# Deployment and Improved Reliability of the Condition Monitoring System for Wind Turbines


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**NTN** is providing information services using condition monitoring system for wind turbines. This article introduces market trends of the CMS and gives some future prospects of the CMS service for wind turbines.

## 1. Introduction

Unparalleled natural disasters and abnormal weather are frequently occurring all over the world. Urgent action is needed to reduce $CO_2$ emissions and other greenhouse gases, that are an underlying cause of these phenomena, and to achieve a low-carbon society. Therefore, renewable energy is garnering a great deal of attention; as solar and wind power generation is increasing worldwide.

Wind power in Japan has been trailing behind Europe and the U.S., but is currently expanding due to national policies such as a Feed-in-Tariff (FIT) system. Due to Japan's location, it faces a harsher climatic environment than Europe, caused by factors such as sudden squalls, turbulence, typhoons, and winter lightning, making problems with wind turbines not unusual. Accelerated steps are being taken to help achieve stable operation, by accurately assessing the equipment's condition, and conducting appropriate and efficient maintenance to reduce downtime, which includes emergency shutdowns.

## 2. NTN's vision

In wind power sector, **NTN** supplies special-purpose bearings, these bearings play a vital role in ensuring wind turbines achieve higher performance and a larger size. We also help improve the efficiency of wind turbine maintenance by offering a wind turbine Condition Monitoring System (CMS) and CMS services employing that system.

CMS services is aimed at monitoring and diagnosing the condition of wind turbines based on data such as vibration and rotational speed, gathered from the wind turbines. In addition to the high-quality manufacturing ("*monodzukuri*") that **NTN** has cultivated over many years, we are focusing efforts as part of our "service and solution business" strategy of providing intangible products such as information and proposals beneficial to our users.

**NTN**'s CMS has a track record of adoption in over 200 wind turbines, with the number of installations increasing year after year. We are highly regarded by power producers as a top supplier in Japan, in part due to our CMS services.

## 3. CMS for wind turbines

### 3.1 History of CMS for wind turbines

Full-fledged adoption of CMS for wind turbines began in Europe around 2000 with the goal of detecting drivetrain problems, caused by sporadic malfunctions. With the dissemination of on-shore wind throughout Europe and the growth of off-shore wind primarily in Northern Europe, the CMS is increasingly being used as a standard tool for condition based maintenance (CBM).

On the other hand, Japan's domestic wind industry has focused on conventional time based maintenance (TBM). Until recently, maintenance procedures such as replacing parts, diagnosing equipment, checking for abnormal noise, and analyzing grease and lubricating oil, have only been carried out periodically. However, there were also cases of overtreatment or over-servicing, where parts that had not reached their service life were repaired to prevent malfunction, and cases where entire units were replaced due to risk management concerns. Additionally, when identifying problem points, we often relied on the heuristics of skilled maintenance workers. Although the dissemination and growth of the CMS in Europe was well known in Japan, one factor which delayed adoption in Japan were the features of the CMS — i.e., data analysis capability, accuracy of information, and cost effectiveness — which had not been fully verified.

Recently, the importance of CMS adoption and data analysis have been increasingly recognized for wind turbines in Japan, due to the increase in active use of IoT and big data in various fields.

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### 3.2 Needs of wind power producers

Wind power producers aim to increase their availability factor, and lower running costs by reducing downtime from inspections, repair, and emergency shutdown. With that goal in mind, power producers use the following criteria for maintenance.

1) Beginning in early autumn and continuing into early spring, when wind conditions are stable, the top priority is power generation, and unplanned maintenance is avoided.
2) Large-scale maintenance is concentrated in the summer.
3) To minimize shutdown time, investigating failures and resolving problems such as abnormal noise or vibration, analysis and repairs must be done quickly and efficiently.
4) Faulty parts and equipment must be accurately identified and necessary parts obtained in a planned manner.

### 3.3 Advantages of CMS for wind turbines

Wind turbines are built based on meticulous surveys of wind conditions, stringent environmental assessments, and consent from the local area. Construction sites are often difficult to access, as they typically include remote areas, such as mountaintops, or offshore locations far from population. Additionally, the nacelle, which houses the wind turbine drivetrain, is located 60–80 m above ground, preventing servicemen from climbing the tower in cases where strong winds or lightning is present. Furthermore, when identifying issues, it is best to directly check for vibration or abnormal noise during operation. However, due to safety, work cannot be performed during the power generation operation. Therefore, the usual approach is to carry out inspection while in an operation shutdown condition or during low-speed rotation, where there is a risk of missing signs of malfunction.

