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Assessment and validation of oil sensor systems for on-line oil condition monitoring of wind turbine gearboxes

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Abstract

The gearbox oil and the wind turbine gearbox condition are correlated. The oil can give the wind turbine operator the necessary information to plan maintenance and avoid costly repairs. Therefore, a test bench that can reproduce the gearbox operating conditions would be necessary to test oil-sensors. This paper presents a first testing approach using a Highly Accelerated Life Test / Highly Accelerated Stress Screening test chamber. It allows assessing the performance of oil properties sensors under extreme ambient temperature and vibration levels, based on measurements from a wind turbine gearbox. Results from a test on an oil properties sensor are presented and discussed.

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1. Introduction

In order to avoid any severe damage, maintenance activities are a key factor to reduce the cost of wind energy. Operation and Maintenance (O&M) costs vary from 18% - 23% for European offshore wind farms and 12 - 30% for onshore projects [1] [2] [3]. As stated by Richardson, availability of offshore wind turbines needs to be in the order of 98% to achieve an acceptable cost of energy [4]. However, availability of offshore wind farms is very variable, usually between 70-90% [5]. In order to increase wind turbines availability, it is necessary to increase the reliability of every wind turbine component. In the study published in [6], an analysis of downtime per failure and failure rate was performed based on the results of the “Scientific Measurement and Evaluation Programme (WMEP)”. This study was based on 15400 turbine years where the gearbox was identified as one of the components with the highest downtime per failure, but with one of the lowest failure rates. Moreover, the study carried out in [7] compares existing surveys in wind turbine component failure rates and downtime. The Windstats report shows that the gearbox has the largest downtime per failure, and Reliawind shows that the gearbox is the drive train subcomponent with the highest contribution to overall downtime. For this reason, it is critical to avoid any major failure, especially for offshore wind farms.

Currently, online condition monitoring systems (CMS) give information about the condition of the drive train in order to detect developing failures at an early stage and facilitate condition based maintenance. However, the present, usually vibration-based CMS have a limited fault-detection certainty. During the last years it has been found that gearbox oil can provide valuable

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additional information about wear-related damage in the gearbox and also oil quality by including particle sensors in their CMS [8] [9] [10].

Several sensor types can be used for online Oil Condition Monitoring (OCM). According to a market research, oil sensors commercially available in the industry can measure humidity, viscosity, ferromagnetic, non-ferromagnetic particles and some special sensors can measure the air content in the oil. However, the use of oil sensors is relatively new for the wind energy industry. Moreover, it is not completely clear which parameters should be measured or which thresholds should be set to allow effective monitoring of the gearbox condition. Currently, the sensors are installed in wind turbines to be validated. This procedure involves high costs and in some cases the results shown by the sensors cannot be easily explained, and further analysis of the data is required. Some studies have been conducted to test oil sensors for functionality purposes [11] [12] and some other for prognosis proposes [13] [14]. However, these tests do not include functionality tests under external effects. In this paper, external effects denote the disturbances that could affect the sensor measurements and that are not related to permanent changes in the oil properties e.g. ambient temperature or vibrations.

This paper presents an approach to validate oil sensors for wind turbine gearboxes based on vibration and ambient temperature tests in a Highly Accelerated Life Test/ Highly Accelerated Stress Screen (HALT/HASS) chamber. Section 2 describes the most common sensors available in the market. Section 3 includes a description of a test method by means of a HALT/HASS chamber. Section 4 shows the results obtained from tests carried out on an oil properties sensor. A discussion about the results and how a new test facility will complement the test method in section 3 is presented. Finally conclusions are drawn from the presented results and an outlook to future work is given.

2. Sensors available for oil condition monitoring

The market offers a large range of products for OCM. The sensors installed in wind turbines include mainly measurement of pressure, temperature and particles. In [15] a detailed overview of the OCM sensor technology for several applications is presented. This study highlights the importance of capacity and viscosity sensors and how dielectric constant sensors could contribute to monitor oil degradation. Based on a market research carried out during this project, more than 20 sensor manufacturers are involved with OCM, offering among others, sensors measuring water content, particles concentration, amount of particles, dielectric constant, viscosity, oil quality. Particle sensors are already installed by some wind turbine manufacturers. Table 1 introduces the most common sensors commercially available in the market:

Table 1. Overview - sensors in the market.

Type of sensor	Output signal
Water-content sensors	Water saturation (%)
Particles-concentration sensors	Particles size distribution according to ISO 4406
Particle-counter sensors	Quantity of particles per unit of time and size
Dielectric constant sensors	Dielectric constant
Viscosity sensors	Kinematic viscosity
Oil-quality sensors	color signal, quality index
Oil-properties sensors	viscosity, temperature, density, dielectric constant

2.1. Water-content sensors

These sensors measure the relative humidity or the saturation level of the oil. Water has several negative effects on the oil. Water catalyzes oxidation affecting the lubrication capacity of the oil and accelerates corrosion of ferrous materials. In addition, water causes additives to precipitate and fosters the growth of microorganisms [16]. A water sensing technology that is widely applied in the industry is capacitance measurement. Capacitance sensors are basically capacitors with polymer dielectric and platinum nickel or gold metallic electrodes. They are suitable for a wide range of applications. The capacitance responds to changes in the relative humidity which can be correlated to the saturation level in the oil [17]. The saturation depends on the type of base stock and additive package. Due to the fact that the operating conditions such as pressure and temperature also have an influence on this value, the saturation level cannot be directly correlated to the water content in parts per million. In this case the saturation curve of the oil is necessary. The significance of water sensors lies in their capability to give information about the saturation level and about the changes in the absolute water content.

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