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A review of technical issues on the development of wind farms

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ABSTRACT

Energy is the prime mover of economic growth and is vital to sustain a modern economic and social development. Renewable energy applications have brought about significant changes in the Indian energy scenario. The identification and efficient use of various renewable energy resources are the thrust areas in energy development. Wind energy is one of the most environment friendly, clean and safe energy resources. The wind energy will continue to be the biggest renewable energy sector in any country in terms of both installed capacity and total potential. This paper reviews some important factors and techniques to be considered for wind turbine installations such as the wind energy resource assessment techniques, environmental factors, grid integration factors, control strategies, impact of offshore wind turbines and hybrid energy technologies, hydrogen production techniques, feed-in tariff mechanism, modeling of wind turbine components including generators, performance improvement techniques. The cost and economic feasibility of the wind energy conversion system as well as the control strategies of wind turbine generators have also been discussed.

Contents

1. Introduction

Wind power harvesting is today a mature technology which at windy locations is economically competitive with conventional power generation technologies [1]. India is a land with abundant wind resources. India's wind power has been experiencing rapid development since 1990. India is the second largest wind market in Asia with a total capacity of 15,880 MW. According to the International Energy Agency, in 2008, more than 400 million Indians did not have access to electricity [2]. The Installed Capacity (IC) of global wind energy at the end of 2011 was 237021.5 MW in 97 countries/ regions which is 20.29% more than that of 2010. All the wind turbines installed around the globe till the end of 2011 generate 500 Tera Watt hours (TWh) per annum which is 16.28%

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higher than that in 2010. The total installed capacity of grid interactive renewable power, which was 16817 MW as on 31.03.2010 was increased to 19,971 MW as on 31.03.2011 indicating a growth of 18.75% during the period. Out of the total installed generation capacity of renewable power, wind power accounted for about 71% as on 31-03-2011[3].

As on March 31, 2012, the installed capacity of the renewable energy based power generation was 24,503 MW which is about 12% of the total installed capacity of 199,626 MW [4]. The grid connected wind energy onshore potential and grid connected renewable energy potential in India are 100,000 MW and 662,881 MW respectively [5]. The potential wind power of India is estimated to be 49,132 MW. The wind power market penetration is expected to reach 8% of the total energy market penetration by 2018 [6]. The generation of electricity by wind turbines does not involve the release of carbon-dioxide. The government of India gives a subsidy to renewable electricity sources like wind and makes the wind power development more attractive to investors on wind energy. India was honored with the world wind energy award of 2005 for making an outstanding contribution of suitable wind power policies [7]. Public sector undertakings, public utilities and corporate bodies are being encouraged to invest in wind power projects to meet their electricity requirements. The Consolidated Energy Consultants Ltd., a leading consultancy organization, provides the micro details of explorations of windy locations, wind characteristics, wind farm layout and selection of most economical and best suited wind turbines.

The Indian Renewable Energy Development Agency was established as a public limited government company in 1987 for financing and promoting self- sustaining investment in power production from renewable energy sources. The Ministry for Non-Conventional Energy Sources started functioning as a separate ministry from 1992 with a view to develops all areas of renewable energy. To help develop an effective utilization of wind energy in India, the Centre for Wind Energy Technology was established in Chennai in the year 1998–1999. The wind resources are inherently intermittent and difficult to control in terms of power output. The stable wind turbine operation with the existing power grid can be accomplished by tackling the technical problems resulting from the unstable fluctuation of wind energy. Grid integration is the most interesting and exciting area of research in the world today. The wind energy resources are remote from the load and existing generation and therefore require the development of transmission. Activities related to wind farm design are continuing to grow on integration of wind energy into transmission and distribution grids. The advanced research capabilities on wind energy are expected to stimulate economic development, reduce energy costs, improve reliability and enhance environmental quality. This article gives a brief overview of various factors and techniques to be considered for wind energy development. The paper will be useful to the wind energy promoters to know the recent developments in the research carried out on wind energy fields and the researchers in the area.

