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Wind power potential assessment of 12 locations in western Himalayan region of India

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ABSTRACT

Wind power potential of a location has to be assessed for its effective utilization. The objective of the present study is to assess the wind resource potential of the western Himalayan Indian state of Himachal Pradesh to identify potential sites along with providing inputs to policy makers for exploiting wind potential of the region for wind power generation and mechanical applications. An overview of current status of wind resource assessment studies is presented to identify suitable techniques. Wind Energy Pattern Factor (WEPF) method is used to assess the wind potential of 12 locations covering different terrains and climatic zones using wind data for the period 2008–2012. Weibull and cumulative wind distributions, Weibull parameters and Wind Power Density (WPD) are determined for these locations. The highest daily mean wind speeds are observed in summers and lowest in winters in the region. Wind shear analysis is carried out which shows that wind speeds at 30 m, 50 m, 80 m and 100 m hub heights are found to increase by 10–17%, 26%, 34% and 39% respectively than those measured at 10 m height. The mean wind speed and WPD for the 12 locations are found to be in the range 3.9–4.7 m/s, 4.7–5.8 m/s, 5.7–7 m/s, 6.2–7.7 m/s and 14.09–22.15 W/m^2, 52.67–82.79 W/m^2, 97.23–152.82 W/m^2, 170.9–268.62 W/m^2, 223.37–351.1 W/m^2 at 30 m, 50 m, 80 m and 100 m heights respectively; thereby indicating fairly good wind potential for rooftop micro-wind turbines, battery charging, water pumping and wind power generation in western Himalayan region. WEPF method is also tested for accuracy. A correlation between measured wind data of Hamirpur and NASA wind data is developed with root mean square error as 0.3855 and R^2 as 92.61% showing that the method has sufficient accuracy. The correlation is used to predict measured wind speeds and power for locations for which measured wind data are not available. Further follow-up research areas are also identified.

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1. Introduction

Wind is one of the fastest growing renewable energy sources for power generation and has become more competitive with conventional energy sources in recent years [1]. Wind power density expressed in watt per meter square (W/m^2) is considered to be the best indicator to determine the potential wind resource, which is critical to all aspects of wind energy utilization. Wind resource although is highly uncertain due to its stochastic nature, but can be predicted with significant accuracy. The varying nature of the wind speed causes the disturbances in wind power grid connected systems and also affects the stability due to the transients in voltage, current, frequency fluctuations, and power quality issues. This necessitates the need to understand the wind behavior at a location using wind forecast and wind prediction techniques. Wind speed prediction was a part of weather forecasting for many decades which was used for ship navigation, air traffic control, satellite launch etc. However, wind power forecasting has gained importance recently with increasingly use of wind in power generation worldwide.

The wind speed distribution determines the performance of a wind energy generation system for a particular location and time quite well. Once wind speed probability distribution is known, the wind energy distribution can easily be obtained. Therefore, the probability distribution of wind speed is of importance in the wind energy potential assessment. A number of probability density functions are used to describe wind speed frequency distributions but the two parameter Weibull distribution [2] is one of the most widely used tools to determine the variation in wind speed and wind energy potential to assess the commercial viability of wind energy applications. The Weibull distribution is also used as a reference distribution in wind energy software Wind Atlas Analysis and Application Program (WAsP) [3]. The need to carry out wind resource assessment is of importance for a country to harness the available wind energy. Much attention has been given in India for the development of renewable energy resources in early 1980s by establishing a separate Ministry of New and Renewable Energy Sources (MNRE); thus India became the first country in the world to take such a major policy decision of far reaching consequences. Wind energy resource in the country needs to be utilized effectively for energy security, ensuring a sustainable path for the country's economic and social development.

