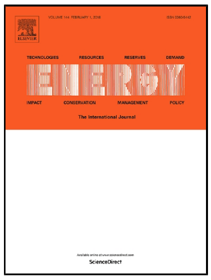

Effect investigation of yaw on wind turbine performance based on SCADA data

Juchuan Dai, Xin Yang, Wei Hu, Li Wen, Yayi Tan

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Effect investigation of yaw on wind turbine performance based on SCADA data

Juchuan Dai[a]*, Xin Yang[a], Wei Hu[a], Li Wen[a], Yayi Tan[b]

[a.] School of Mechanical Engineering, Hunan University of Science and Technology, Xiangtan 411201, China
[b.] XEMC Windpower Co., Ltd., Xiangtan 411000, China

Abstract: Due to the time-varying wind direction, yaw operation of wind turbines is a common state. Under yaw, the aerodynamic behavior of wind turbines is complicated, and also causes complex energy capture performance. To clarify some vague knowledge, a detailed investigation of yaw effect based on SCADA data is carried out. Firstly, a yaw coefficient definition and its specific calculation method are presented. Furthermore, to analyze the energy capture mechanism, the loss factor of energy capture (power coefficient) is subdivided into aerodynamic loss factor and inertia loss factor, which means both the effects of aerodynamic characteristic and mechanical inertia on energy capture are considered. According to this understanding, power coefficient is expanded as a function of four factors. Then, a single-valued processing method is employed to investigate the relationship between wind speed and output power. Subsequently, relationship between yaw coefficient and output power are investigated. Comparative investigations are carried out by two different methods, that is, least square fitting (LSF) method and kernel density estimation (KDE) method. Also, characteristics of power coefficient and rotor torque under yaw are investigated. Effect laws of yaw coefficient on wind turbine power, power coefficient, and rotor torque are obtained. Finally, the relationship between the internal control mechanism and external output of wind turbines is discussed.

Keywords: wind turbines; yaw operation; SCADA data; power coefficient

1. Introduction

Renewable energy has great potential to enhance the diversity of the energy supply market and to ensure long-term security[1]. Especially, wind power is an abundant, renewable and clean energy source has been the world's fastest-growing source of electricity in the world[2, 3]. The total installed capacity of wind power has reached 486GW in 2016 based on world wind energy association (WWEA) data; all wind turbines installed can provide about 5 % of the world's electricity demand. As a development trend of wind turbines, the unit capacity is increasing, for example, Vestas has launched V164-8MW wind turbine in 2014. On the other hand, with available land wind farm dwindling, the future wind farm will have to expand from onshore to offshore[4]. Subsequently, various challenges are more severe in an offshore wind farm. Therefore, how to further improve the efficiency of wind energy capture, and improve the reliability of wind turbines has become the industry focus. All of these ask for further understanding of the operating mechanism and performance evaluation on wind turbines in a complex service environment. However, in the process of energy converting, multi-physical processes are involved, energy capture, conversion, and loss mechanism are complex, and understanding of many phenomena need numerical simulation or experimental analysis such as dynamic stall[5], wake effect[6, 7]. Furthermore, due to the random nature of the wind resource, the rotor aerodynamic effects become even more challenging. The design of systems for converting wind energy into electric energy, energy capture mechanism and efficiency of wind turbines become of prime concern. Support vector machine (SVM) [8], fuzzy logic control (FLC) [9], sliding mode control (SMC) [10] and some other advanced methods such as perturbation-observation-method[11] have been employed to realize maximum power point tracking (MPPT).

For a wind turbine with fixed mechanical structure and control strategy, the effective wind speed and wind direction acting on the wind rotor is the basic effect factor on energy capture and aerodynamic load. Yaw will, therefore, lead

* Corresponding author. Tel +86 0731 58290843
E-mail address: daijuchuan@163.com