In response to the concerns above, adoption of the CMS enables remote monitoring of the drivetrain of wind turbines even during the power generation operation. The CMS also enables identification of problem points and early detection of malfunction by identifying slight changes in conditions from data. These condition changes are difficult to pick up, despite the skilled maintenance workers. The CMS has made it possible to determine whether maintenance is needed, and gauge the urgency, so that replacement parts can be obtained and replaced at periodic inspection or other planned shutdowns. This efficiency helps reduce shutdown periods and lost profits.

### 3.4 Configuration of Wind Doctor™ system

In 2012, **NTN** marketed Wind Doctor™, a CMS for wind turbines. Since then, we have offered monitoring results and condition information, derived from the gathered data, to power producers, wind turbine manufacturers, and showcased the effectiveness of the CMS through discussion of wind turbine events.

The system configuration is shown in **Fig. 1**. Data gathered from wind turbines is recorded and stored in a cloud server. Through various types of signal processing and analysis inside the server, the system detects problems with the components of the drive train, and automatically notifies a preset point of contact (automatic first decision).

If signs of damage or changes are identified from additional diagnosis by our engineers, that information is communicated through a report with recommendations to the service subscriber.

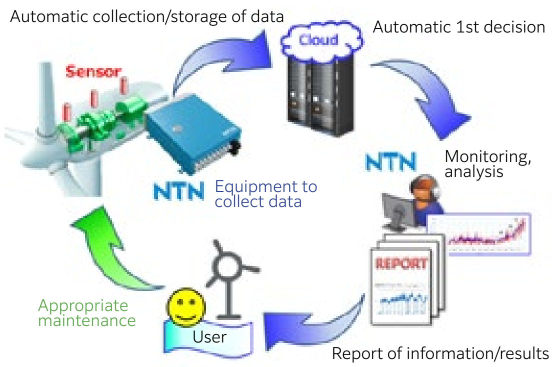


**Fig. 1** System configuration of Wind Doctor™

When monitoring changes or trends in mechanical equipment, it is best to conduct measurements while the equipment is running at constant speed. However, wind turbines interact with nature, wind speed and direction is constantly changing, leading to an unavoidable decline in monitoring accuracy. In order to minimize the effects of the operating conditions, the Wind Doctor™ records those conditions together with sensor signals. We then focus on similar conditions within the data set, extract applicable data, and use that for diagnosis.

### 3.5 The uniqueness of Wind Doctor™

In addition to providing standard CMS functions, we strive to differentiate Wind Doctor™ from other products. Examples of this are described in 3.5.1 to 3.5.3.

#### 3.5.1 Event recording function

Normally, the CMS performs measurements with a fixed sampling cycle. When monitoring trends of a wind turbine with no problems, sampling a few times a day is sufficient. On the other hand, it is best to shorten the measurement intervals in order to evaluate changes and record sudden events caused by worsening conditions on wind turbines experiencing issues. Setting the interval to zero and acquiring data continuously is ideal; however, this increases the operating load on the CMS unit, and causes an enormous increase in the amount of recording done by the server, increasing difficulty.

Thus, the Wind Doctor™ is equipped with an additional event recorder function. If an external signal trigger or a preset internal threshold is exceeded, then the function automatically records measurement data for a certain time before and after, taking that moment as a starting point. This enables data to be captured when a sudden disturbance or malfunction occurred during the interval, and use of the data in analysis. A specific application example is described in section 4.

### 3.5.2 CMS dedicated communication unit

There are two methods of sending the CMS data: using the wind turbine LAN, or installing an additional CMS dedicated line with a separate channel.
The former can use the existing communication environment of the wind turbine; however, a robust network security must be provided to prevent unauthorized access and viruses. In contrast, when a CMS dedicated line is installed, it is completely isolated from the wind turbine LAN. In the event of unauthorized access to the wind turbine or the CMS, the effects will not spill over to the other side. The CMS dedicated communication unit in **Fig. 2** is a data communication tool employing a mobile phone line and router, and self-checking functions are better than the commercial communication modules called IoT gateways. More specifically, the unit is equipped with a function for automatic recovery if malfunctions occur such as a communication error or communication freeze due to a drop in electromagnetic wave strength.

The unit is also linked with a data acquisition module, and setting can be done to force a reboot of the data acquisition module when issues arise in the measurement operation.

**Fig. 2** Communication Unit

### 3.5.3 Improved analysis accuracy

A wind turbine is composed of multiple drive units and parts, and operates under conditions exposed to the natural environment. Various types of noise inevitably occur inside the nacelle, and superposition of this noise on the sensor signal is unavoidable. Specifically, there is a mixture of noise from various directions around the main shaft, which is fastened solidly to the nacelle frame. Examples include transmitted vibration from the hub, operation vibration from the motor for yaw drive, squeaking due to wind gusts and stress, operation vibration of hydraulic pumps, and so forth. Additionally, the rotational speed of the main shaft is low, at about 15 min$^{-1}$; therefore, the issue of vibrational energy due to damage is small, and the S/N ratio is extremely low. To improve analysis accuracy with Wind Doctor™, we've incorporated the technique of identifying disturbance noise using the spectrogram shown in **Fig. 3**.

