

Hybrid wind turbine diagnostic system - a brief overview

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Abstract. The paper presents a short review of systems for diagnostics and forecasting the condition of wind turbines. Systems based on the analysis of data such as vibrations were indicated. Then, the SCADA system as a diagnostic tool was discussed. The article indicates the need to create a hybrid system based on SCADA that can predict the condition of wind turbine blades.

1 Introduction

Increasing the share of energy from renewable sources and cogeneration in the electricity market may affect indicators characterizing the operation of the power system, including reliability indicators.

The availability of thermal power plants, both coal and nuclear, is high, usually 90%. Due to their stable operation, these power plants can be basic power plants in the power system. Unfortunately, renewable energy sources do not offer such stability. The operation of these sources can be stabilized based on favorable locations. In the case of wind farms, indicators for individual plants may vary significantly, greater availability is expected in off-shore locations.

The average annual duration of use of the installed capacity of wind farms varies for different locations and different countries. The values for land-based power plants range from 1,700 to 3,000 h/year.

In Poland, there is currently a tendency to diversify the energy mix. Wind farms are increasing their share in the generation capacity. Compared to photovoltaic farms, they also enable electricity production at night. In the absence of appropriate energy storage or pumped-storage power plants, the use of photovoltaics is currently a heavy burden on the power grid.

The main factor determining the volume of energy production in wind farms is the availability of wind as an energy carrier. Due to its unpredictability, the power generated by wind turbines is stochastic. Many researchers are working on developing appropriate mathematical models to predict energy production and to manage power in the energy system.

However, an important risk factor that can be reduced is the readiness of the turbine for operation. For the purposes of reliability analyses, it is important to create a wind farm model that will allow for simulation of electricity production [1].

Wind turbines operate in difficult environmental conditions, which may cause faults and inefficiencies. This especially applies to offshore wind turbines. Their maintenance is very expensive. According to McMillan and Ault [2], the operating costs of offshore wind turbines are twice as high as those on land and amount to 20% -35% of the total operating costs of

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wind conversion systems. For this reason, it is important to improve the reliability of wind turbines, their availability and productivity. The most important solution used for this purpose is condition monitoring and fault diagnosis. This allows you to identify where failures are occurring and assess their severity so that appropriate action can be taken. This approach avoids further damage that may lead to dangerous situations during the operation of wind turbines.

In the work of Tchakoua et al. [3] discussed existing techniques for monitoring wind turbines and indicated emerging trends. However, Liu et al. [4] discussed the most common faults in turbines. The main types of failures of offshore wind turbines were dealt with by Lau et al. [5]. The works [6, 7] dealt with fault tolerant control and prognosis and resilient control for wind turbine systems. Abid et al. described an overview of issues related to fault prognosis and predictive maintenance in their work [8].

A wind turbine is a complex machine that consists of mechanical, hydraulic and electrical parts. The flow of wind through the rotor blades forces them to work and rotate the rotor on which they are mounted. Depending on the design, further energy conversion may also involve an accelerating gearbox. The mechanical energy from the shaft is converted into electric current in the generator. The hydraulic assemblies of a wind turbine are responsible for positioning the nacelle and rotor blades to change wind speed. Monitoring the condition of a wind turbine allows you to check its operating parameters in order to identify faults early. Diagnostics is performed to detect, locate and identify existing faults. This allows you to plan a system repair strategy to prevent total failures.

2 Examples of diagnostic systems

To maintain a high level of availability, it is necessary to properly plan inspections and renovations, thanks to which the owner can replace the wearing part early enough. A spectacular example is the replacement of a bearing, which will prevent damage and subsequent replacement of the gearbox or generator. In addition to the direct costs of parts, it is necessary to rent a crane, which is also a high cost, especially for turbines installed on the shelf.

In the case of wind turbines, gears and bearings are most often damaged. These are defects that develop gradually and it is possible to monitor the development of the damage. There is extensive literature describing damage to this type of machines, as well as methods of their detection [9].

Many methods have been proposed for monitoring the condition of wind turbines [10], [11]. Commercial condition monitoring systems (CMS) mainly use high-resolution vibration signals to monitor the technical condition, fault diagnosis and forecasting of wind turbines. However, these CMS systems require the installation of additional vibration sensors and advanced signal processing techniques to extract useful information (such as fault-related features) from the CMS data.

Particularly useful methods used to determine the technical condition are order tracking and enveloping.

