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Suggestions for improving wind turbines power curves

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Abstract

The question is usually not whether a wind turbine can be designed to optimise the power production at the site, but rather whether an existing wind turbines with a certain rotor can be modified in order to improve the power production. In this paper the various methods for improving the wind turbines power output were investigated experimentally and theoretically. The effect of changing the rotational rotor speed on the power performance of Nordtank 300 kW stall-regulated, horizontal axis wind turbine was investigated experimentally. This was performed by changing the setting program for operating the wind turbine. The variation in the aerodynamic performance of the wind turbine rotor due to changing the pitch angle was investigated experimentally in Hurghada wind farm. The manufacture setting tip angle for Nordtank 300 kW wind turbine is (–1.8°). In this study, the angle was changed to two values (–2.8°) and (–0.8°). Also, to improve the blade performance of a wind turbine operating in low wind speed ranges; the vortex generators may be used. These vortex generators were placed over low-pressure surface of blade or tip blade part. In this study, two types of vortex generators, rectangle and triangle shapes were investigated.

Keywords: Wind turbine; Performance upgrading; Pitch regulated; Stall regulated; Vortex generators

1. Introduction

Once a wind turbine is installed and passed its operational checkouts, it is put in regular operating mode. As a piece of machinery, it can then be evaluated on its performance, reliability and maintenance costs and compared with other similar machinery on an economic basis. The performance of the wind turbine is an important measurement because the economy is to a large extent based on the ability of the turbine to produce power. For the power performance analysis, the wind speed is characterized by their velocity distributions over the time. These analyses of wind turbine performance were carried out in the case of steady state of wind flow only. Because, the real conditions of unsteady flow are not well understood, particular difficulty is encountered in characterizing the

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amplitudes and frequencies of the aerodynamic forces whenever the flow is not well defined, such as in stall regime. The main factor which affects the wind turbine sales is its power curve, which defined as a table of data, consisting of connected values of net electric power from the wind turbine and the wind speed [1].

The potential of wind available for power production varies greatly over Egypt. It also varies considerably from region to region and within regions. When a site is selected and a proper sitting accomplished resulting in a Weibull distribution function for the wind speed, the next step, to decide upon is the appropriate wind turbines. Due to the large variations in wind climate, one should ensure that the chosen wind turbine design is the best possible for the particular locations. The traditional procedure is to calculate the mean production from one or more available turbines. This, however, does not ensure that the selected turbine gives optimum production at the site as the turbine may have been designed for another wind regime. The objective of the work is to study the various possible methods to improve the power curve of stall-regulated, horizontal axis wind turbines which are operating in low regimes of wind speed sites. The annual mean wind speed in Hurghada site was greatly lowered recently due to change of site surface roughness. The study was performed in Wind Energy Technology Centre, in Hurghada wind farm, at 12.5 km north of Hurghada city. The site area is about 2.5 km times 1 km with the length parallel to the coastline. The prevailing wind was westerly coming from the north.

2. Wind turbines power curve analysis

2.1. Wind turbine efficiency effect

The overall efficiency of a wind turbine is defined as, the ratio of the actual power output at a given wind speed to the total available power which passes through the swept area of wind turbine rotor. It is evident that, the best utilization of the energy in the wind can be obtained when the turbine efficiency reaches its highest value at a point close to the maximum of the power density function of the wind. Thus, the aerodynamic efficiency curve of the wind turbine should be matched to the wind speed distribution [2]. By assuming the wind turbine with a simple linear power curve as shown in Fig. 1, the efficiency curve becomes

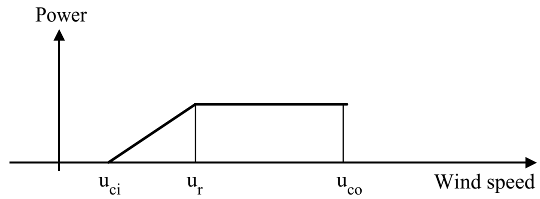

Fig. 1. Simple linear wind turbine power curve.

$$C_P(u) = \frac{P(u)}{E(u)\,A_R} = \frac{S\,(u - u_{ci})}{1/2\,\rho\,u^3\,A_R}, \quad u_{ci} \le u \le u_r \quad (1)$$

and

$$S = \frac{P_{max}}{u_r - u_{ci}} \quad (2)$$

The maximum efficiency for any wind turbine takes place at a certain wind speed, u_m, which can be determined by differentiating Eq. (1), leading to $u_m = 3/2\ u_{ci}$, then, the power output can be written as

$$P(u) = 3/2\ C_P\rho(u_m)\ A_R u^2_m (u - 2/3\ u_m) \quad (3)$$

By using the approximated piecewise linear function with few nodes as shown in Fig. 2. The power of the wind turbine can be written as

$$P(u) = P_i + \left(\frac{P_{i+1} - P_i}{u_{i+1} - u_i}\right)(u - u_i) \quad \text{for } u_i \le u \le u_{i+1} \quad (4)$$

The analytical solution of this equation is

$$P = \sum_i \frac{P_{i+1} - P_i}{\alpha_{i+1} - \alpha_i}\left[G_K(\alpha_{i+1}) - G_K(\alpha_i)\right], \quad (5)$$

where $\alpha_i = u_i/A$.