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Performance improvement in an Indian wind farm by implementing design modifications in yaw and hub hydraulic systems—A case study

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ABSTRACT

In India, wind power has emerged as the leading green energy technology with an average growth rate of 30%. Wind power has been concentrated in few regions especially the southern state of Tamil Nadu, which maintains its position as the state with the largest wind power installation. Due to the rapid growth of wind farms, the technical availability and the performance issues are to be studied in detail in specific locations where the wind is turbulent in nature. As most of the European wind turbine designs are facing critical problems in Indian atmosphere, detailed study in the individual wind farms is required to increase their performance. Hence rather than the technical advancements of wind turbine generator (WTG), certain measures to enhance the power production in the existing wind farms are essential. This paper deals with two critical issues and suitable remedial measures in an existing wind farm. The proposed designs are implemented and tested in the wind farm. The performance analysis is made for two years duration before and after installation. It is observed that the effectiveness of the yaw system and hub hydraulics was enhanced.

Contents

1. Introduction

Growing demand on power needs is gradually gaining interest on developing wind energy conversion systems as a suitable source of renewable energy. The economical and environmental factors also contribute to the research and development on

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exploring various means of increasing the performance of wind turbine generators. The majority of the commercial wind energy conversion systems in India are equipped with horizontal axis, upwind configured wind turbine generators (WTG) due to their various advantages.

In the last decade, the average annual growth of installed wind farm capacity in the world is around 30%. Harnessing of wind energy could play a significant role in the energy mix of each nation [1,2]. The sun radiates 1 PW or 1014 kW h, of energy every hour; as little as 3% of this if being converted into wind energy, will be able to meet the global power demand today. It is estimated that about 10^6–10^7 MW of usable power is continuously available in the earth′s winds. The magnitude of this vast potential is in striking contrast with that of the hydro power potential of the earth. As per projections made by the Global Wind Energy Council, the present installed capacity is 158.5 GW. The size of the global annual wind market is expected to reach 62.5 GW by 2014 and the cumulative capacity by 2014 would be around 409 GW.

There are three basic designs of large and medium wind turbine generators that are operational around the world. The basic type is a gear driven fixed speed wind turbine driving a squirrel cage induction generator connected to the grid. The next type is variable speed wind turbine employing gear mechanisms and doubly-fed induction generator with required power electronics interface. The third one is direct driven wind turbine employing synchronous generators controlled by power electronic converters [1,3–5].

India, being an important player in wind power development is actively contributing in harnessing wind energy for electrical power extraction. It is the fifth largest producer of wind power after China, USA, Germany and Spain with a total installed capacity of 18.421 GW as of December 2012. They employ grid connected induction generators which convert wind energy to electrical energy to be fed to the grid [6].

As the concentration of WTG is more in Kanyakumari district of Tamil Nadu, India, the performance issues play a vital role. This paper aims on analyzing the performance measures of a wind farm located in this area and the reasons for low power production in a group of wind turbine generators compared to the neighboring machines. A novel strategy to improve the production by modifying the existing design in the yaw system is proposed, implemented and analyzed for a significant period of time. The results obtained are encouraging in terms of power production when compared with the neighboring machines and the previous year′s performance. There are thousands of similar group of wind turbine generators in this turbulent windy area. Hence the proposed design may be applicable to those wind turbine generators. Commercially most of the other wind farms are also installing the proposed designs to increase the power production.

2. Wind power in India

In India, wind power is at the threshold of a new era. The wind power programme in the country was initiated towards the end of the sixth plan, in 1983–1984. A market-oriented strategy was adopted from inception, which has led to the successful commercial development of the technology. The Indian wind energy sector has shown impressive growth in the past few years and investments into the sector have increased significantly. The total potential for wind power in India was first estimated by the Centre for Wind Energy Technology (C-WET) at around 45 GW and was recently increased to 48.5 GW, which is presently adopted by the Government as the official estimate.

Wind in India is influenced by the strong south-west summer monsoon, which starts in May–June, when humid air moves towards the land and the weaker north-east winter monsoon, which starts in October, when dry air moves towards the ocean. During the period March to August, the wind is uniformly strong over the whole Indian peninsula, except the eastern peninsular coast. The speed of the wind during the period November to March is relatively weak, though higher winds are available during a part of the period on the Tamil Nadu coastline.

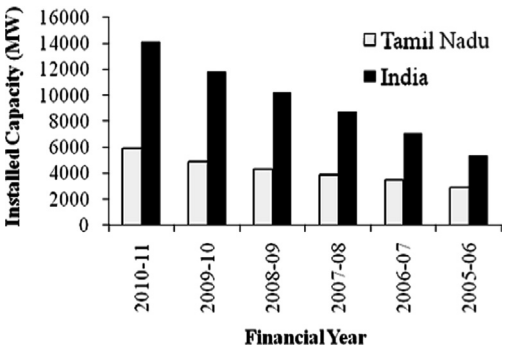

Fig. 1. Development of wind power in India and Tamil Nadu.

Wind power has been concentrated in a few regions, especially the southern state of Tamil Nadu, which maintains its position as the state with the largest wind power installation, with 7154 MW installed until February 2013, representing 39% of India′s total installed capacity. Tamil Nadu being the first state to introduce wind farms in the country has achieved tremendous success in harnessing renewable energy for generation of grid quality power. The state is endowed with three prominent passes having high wind potential namely, Aralvaimozhy pass in Kanyakumari District, Shengottah pass in Tirunelveli District and Palghat pass in Coimbatore District. The average annual wind velocity for the above locations is assessed as 19–25 km/h, 18 22 km/h and 18–22 km/h respectively. Recent study has identified some wind potential sites in coastal area near Chennai, Rameswaram, Palani and Theni.

The development of wind power in the whole of India and only Tamil Nadu during the last six years is illustrated in Fig. 1. The World Institute of Sustainable Energy predicts an annual market of 5000 MW of wind power by the year 2015. Emerging technologies like repowering, offshore wind, etc., are also being explored.

3. Theory of wind turbine generators

The principal components of a modern horizontal axis wind turbine generator (WTG) are the tower, the rotor, nacelle assembly and controller. The nacelle accommodates the gear transmission mechanisms, braking systems, generator and the yaw system for steering in response to changes in wind direction. Switching and protection systems, transmission lines, transformers will also form the part of a wind farm [7].

3.1. System description

Certain investigations are done in a 10.02 MW wind farm at Aralvaimozhy pass Muppandal area in Tamil Nadu, India, having various models and capacities of WTG. The performance of a specific group of 250 kW, Danish machines in the wind farm is found to be low when compared to the neighboring different make machines of same capacity.

3.2. Design configuration

The wind turbine rotor in the said group of WTG consists of a hub, rotor blades and blade extenders to increase the rotor