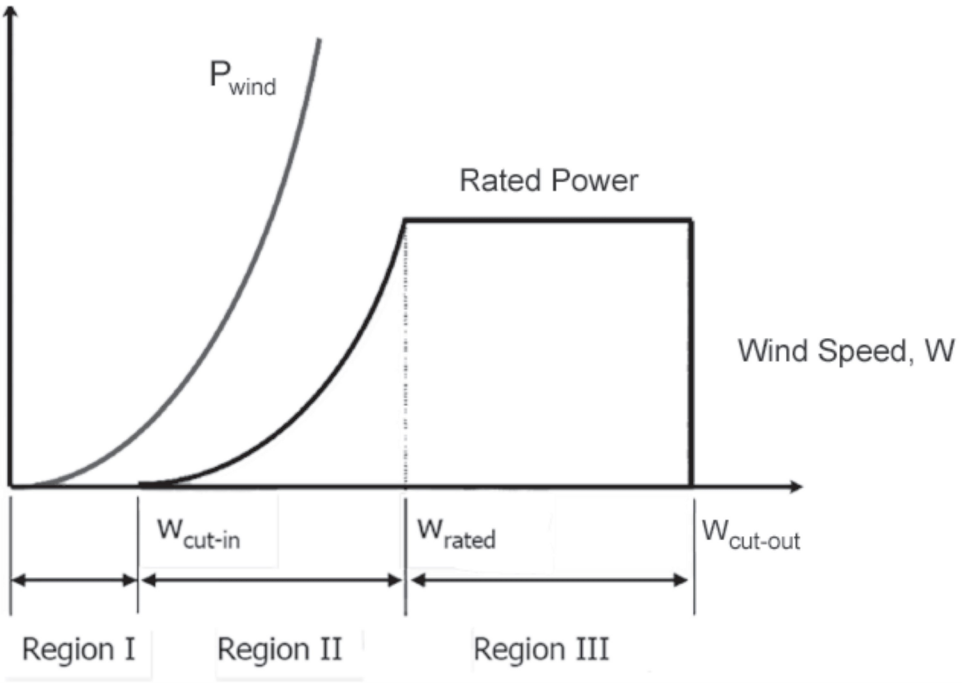

Fig. 2 Power curve of a wind turbine [2]

The wind turbines, access road, internal roads, crane platform can be seen in a wind farm located in CQ Australia. Refer Figure 3.

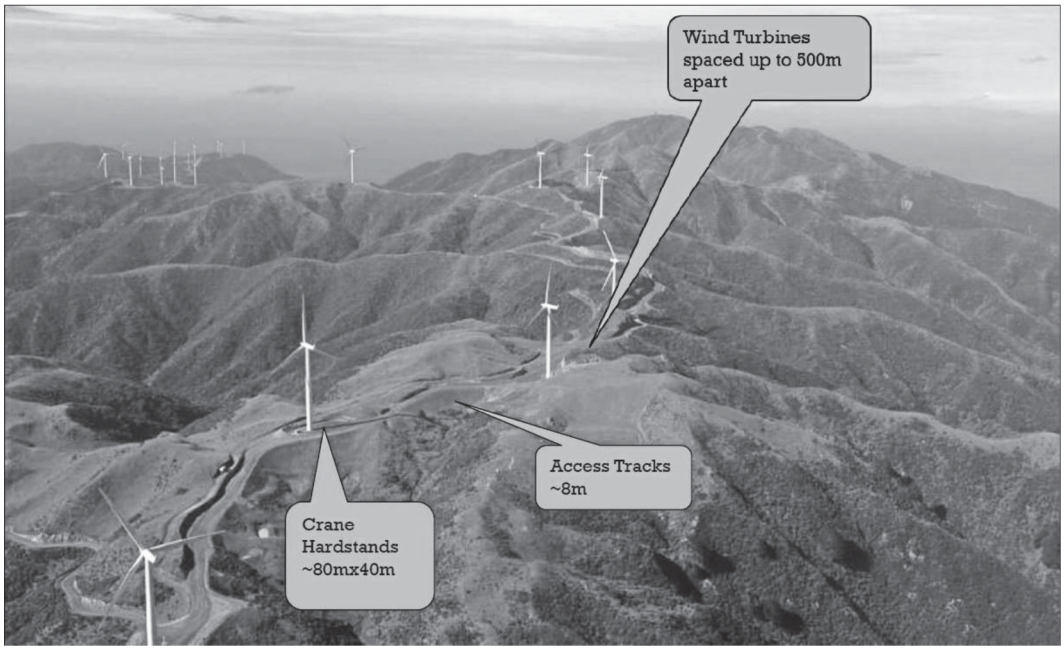

Fig. 3 Wind farm view [3]

(d) Advantages of the Wind Power Project - Following are the major advantages of wind power projects :

(i) The technology of electricity generation from wind has been developed fully for smooth and trouble-free operation as well as for its economic viability.
(ii) It is pollution free and eco-friendly.
(iii) Low gestation period–less than six months from concept to commissioning, enabling fast bridging of power gap even in remote areas.
(iv) With no fuel consumption, power generation becomes almost free after recovery of capital cost. O&M, cost is nominal.
(v) It can be developed in modular form with facilities for extension at a later date.

