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Review

Gearbox condition monitoring in wind turbines: A review ☆

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ABSTRACT

Wind turbine technology is experiencing rapid growth with respect to size, market share, and technological design. Operational and maintenance cost directly determine whether the system is efficient in terms of energy production in comparison with other types of power plants. Condition monitoring of wind turbines is the major field of studies in recent years aiming to increase lifetime expectancy of components while reducing operation and maintenance cost. Operators and researchers are focusing on improving fault detection techniques in order to render wind turbines more reliable. Gearbox in wind turbines has the greatest share of downtime among all other components affecting directly the cost of operation and maintenance. This paper gathers a review on different methods and techniques for gearbox condition monitoring in wind turbines. Furthermore, various methods and techniques in the literature will be presented in order to get an insight onto the most used methods in wind turbine gearbox condition monitoring. Challenges and future aims are also discussed to determine the focus of condition monitoring systems.

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1. Introduction

Wind power gained remarkable attention in the past decade since worldwide policies are fighting climate change through the support and investment into renewable energy sources. Recent investments into renewable energy-based power plants increased to a level of 3–1 compared with fossil fuel and nuclear power plants. Compared to a 50 GW mark in 2014 [1], 2015 witnessed the highest annual installation with 63 GW (22% increase) [2]. Statistics shown in Fig. 1 prove that wind power installation is soaring towards leading the path to electrical power production. With such a big role rise important challenges regarding reliability, cost-effectiveness and energy security. In order to tackle the challenges facing wind turbine energy, researchers shifted their attention towards condition monitoring and preventive maintenance in order to reduce operation cost and downtime of wind turbines. Failures of wind turbines during the last decade have gradually decreased while remaining an important issue to tackle considering the aim of cutting down operation and maintenance cost.

Wind turbines withstand randomly changing weather conditions, temperature, wind shear, wind speed, and load. Wind turbines are a combination of several complex systems connected altogether (hub, drive shaft, gearbox, generator, yaw system, electric drive, etc.). With the numerous and various parts in wind turbine systems, failures could occur to any of the components causing either end of operation or damage to other components. Reported failure rates of different system components are shown in Fig. 2a [4]. All components are prone to failure. Nonetheless, the focus of manufacturers is shifted towards which of the components will cause the longest downtime for maintenance and impose the highest repair costs. Fig. 2b shows the downtime caused by every component failure occurrence. Gearboxes come second in the downtime per failure due to their size and robust link to other components making it harder to access, repair, or even replace [5].

Gearboxes operate under harsh environmental conditions. They are responsible of stepping up the speed transmitted by the low speed shaft (LSS), towards meeting the requirement of that of the high speed shaft (HSS) that drives the generator. Thus, they endure all the vibrations caused by the turbine-side components and wind, along with all fluctuations imposed by the load through the generator. Faults in gearboxes may occur to several components among which: tooth crack, internal shaft, HSS bearing, LSS bearing, ring gear, helical gear, poor lubrication, housing, etc.

This paper will go through, and discuss different approaches, techniques, and methods for gearbox condition monitoring in wind turbines and will be structured as follows: Section 2 goes through the condition monitoring basics, process, and approaches. Section 3 mentions different lubrication analysis techniques for wind turbine gearbox fault detection. Followed by acoustic emission analysis in Section 4. Section 5 discusses different vibration analysis techniques applied to wind turbine gearbox fault detection. While Section 6 goes through several machine current–based techniques for fault detection. Section 7 discusses the application of SCADA for gearbox fault detection. Section 8 will interpret and conclude on the material mentioned throughout the article.

2. Condition monitoring process and approaches

Reliability remains the major manufacturers' concern and it is achieved by consistently dealing with faults through strategies and techniques capable of preventing or at least minimizing the effect of these faults. Faults are usually

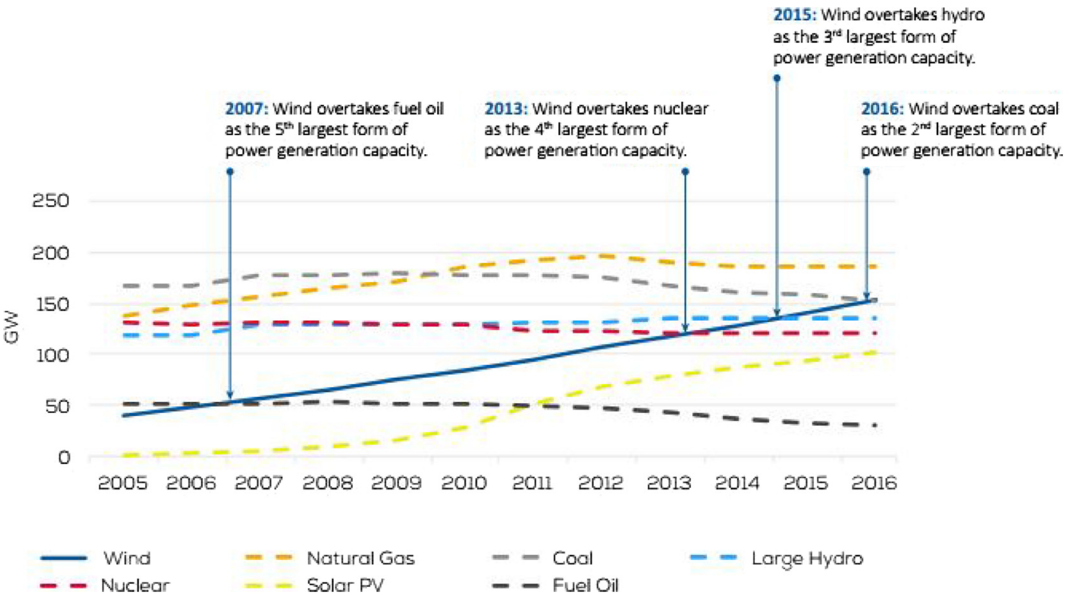

Fig. 1. Evolution of the cumulative power capacity in the European Union of different power sources [3].