The wind data of India measured at 243 meteorological stations in 13 states are published in seven volumes entitled: Wind Resource Survey in India. Later micro-wind surveys of 97 sites in 10 states were carried out. Major initiative on wind resource assessment was undertaken with the establishment of Center for Wind Energy Technology (C-WET) at Chennai by MNRE in 1998which looks after the development of wind energy program in the country. The wind resource assessment program coordinated by C-WET has covered 31 states and union territories by establishing 1244 wind monitoring and wind mapping stations. 233 potential sites have been identified in the country. CWET has developed Wind Power Density (WPD) map of India at 50 m level based on data from 11 states and 2 union territories.

The potential for wind power generation for grid interaction in India is estimated as 48,500 MW, out of which 43,000 MW lies in Class 2 category with WPD 200–300 W/m^2 and 4380 MW in class 3 with WPD 300–400 W/m^2 and 4380 MW in Class 3 (WPD 300–400 W/m^2) [2]. Indian Wind Atlas, published by C-WET, provides mean wind velocity and mean power density maps of different regions of the India at 50 m and 80 m heights above ground level [4] and has estimated the wind potential for electricity generation in India as 49 GW at 50 m height which has now been re-assessed as 102 GW at 80 m hub-height as shown in Fig. 1.

The development of wind power in India began in 1990s and has significantly increased during last 23 years. The policy support for wind power generation has led India to become the fourth largest installed wind power capacity country in the world over 20 GW during 2013. However, the rate of growth has slowed over the past three years. At present, wind power accounts for about 67% of total renewable energy installed capacity in the country; grid-connected renewable power (29.9 GW) accounts for almost 12.8% of India's overall installed power generation capacity (∼232 GW) and accounts for about 5% of electricity generation [5]. The installed capacity of wind power generation in India as up to 31 January, 2014 is 20,226 MW mainly spread across states of Tamil Nadu (7251 MW), Gujarat (3384 MW), Maharashtra (3472 MW), Karnataka (2312 MW), Rajasthan (2734 MW), Madhya Pradesh (386 MW), Andhra Pradesh (648 MW), Kerala (35 MW), Orissa (2 MW), West Bengal (1.1 MW) and other states (3.3 MW). A target of an additional 30 GW of grid connected renewable power is set in the 12th five year plan (2012–2017), of which 15 GW is projected to come from wind power alone [6]. The approved outlay for 12th plan for New and Renewable Energy programmes was INR 33 billion (∼ US $ 539million).

Indian market has also emerged as one of the major manufacturing hubs for wind turbines in Asia with annual production capacity of 19 manufacturers offering 50 models of wind turbines with total annual production capacity of over 10 GW and more than 20 wind turbine manufacturing and supply companies are expected to operate by the end of 2014. The government of India has planned to launch

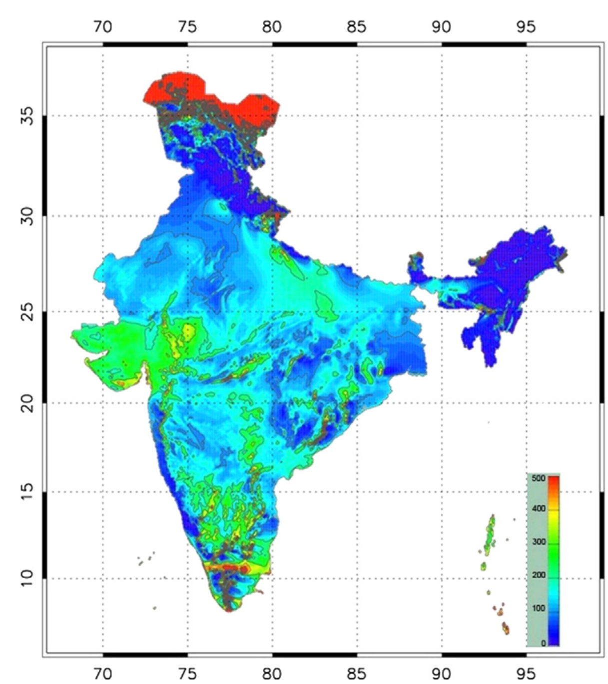

Fig. 1. Wind energy potential of India at 80 m height [4].