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The structure healthy condition monitoring and fault diagnosis methods in wind turbines: A review

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ABSTRACT

Wind turbines have been developed fast in the recent years and at the same time have brought some problems. It is important to maintain the healthy condition of the running turbine because the consequences after faults are miserable for both the company and owner. There is a constant need to reduce the costs of operating and maintaining the turbines. Therefore, it is very important to detect the faults/failures early so as to minimize downtime and maximize productivity. This paper reviewed the structure of wind turbines and analyzed the different components of wind turbines in order to detect the faults that may happen. Meanwhile, this paper mainly reviewed fault diagnosis methods of wind turbines in the last three years. The main purpose of this paper is to supply some information on structure healthy condition monitoring (SHCM) and fault diagnosis in wind turbines for related researchers.

Contents

Abbreviations: SHCM, Structure healthy condition monitoring; VAWT, Vertical axis wind turbine; HAWT, Horizontal axis wind turbine; O&M, Operations and maintenance; VRG, Variable ratio gearbox; AC, Alternating Current; WT, Wavelet transformation; WVD, Wigner- Ville distribution; EMD, Empirical mode decomposition; IMFs, Intrinsic mode functions; SHM, Structural health monitoring; EEMD, Ensemble EMD; CMS, Condition monitoring system; DFIG, Doubly Fed Induction Generator; WTGs, Wind turbine generators; PMSG, Permanent-magnetic synchronous generator; DG, Direct generator; SCADA, Supervisory control and data acquisition; NN, Neural network; ES, Expert system; FD, Fault diagnosis; SVM, Support Vector Machine

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1. Introduction

Wind energy is one of the fastest growing renewable energy resources, and at the same time it is going to have remarkable share in the energy market [1]. According to the collected statistical data, nearly 2.3% of the world's electric power supply is provided by the existing wind farms. Rapid incense in the construction of wind power farms is taking place worldwide; in the highest proposed growth scenario, it is estimated that by 2020, wind power could supply 2.600 TWh, about 11.5–12.3% of global electricity supply, rising to 21.8% by 2030 [2]. At the end of 2011, China's total installed wind power capacity had already reached 62.73 GW, ranking the first in the world for the second time after the year 2010. In 2010, about 4 Chinese wind turbine companies, namely, Sinovel, Goldwind, Dongfang Electric and United Power were in the top 10 largest wind turbine producers in the world [3].

The wind turbine which is widely used around the world can be divided into vertical axis wind turbine (VAWT) and horizontal axis wind turbine (HAWT) based on the structure [4]. But to make wind power competitive with other sources of energy, some of the performances such as availability, reliability, efficiency and the life of turbines have to be improved. As the wind energy sector grows, business economics will demand increasingly careful management of costs. For a 20-year life turbine, the operations and maintenance (O&M) costs of 750 kW turbines might account for about 25% -30% of the overall energy generation cost or 75–90% of the investment costs [5–6].

Furthermore, one of the projections in 2002 reveals that the O&M costs for 2 MW-type turbines might be 12% less than an equivalent project of 750 kW machines. These 2 MW-type turbines together with 2.5 MW and 3 MW turbines have already become the workhorses of the wind power industry. To reduce inspection and maintenance costs has thus become an increasingly important problem as wind turbine size and numbers have continued to rise [7]. The purpose of the paper is to present the structure of the wind turbine and analyze the different components of wind turbines in order to detect the faults that may happen, and then some present comparison methods can be used in diagnosing the faults when facing different faults that happen in different components.

The organization of the paper is as follows: Section 1 presents the main structure of some typical wind turbines. Section 2 introduces the typical structure of a wind turbine. The detail faults in wind turbines components are listed in Section 3. Section 4 analyzed the structure healthy condition monitoring (SHCM) methods according to turbine faults' categories. Section 5 analyzed the advantages and disadvantages in the nowadays fault diagnosis (FD) methods. Some conclusions are given in the last section.

2. The typical structure of wind turbine

Most wind turbine machines are 3-blade units comprising the major components as shown in Fig. 1 [8]. Driven by the wind source, turbine blades and rotor can transmit energy from wind energy into mechanical energy, via the main shaft through the gearbox to the generator. The main shaft supported by bearings and gearbox have the function to optimize the generator speed to be as closed as possible for the generation of electricity. Alignment with the direction of the wind is controlled by a yaw system and the housing (or named "nacelle") is mounted at the top of the tower.

Some drawbacks such as leaking and corrosion can be relatively easy detected by visual inspection. Discoloration of component surfaces may indicate slight temperature variations or deteriorating condition. The sound coming from bearings can also indicate physical conditions. However, most typical failures demand some sophisticated approaches to detect, such as cracking and roughness on the blades' surfaces, electric short circuits in the generator, overheating of the gearbox, bearing faults, faults of wind energy conversion system, and material wear and fatigue in wind turbine system, etc. Therefore in next sections we will discuss these typical wind turbine faults and corresponding condition monitoring methods.

3. Typical faults in wind turbines

3.1. Typical blade faults

For some reasons, wind turbines work directly in the wind, rain, snow and other harsh environments. The diameter of wind turbine blades becomes bigger and bigger in order to capture more wind energy. This makes it easy to lead to some faults directly on the blades, such as the rotor imbalance, blades and hub corrosion, crack, and serious aeroelastic deflections in large wind turbines [9].

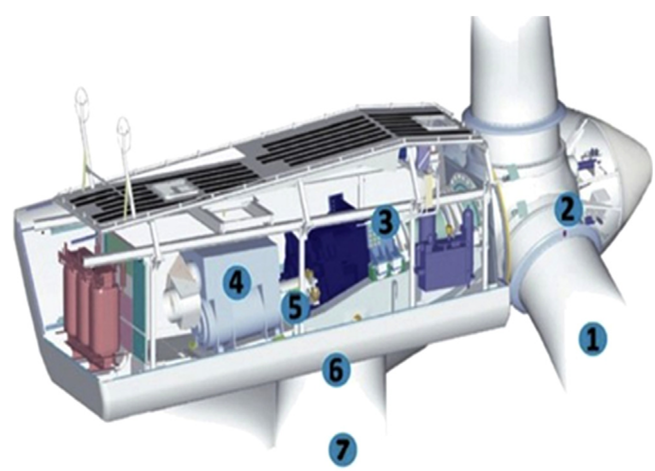

Fig. 1. The main structure of a typical wind turbine. (1) blades, (2) rotor, (3) gearbox, (4) generator, (5) bearings, (6) yaw system and (7) tower.