Renewable and Sustainable Energy Reviews 34 (2014) 20–29

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Tower distortion and scatter factors of co-located wind speed sensors and turbulence intensity behavior

Shafiqur Rehman

Center for Engineering Research, Research Institute, King Fahd University of Petroleum and Minerals, Dhahran 31261, Saudi Arabia

ARTICLE INFO

Article history:
Received 18 August 2013
Received in revised form
2 February 2014
Accepted 1 March 2014
Available online 20 March 2014

Keywords:
Wind speed
Wind anemometer
Wind tower
Tower distortion factor
Scatter factor
Turbulence intensity
Wind power density

ABSTRACT

The present study aims at evaluating the performance of wind speed sensors installed at different heights on a 40 m tall wind mast during a period of 33 months between July 01, 2006 and April 01, 2009. The performance has been evaluated by estimating the tower distortion factor (TDF), scatter factor (SCF), and studying the correlation ship between the co-located wind speed sensors. A total of 23,730 hourly mean wind speed records were used to evaluate each sensor. The overall values of TDF between wind speed sensors WS5/WS6 at 40 m and WS3/WS4 at 30 m were found to be 0.025 and 0.021 without tower shading and 0.047 and 0.035 with tower shading. The study showed that the performance of sensors did not deteriorate with time rather lower values of TDF were obtained with passage of time. At 40 m AGL for wind speed sensor WS5 the tower shading effect was pronounced (>1) within wind direction range of WD2 from 169° to 195° and in case of wind speed sensor WS6, the tower shading effect of <1 was evident from WD2 of 240° to 270°. More or less the same type of observations was noticed for wind speed sensors WS3 and WS4 at 30 m AGL. The SCF values were higher for wind speed sensor at 40 m compared to those at 30 m AGL.

Contents

1. Introduction

In this modern era of fast technological development and energy intensive life styles, the energy requirements are increasing tremendously on global, regional and national levels. Besides regular means of power production to meet these energy demands, new and renewable sources are being encouraged to supplement these requirements. Utilization of renewable sources of energy has two fold benefit, one it reduces the dependence on fossil fuels which means reduction in greenhouse gases (GHG) emissions and two to supply energy where there is no national or regional electrical grid. The fast developing and widely used sources of clean energy include the wind, solar thermal, solar photovoltaic (PV), hydro-, geothermal, and biomass. Of these sources of clean energy wind energy has been adapted by industries and accommodated by individual users due to its availability, ease of maintenance, low cost of operation and maintenance. The annual cumulative wind power installed capacity reached 282.587 GW in 2012 compared to 238.050 GW in 2011,

E-mail address: srehman@kfupm.edu.sa

http://dx.doi.org/10.1016/j.rser.2014.03.007
1364-0321/

Table 1
Details of the equipment installed at Juaymah.

S. no.	Item description	Technical information
1.	Symphonie internet enabled data logger	12 Channel, memory and remote data transfer facility, Symphonie GSM iPack kit
2.	Wind speed sensor, NRG#40 Three cup anemometer	Type: AC sine wave Accuracy: 0.1 m/s, range: 1–96 m/s Output: 0–125 Hz, threshold: 0.78 m/s
3.	Wind direction vane, NRG#200P	Type: potentiometer Accuracy: 1%, range: 360° mechanical Output: 0-Exc., voltage threshold: 1 m/s Dead band: max: 8° and typical 4°
4.	Temperature sensor #110S	Type: integrated circuit Accuracy: ±1.1 °C, range: −40 °C to 52.5 °C Output: 0–2.5 V DC Operating temperature range: −40 °C to 52.5 °C
5.	Pyranometer Li-Cor #LI-200SA	Type: global solar radiation Accuracy: 1%, range: 0–3000 W/m^2 Output: voltage DC Operating temperature range: −40 °C to 65 °C