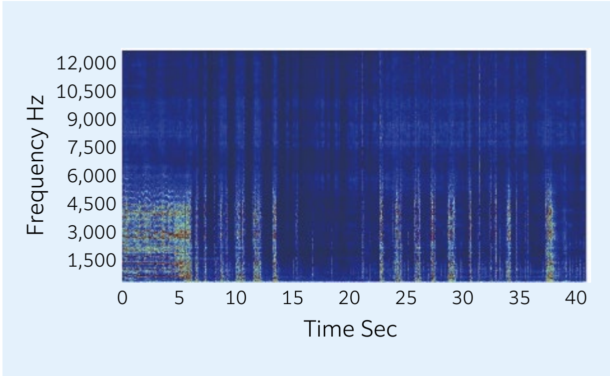


**Fig. 3** Spectrogram

To conduct high-accuracy vibration analysis of the rotor, ideally data is measured while rotating at a constant speed, but as mentioned above, a wind turbine interacts with natural unpredictable wind, and thus fluctuations in rotational speed inevitably arise, as indicated in **Fig. 4**. Analysis accuracy declines due to these fluctuations, and in some cases it becomes challenging to detect abnormalities.

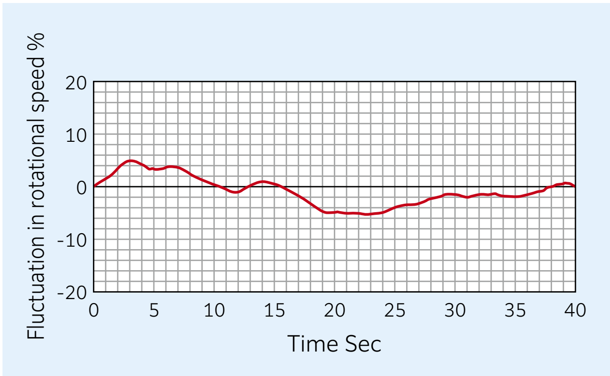


**Fig. 4** Rotation fluctuation

As a countermeasure, Wind Doctor™ has a function to correct fluctuations in rotational speed. **Fig. 5** shows the raw frequency spectrum before correction, and **Fig. 6** shows the frequency spectrum after correction. The corrected graph clarifies the frequency peaks and shows the effectiveness of the correction.

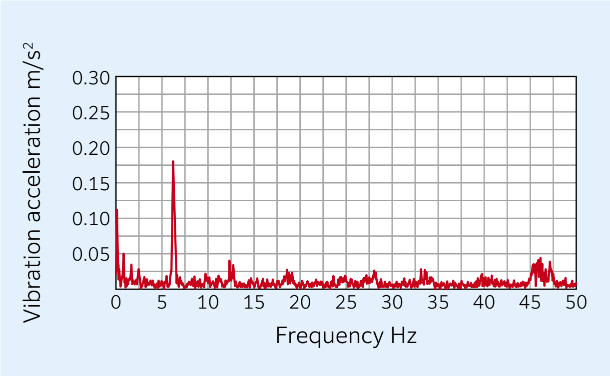


**Fig. 5** Raw frequency spectrum

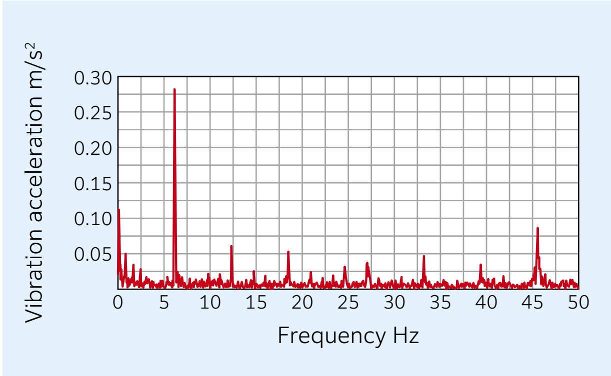


**Fig. 6** Corrected frequency spectrum

## 4. Event recording function applications

This section describes applications of the event recording function in 3.5.1.

Presently, the New Energy and Industrial Technology Development Organization (NEDO) is engaged in a research and development project on technology for more sophisticated management of wind turbines. The goal of this project is to raise the availability factor of wind turbines to 97 % or higher, with the support of the University of Tokyo, National Institute of Advanced Science and Technology (AIST), and Chubu University to establish the necessary technology.

Chubu University is working to achieve more sophisticated wind turbine management by organically linking lightning detection technology with wind turbine issues, and developing an understanding of lightning strike characteristics. They are specifically using a lightning detection system exemplified by the Rogowskii coil in **Fig. 7** to analyze the effects of lightning strikes. This involves comprehensive comparative examination of: ① Lightning strike data such as current wave crest values and electric charge, ② Lightning damage data such as malfunction points and conditions, and ③ SCADA and CMS data.