(e) Limitations of the Wind Power Project - Following are the major limitations of wind power projects :

(i) Adequate wind is not available at all the places. It is very much site specific
(ii) Wind is variable in nature and so is the output from wind electric generator
(iii) Wind alone cannot give firm power

III WIND POWER DEVELOPMENT

(a) Essentials for Establishment - Following are the essential requirements of establishment of wind power projects:

(i) Availability of adequate wind resources for viability
(ii) Availability of land
(iii) Availability of strong grid in view of the variable power evacuation
(iv) Availability of appropriate logistics

(b) Policy initiatives by the Government - An independent ministry named New and Renewable Energy, dedicated to the wind power development was formed. Government of India has formed an independent ministry for renewable energy called Ministry of New & Renewable Energy (MNRE). MNRE has been formulating policies/guidelines for development of wind power projects in India. MNRE created a financing wing for renewable energy projects named Indian Renewable Energy Development Agency (IREDA).

MNRE has also formed a research & Development organization for wind power projects named National Institute for Wind Energy (NIWE) formerly known as Centre for Wind Energy Technology (C-WET) as technical arm of MNRE for Wind Power. There are State Nodal Agencies to promote renewable energy program in their states through state governments working in coordination with MNRE.

(c) Wind Resource and Wind Power Potential - It is seen from equation (1) that wind turbine output varies as a cube of the wind speed. The wind speed increases with the height above ground as can be seen in Figure 4. Hence, the trend has been to install the turbine at a higher elevation to maximize the power generation.

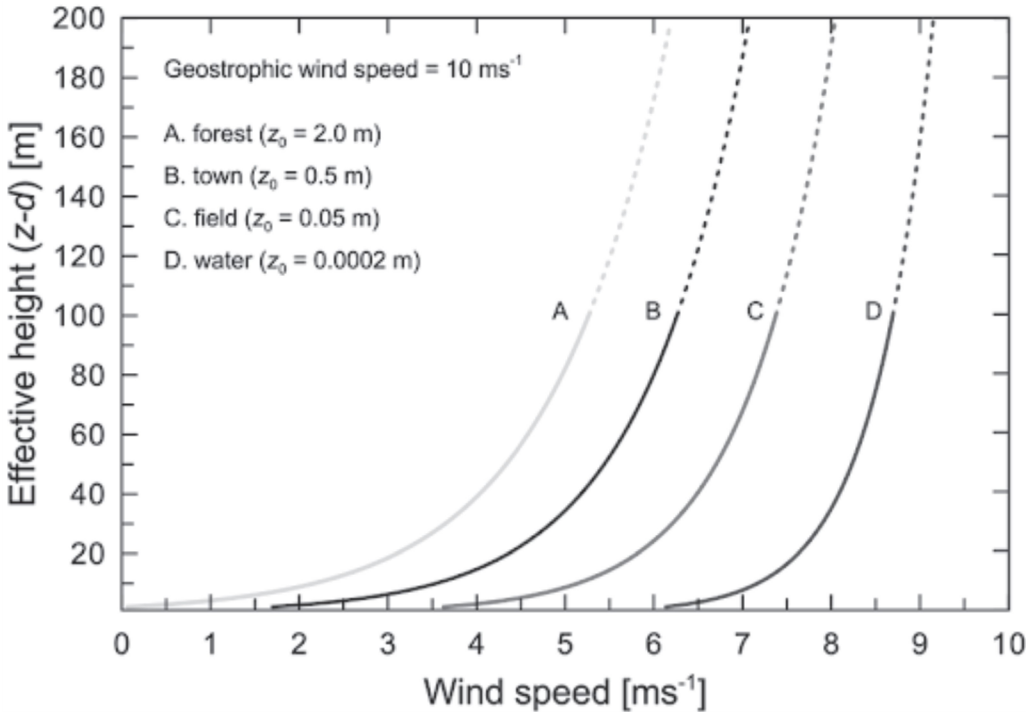

Fig. 4 Variation in wind speed with height [4]

The wind resource is variable by nature as it varies from place to place and time to time. Hence, selection of site is governed by the available wind resource. Thus, wind resource assessment at probable site becomes the starting point for installation of wind turbines in a wind farm. Wind resource assessment is the process of estimation of power generation which provides the basis to the wind farm developers to take appropriate decision.