2. Wind power resource assessment techniques

Several authors have worked on area such as wind resource assessments and its models, wind power potential and wind power density, site selection and site matching, estimating and forecasting of wind energy production and energy loss owing to wake effect. These reviews are based on wind-speed prediction and forecasting. The development of techniques for accurate wind-resource assessment under research and development is described as follows: Daniels (1988) presented wind data of four turbine siting methods and compared it with the wind speed estimates made prior to the project for large wind turbines located in Kahuku on the Hawaiian island of Oahu. The result produced the best trade estimates of both mean speed and ranking of the turbine sites [8]. Bechrakis et al. (2004) analyzed wind resources for an area using short term data correlated to a long term data set [9]. Redman (2004) assessed wind energy resources to the wind energy prospects of Saudi Arabia. The correct wind resource measurements taken for an area by using wind meteorological towers are essential in wind potential exploitation. Wind resources are known to be rarely consistent and vary with time, season, terrain type and height above ground. These factors are to be thoroughly investigated prior to any exploitation [10]. King and Hurley (2004) described the wind resource potential assessment of a wind farm by using Molded Site Data wind correlation method. The performance of this method of assessment resulted in expected accuracy [11]. Archer and Jacobson (2005) evaluated global wind power in the United States and the data analyses indicated that 15% of the data stations in the United States has the annual-average wind speed above 6.9 m/s (15.4 mph) at 80 m [12].

Singh et al. (2006) reviewed the wind-speed prediction, forecasting techniques and the methods for accurate assessment of wind-power potential. The assessment of power output from a wind turbine will be accurate, if the wind speed is measured at the hub height (30–50 m) of a wind turbine-generator. However, the existing wind data available at most of the meteorological stations worldwide are measured at a height of 10 or 20 m above the ground [13]. Rehman et al. (2007) carried out a study on wind resource assessment for Saudi Arabia [14]. Nguyen (2007) estimated the wind resources available in Vietnam [15]. Lackner and Manwell (2007) described an objective decision-making approach for wind resource assessment at site. A recursive dynamic program was used to evaluate the option for continuous measurement. The results indicated that it was an extremely effective method for reducing the average measurement time [16]. Sreevalsan et al. (2007) discussed the wind farm site assessment based on Measure-Correlate-Predict method by using Fast-Fourier Transforms and validated the result with measured data at the observed site [17]. Buflasa et al.(2008) carried out wind resource assessment for the development of the wind farms in the Kingdom of Bahrain [18]. Elamouri and Ben Amar (2008) have evaluated the wind speed characteristics and the wind power potential for the 17 locations in Tunisia at an altitude of 10 m above ground level [19]. Ziter and Lubitz (2010) investigated the use of vertical extrapolation method to reduce the uncertainty associated with tower-mounted anemometer wind speed measurements and performed an experimental study with a meteorological mast. The results indicated that the power law extrapolation could significantly reduce the uncertainty of wind speed predictions at hub-height level especially if concurrent wind speed measurements were available at multiple elevations. A porous disk wind tunnel test was also performed experimentally and compared with the three-dimensional wind speed measurements to identify the upper limit of anemometer placement. It was recommended that the topmost anemometer be positioned at one rotor diameter below hub-height [20].

Yoreley Cancino-Solorzano et al. (2010) evaluated the wind persistence properties using analytical methods to identify the best site for a wind farm in Mexico. The results indicated that the coastal areas have the best properties of wind speed persistence for the generation of electricity from wind energy [21]. Johnson (1978) determined Weibull parameters by using the Weibull distribution methods for the wind resource assessment to an economic design of wind electric systems [22]. Corotis et al. (1978) analyzed the seasonal characteristics of the wind speed persistence by using probabilities models and compared the obtained results with potential and exponential laws [23]. Wasynczuk (1981) described