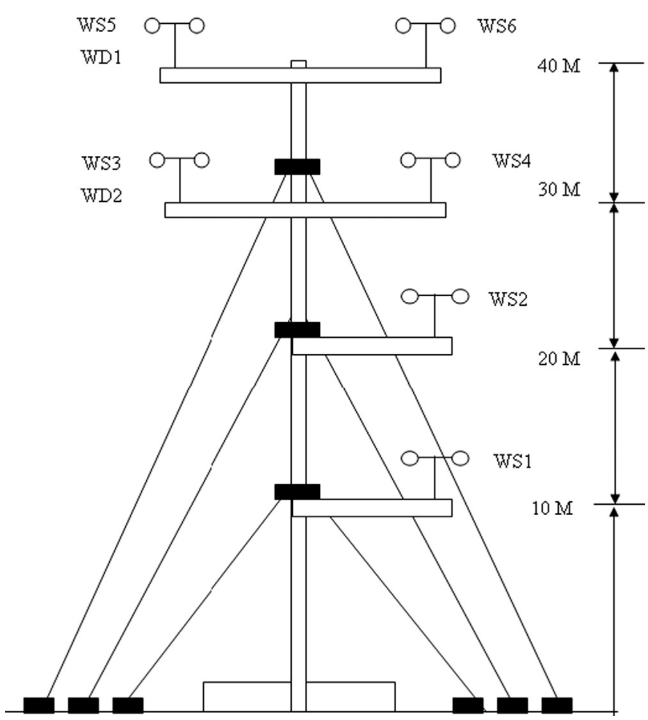

Fig. 1. Schematic diagram of placement of wind speed (WS) and wind direction (WD) sensors on 40 m tall wind mast.

an increase of 18.71%, Ref. [1]. With cumulative installed capacity of 75.324 GW, China remains the leader in wind power industry by the end of 2012. United States of America, Germany, Spain and India remained at 2nd, 3rd, 4th, and 5th place with total wind power installed capacities of 60.007 GW, 31.308 GW, 22.796 GW, and 18.421 GW, respectively by the end of 2012. With respect to new additions, USA remained on the top with 13.124 GW and China remained at the second place with 12.960 GW new wind power installations. However, Germany, India, and Spain remained at 3rd, 4th, and 5th, with new additional capacities of 2.415 GW, 2.336 GW, and 1.122 GW; respectively.

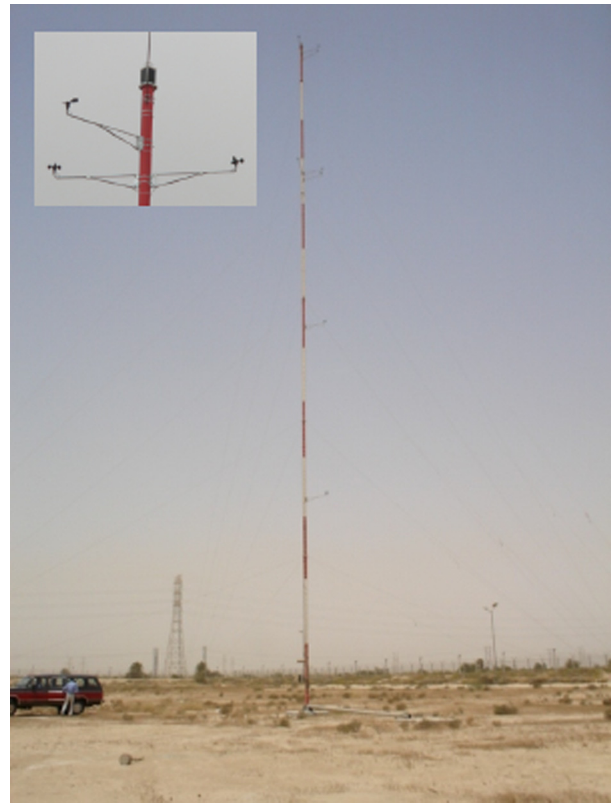

Fig. 2. Erected wind tower at Juaymah site.

Wind power resource assessment is the key for effective and efficient wind power realization. Accurate wind resource assessment fully depends on the accuracy of the wind speed measurements. The wind speed measurements, though seems to be perfect, are affected by various inherent factors such as tower shading, sensor aging, power fluctuation, and dust accumulation effects. Of these, power fluctuation and dust accumulation effects are taken care by continuous monitoring and maintenance of the sensors but aging and shading effects need to be analyzed and taken care while conducting wind resource assessment. The local wind field is changed by a tower supporting an anemometer and also affects the readings of the anemometer. The impact of the tower on wind speed is most pronounced within the tower wake. The top mounted wind anemometers are least suffered from flow distortion caused by the tower and the protruded booms and hence provide the most accurate measurements, Lindelöw et al. [2]. However, in practice it becomes necessary to make measurements at lower heights for detailed wind shear information. This is usually carried out by installing cup anemometers on booms protruding from the tower. According to the IEC standard the influence on the wind speed measurement from the flow distortion induced by the tower must be kept below 1% and the influence from the boom should be below 0.5%, IEC-61400-12-1 [3]. Filippelli and Mackiewicz [4] reported larger than expected measurement deviations of cup anemometers mounted on tubular towers.

Canadillas et al. [5,6] carried out inter comparison between lidar and conventional mast-based instruments, such as cup/sonic and vanes based on 10-min averaged wind speed data and found good agreement between the two data sets with high correlation of more than 0.99 for all heights. Westerhellweg et al. [7] reported the assessment of the direction dependency of turbulence intensity in the German Bight. At the location of Fino1 a variation of turbulence intensity dependent on the wind direction was observed with higher turbulence intensity from north wind directions. The data at