To estimate the energy yield of a wind farm, the wind resource measurement at probable site is the first step. The data at 10 minutes interval are recorded for minimum period of 1 year and to work out an annually representative wind speed frequency distribution.

In India wind monitoring at government level has been done initially by the Indian Institute of Tropical Meteorology, Bangalore and subsequently by the National Institute of Wind Energy (NIWE). Some private developers have also started wind resource measurement on their own. As on 31st March 2020, wind masts were erected at 914 locations, out of which 249 locations have shown minimum wind power density of 200 W/m^2 at 50 m height. In order to maximise the generation, the trend is for higher rating, higher rotor diameter and higher hub height based on advanced technology. In view of this, the wind mast heights have also been increasing. Accordingly, the tallest wind mast installed in India is 150 m high.

Generally for flat terrain, an area within 10 km radius of the wind mast is considered under the influence zone of the mast. However, for complex terrain, this may get reduced.

The estimated wind power potential at different heights above ground level is given in Table 1.

Table 1
Estimated wind power potential in India [5]

Height (magl)	Estimated Wind Power Potential
50 m	49,130 MW
80 m	1,02,788 MW
100 m	3,02,252 MW
120 m	6,95,509 MW

(d) Installed Wind Power Capacity - The installed wind power capacity of wind power projects in India as on 31.1.2021 is 38,684 MW. The installed wind power capacity in the leading states in India as on 31st January 2021 is given in Table 2.

Table 2
Installed wind power capacity in India [6]

Rank	Country	Capacity (MW)
1.	Tamil Nadu	9428 MW
2.	Gujarat	8245 MW
3.	Maharashtra	5000 MW
4.	Karnataka	4872 MW
5.	Rajasthan	4327 MW

(e) Manufacturing and Services - In India Wind power development started by installation of the demonstration projects by the Government of India. The wind turbines ranging from 55 kW to 3000 kW of different makes have been installed.

National Institute of wind Energy (NIWE) under MNRE updates and issues the revised list of Models and Manufacturers (RLMM) of WEGs having valid Type Certificates from recognized international testing agency. However, now RLMM list is issued directly by MNRE. In India WEG manufacturers have established manufacturing plants. Currently there are more than 15 WEG Manufacturers with manufacturing capacity of about 8000 MW of wind turbines and associated equipment/systems. They have established technology to manufacture from units 225 kW to 3000 kW rating. There are ancillaries and component/spares suppliers for the WEGs. There are also service providers like WEG transportation, erection, civil works, electrical works, wind resource assessment, operation & maintenance, repairs, liaisoning, scheduling & forecasting, consultants etc.

As per the available information there are more than 35,000 WEGs belonging to more than 5300 parties of different make ranging from 55 kW to 3000 kW.

IV OPTIMUM UTILIZATION OF WIND RESOURCE

MNRE has taken initiatives for making optimum use of wind resource by issuing the policies for repowering of the existing old wind farms, wind-solar hybrid power projects and offshore wind power development. These are discussed next.

(a) **Repowering of Wind Farms -** Repowering means replacing old turbines with fewer, larger and taller modern turbines which are more efficient and can generate more energy. MNRE issued a new policy for repowering of wind farms in August 2016.

The objective of the Repowering policy is to endeavour for optimum utilization of wind energy resources. Most of the wind-turbines installed up to the year 2000 have capacity up to 500 kW and are installed at sites which have high wind resource. It is estimated that over 3,000 MW capacity installations are eligible for repowering.

For repowering, Indian Renewable Energy Development Agency (IREDA) provides an additional rebate of 0.25% on interest applicable for the new wind power projects.

In Coimbatore, Tamil Nadu a repowering project Phase-I was completed in which 10 turbines totalling 3.4 MW were replaced by 4 large turbines of the same total capacity. However, due to advanced technology and higher CUF, the generation is estimated to increase by over 1.5 times.

(b) **Wind-solar Hybrid Power Projects -** In order to optimize the wind and solar resources, MNRE issued policy in May 2018 for not only the new wind-solar hybrid plants but also for encouraging hybridization of existing wind and solar plants.

The solar and wind power being variable in nature which poses challenges on grid stability. The solar and wind resources are complementary to each other and their hybridization would minimize the variability apart from optimal utilization of the infrastructure including land and transmission system and also O&M man power. The existing wind farms generally have possibility of installing solar PV plants and similarly there may be wind power potential in the existing solar PV power plants.

The energy storage may also be provided to the project to reduce the variability of output power from wind solar hybrid power project and also ensuring supply of the firm power for a committed period.

Some hybrid power projects are under execution in India. A hybridisation of existing 50 MW wind (existing) and 28.8 MW solar PV project was commissioned in in Raichur District in Karnataka in 2018.