Winter lightning, a peculiar phenomenon in Japan, has become the catalyst for these efforts. The coasts of Hokuriku and Tohoku regions of Japan are suitable sites for wind turbines due to their favorable wind conditions. However, extremely high energy lightning, strikes the wind turbines frequently during the winter in these regions. These frequent strikes lead to constant accidents, where the blades of wind turbines become damaged. To prevent secondary damage in the surrounding area from fragmented pieces falling from lightning strikes, it becomes necessary to shut down operations, and promptly carry out an inspection, either visual or using other techniques, before resuming operations. Decline in the availability factor due to lightning issues and the associated response is 4-5 %. Therefore, there is a demand for operation improvements that help raise the availability factor, such as enabling remote decision-making to determine whether to operate or shutdown based on data analysis.

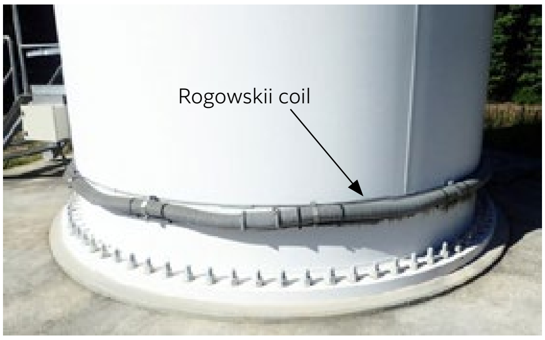


**Fig. 7** Rogowskii coil

**NTN** is not a direct participant in this NEDO project, but we are assisting by using the event recording function of Wind Doctor™ to acquire and accumulate data during normal conditions and lightning strikes, and making that information available to the project.

The configuration of the system is shown in **Fig. 8**. A lightning detection system at the base of the tower detects the high current that flows during a lightning strike, and sends out a lightning strike signal. This is transmitted to a signal repeater in the nacelle, via optical fibers installed inside the tower, and input as a trigger signal to the data acquisition module. The event recorder function inside the Wind Doctor™ activates, and records vibration data for a specified time before and after the lightning strike.

We have installed this system in multiple wind turbines in the Hokuriku region, and are continuing to gather data.

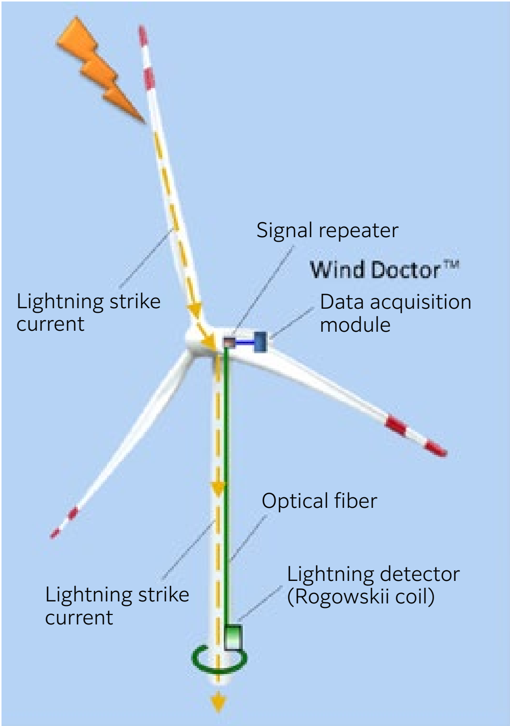


**Fig. 8** CMS with Lightning detection system

## 5. Issues for the future

As previously noted, it is difficult to detect problems due to the low signal level at parts which rotate at low speed such as the main shaft and gearbox input. Maintenance costs are high for these components, and there is a pressing need to accurately assess their status. Therefore, as a provider of the CMS services, we need to establish highly accurate problem detection technology. Another important issue is detecting indications of parts missing or falling out, which may lead to sudden accidents. Users have high expectations from more sophisticated CMS.

Additionally, further evolution of the entire system is needed, including improvements to the malfunction detection performance, implementing machine learning and other types of AI, suited for cutting-edge technical innovation, and linking with prediction of damage magnitude and progression.

## 6. Conclusion

This article has covered market trends, efforts by **NTN**, and future prospects relating to CMS for wind turbines.

Broader use of renewable energy is the key to protecting the environment and achieving a low-carbon society. Therefore, we need to discover equipment issues, detect malfunctions early, and carry out proper maintenance. We are convinced that the CMS and its associated services will play an increasingly important role in this sector.

Going forward, we will continue advancing by integrating tangible and intangible assets through IoT, and contribute to society through a variety of services.

## References


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