The use of these methods is necessary due to the low-speed nature of the movement and significant speed variability.

To achieve such parameters, it is necessary to use long sampling times of vibration signals. Since the turbine operates at a variable speed during this time, the spectrum lines generated by the supervised element would be blurred if the row analysis method was not used.

As a result, there has been and is rapidly increasing demand for wind turbine monitoring and diagnostic systems. Wind turbine monitoring and diagnostic systems should provide:

- database recording the history of turbine operation,
- data browser module optimized for remote access,

- a set of advanced tools for early detection of rolling bearing damage,
- a set of advanced spectral analysis tools adapted to variable speed machines,
- creating configuration reports,
- module for automatic setting of alarm thresholds,
- automatic determination and configuration of frequency components,
- notification of detected exceedances.

During operation, the condition of the machine is determined. It is possible to define several such states. Typical states are: standstill, low power, high power. Different alarm thresholds can be defined for each state.

Oil and wear residue analysis has also been proposed to monitor the lubrication status of wind turbines, because wind turbines have many lubricated components or subsystems, such as main bearing, gearbox, generator bearing, pitch and yaw systems, and the lubricant has a serious impact on them service life conditions [12]. However, you need to disassemble components or enter wind turbines to collect grease samples for analysis. Although the benefits of oil and wear analysis techniques have been widely recognized in the wind industry, these techniques are offline and invasive for the wind turbines being monitored [12]. These limit their use in online monitoring of the condition of wind turbines.

This SCADA data contains rich information about the condition of wind turbines and can therefore be used for condition monitoring. This does not require the installation of any additional sensors, as is the case with vibration, oil and wear residue monitoring techniques [13].

3 Hybrid system – blade condition testing based on information from the SCADA system

The wind turbine is equipped with a number of sensors, the data from which is archived in the SCADA system. Generally speaking, SCADA generates data whose typical form is time mean, minimum, maximum, and standard deviation: the averaging time scale is typically 10 minutes, and the control system sampling rate is typically on the order of one or a few seconds. SCADA systems record atmospheric conditions in the nacelle (wind intensity and direction), wind turbine response (yaw position, pitch angle, etc.), main information on the conversion of wind kinetic energy into a usable form (active and reactive power, etc.), possibly temperatures and pressure at appropriate points in the wind turbine. In his work [14] described how it is possible to describe the condition of turbines based on the comparison of the power curve and the anemometer readings from the nacelle. A comparison of two turbines is presented in Figure 1.

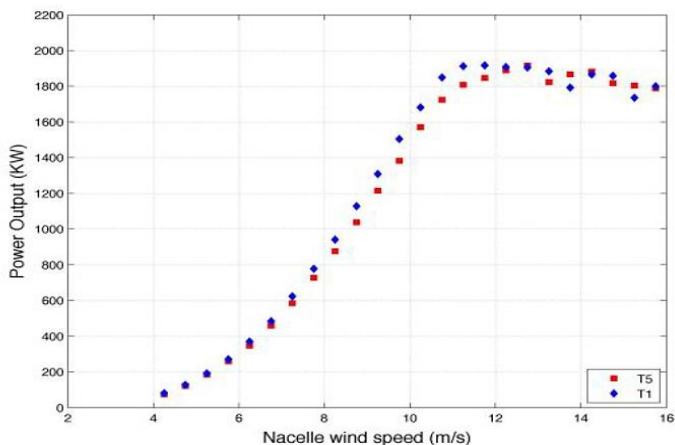


Fig. 1. Power curves of turbines T5 and T1. D1 data set, 0.5 m/s nacelle wind speed interval [14].

Using the method they developed, they described and identified a turbine that differed negatively from the others. Therefore, they hypothesized that it was incorrectly positioned in relation to the wind.

4 Conclusions

Currently used methods of forecasting or assessing the technical condition allow obtaining information about the current and future condition of wind turbines. However, each of them has its limitations. Condition forecasting allows planning to disconnect the turbine from operation if such a need arises. Then the inspection can be carried out. However, little information can be obtained about the immediate condition of the laminates that make up the rotor blade. Therefore, an appropriate tool should be developed based on data obtained from the SCADA system to predict the time of inspections using UAV drones equipped with cameras to analyze the surface condition. Such a tool should be based on data that is continuously obtained from the SCADA system in such a way as not to increase diagnostic costs. An appropriate analysis system will be developed by the research team as part of further work on the problem.

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