(c) **Offshore Wind Power -** India has a 7,600 km of coastline. The coasts of Gujarat and Tamil Nadu have potential to be exploited for the development of offshore wind power.

The National Institute of Wind Energy (NIWE) invited leading offshore wind technology suppliers for technical discussion. After this, knowledge building and activities related to offshore wind development and advance investigations initiated through two projects viz. FOWIND (2013-18) and FOWPI (2016-19). The national offshore wind policy was issued in 2015 to create interest in developers and investors.

More studies and analysis will be required to identify bankable offshore wind sites. It is learnt that India has established inter-governmental cooperation and bilateral agreements with the European countries to share their experiences in the development of offshore wind forms. A bilateral agreement signed with Denmark.

The Indian government is looking into setting up structures for power purchase agreements as well as offshore wind auctions. The cost will be high for the first offshore project hence, in order to lower the cost, it would be necessary to provide some Viability Gap Funding.

V CONSULTANCY SERVICES

There are several wind energy consultancy organizations in India such as National Institute of Wind Energy, TERI, CECL, DNV, MITCON etc. The services offered include site Identification, Wind Resource Assessment, Micro-siting, Energy estimation, Validation, Feasibility studies, Detailed Project Report preparation, Design and Engineering, etc.

(a) **National Institute of Wind Energy -** The NIWE was established in Chennai in 1998 as an R&D institution by the MNRE then MNES. It was converted into an autonomous institution. A Wind Turbine Test Station with technical and partial financial support from Danish International Development Agency (DANIDA), Government of Denmark, was established at Kayathar, Thoothukudi District, Tamil Nadu, as an integral part of NIWE. Main functions are: [7]
   (i) Assesses and analyses wind resources and preparation wind maps/atlas
   (ii) Develops standards, guidelines, procedures, protocols for design, testing and certification
   (iii) Accords type approval/type certification
   (iv) Consultancy services to the customers.

(v) Wind Turbine Testing including Power performance/load/power quality measurements,
(vi) Safety and functional tests yaw efficiency test and also the user defined measurements.
(vii) Standards and certification
(viii) Wind Power Forecasting Services
(ix) Training to National, international participants, customised training

(b) Consolidated Energy Consultants Limited - CECL, Bhopal needs special mention. CECL has been offering the concept to commissioning consultancy services in wind energy for 35 years. However, there are certain unique features associated with CECL as given below: [5]
(i) Pioneer: One of the pioneer consultants in Wind Energy Sector in the country.
(ii) CECL is the first and so far only company to take initiative of making a joint sector company - MP Wind farms Ltd. (MPWL) along with state government and central government for acting as single window agency for development, operation and maintenance of wind farm on behalf of many small investors. MPWL established a wind farm project at Jamgodrani, Dewas, Madhya Pradesh.
(iii) CECL has been annually publishing Directory Indian Wind Power ever since 2001. It is the only document which provides comprehensive and authentic information and data bank pertaining to wind power in India. It is very useful not only for the investors, developers, planners, consultants etc. but also to the researchers.
(iv) Besides having internationally acclaimed softwares, CECL has developed on its own a number of softwares to ensure grid compatibility and financial viability.

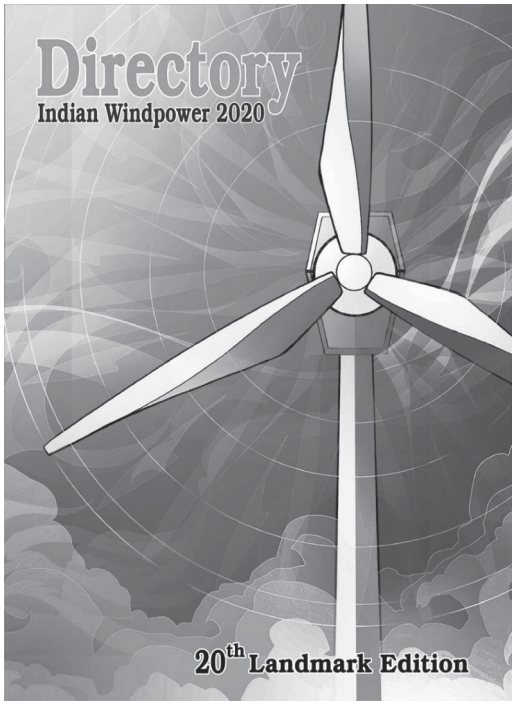

Fig. 5 Directory Indian Wind power [5]

VI CONCLUSION

The renewable sources of energy, mainly solar and wind have emerged as the leaders in fighting against the challenges imposed by the climate change. The conversion of wind energy into electrical energy, wind resource assessment, installed wind power capacity; various services from concept to commissioning have been discussed. An overview of the initiatives taken to make optimum utilization of wind resources in the form of repowering, wind-solar hybrid and offshore wind power development have been covered.

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