Considerations on wind power utilization in cold regions

A note on wind turbine operations in cold climates

Masafumi Yamazaki... Satoshi Kanayama ・*・ Kenichi Iwai ・**・ Masao Hosomi ・**・ Shigeo Kimura **
MasafUmi YAMAZAKI, Tomo KANAYAMA, Ken'ichi IWAI, Masanao HOSOMI, Shigeo KIMURA

1. Introduction

In recent years, the construction of wind power plants has increased in cold regions such as mountainous areas, as well as in high latitudes such as Northern Europe 1) In wind power generation in such cold regions, the decrease in power generation caused by ice accretion, partial failure of windmills, and the increase in the danger of ice throws[2)] In this paper, we summarize the basic knowledge of the effect of ice accretion on windmills and the countermeasures, and discuss the findings obtained from the data of wind power plants actually operating in cold regions.

2. Effect of ice accretion on windmills

In cold regions, ice accretion occurs on the surface of structures when supercooled water droplets, which exist as clouds and fog, collide with structures[3)] In windmills, ice accretion occurs on meteorological instruments such as anemometers on blades and nacelles under conditions where supercooled water droplets exist in the surrounding environment and the wind is blowing at the speed required to resolve the supercooling of water droplets (ice accretion environment).

2-1.Reduced power generation efficiency

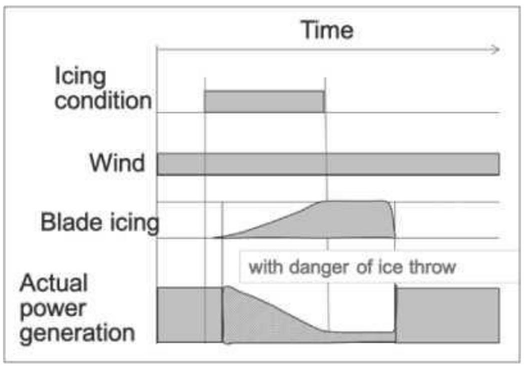

Figure **1.** Blade icing conditions and power generation losses

When ice accretion occurs on a wind turbine blade, the aerodynamic characteristics deteriorate, so the same air temperature and wind speed compared to when no ice accretion occurs. Lecture at the 41 th Wind Energy Use Symposium on December 5, 2019

* * Member Faculty of Engineering, Kanagawa Institute of Technology
Shimo-Ogino, Atsugi, Kanagawa 243- 0292! 030

**・ Non-members Kanagawa Institute of Technology, Faculty of Engineering

***・ Non-member Komai Hartech Co., Ltd.
4-2-21 Tachiuribori, Nishi-ku, Osaka-shi, Osaka 550 0012

As shown in Fig. **1**, when power generation continues in an icing condition, the blade icing on the blades gradually grows. The degree of decline in actual power generation increases with the growth of this ice. Unless special deicing measures are taken even after the icing condition is resolved, ice will continue to exist on the blades until it is completely removed by melting due to temperature rise or solar radiation, or by sublimation of the ice itself, and power generation will continue to decline accordingly.

2-2. Ice Throw

When the ice generated on the blades by power generation in an icing environment grows large, it may break off and scatter around the blades as they rotate. This phenomenon is called "Ice Throw," and there is a risk of damage to structures surrounding the windmill, and damage to windmill workers and passers-by.

2-3.Mismeasurement of weather observation equipment

In an ice accretion environment, it has been reported that ice accretion also occurs in weather observation equipment on a nacelle, resulting in incorrect measurement values being recorded. For example, if ice accretion occurs in the force-up area, a value slower than the actual wind speed is recorded. Also, if the heating area does not cover the entire windcup, ice accretion may occur in the unheated area, even if the equipment is equipped with a heating function.

3. Investigation of power generation reduction due to ice accretion

The change in power generation due to ice accretion was investigated using data from a wind power plant in Russia using the "T19 IceLoss Method"[4)] (TILM), which is provided free of charge by VTT through IEA Task19. When SCADA data is given as input to this software, a power curve is calculated from the data when the outside air temperature is 3 degrees Celsius or higher, and based on this, the period of ice accretion and the power generation loss at that time are calculated by comparing the power generation when the outside air temperature is below freezing. 2 months of SCADA data were used from May to June 2019.

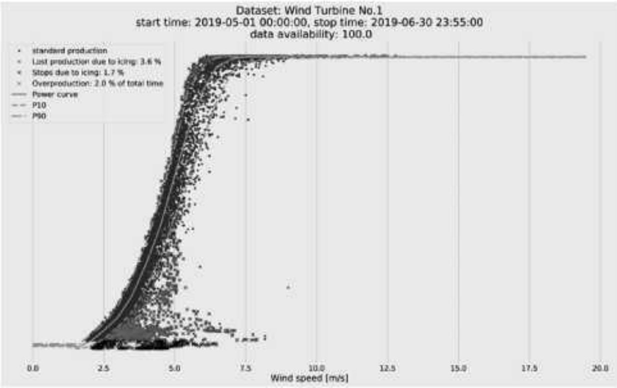

Figure **2.** Analysis results by **TILM**

In TILM, if the amount of power generated when the outside air temperature is below freezing exceeds the power curve that increased the wind speed by 10%, it is judged as overpower, and if the amount of power generated falls below the power curve that decreased the wind speed by 10%, it is judged as a loss of power generation. These criteria are indicated by two dashed lines in Figure 2. The points in the plot are green for overpower generation, red for loss of power generation, and black for stoppage of operation due to ice accretion. A period of 66 hours of ice accretion was observed in the records for the two months under consideration. The loss of power generation due to ice accretion was about 3.6%, 2.6 MWh, against the total power generation of 43.2 MWh. In Figure 3, the change in air temperature over the same period was plotted In addition, the capacity utilization rate for the period under analysis was 19.7%, which makes it easy to judge that the windmill is operating normally. Since more power can be generated by taking appropriate measures against ice accretion, it is important to understand the condition of ice accretion in wind power generation in cold regions.

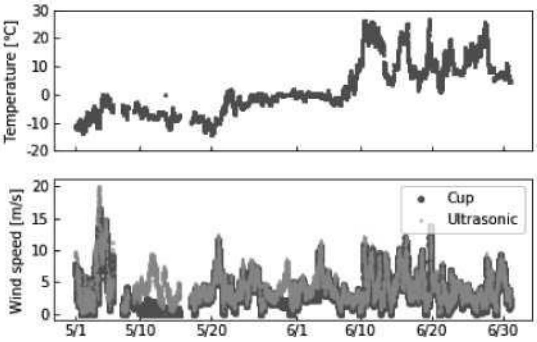

Figure 3. Temperature and wind speed measurement results for the target period

The bottom of Figure 3 shows the wind speed measurement results by the wind cup type anemometer and the ultrasonic type anemometer. The difference between the two measurements was seen around May 10. Both anemometers have a heating function to enable measurement in cold regions, but the wind cup type anemometers are used.

It is probable that ice accretion occurred in the part of the anemometer that was not heated enough by the heater, resulting in low wind speed values being recorded.

4. Measures against ice accretion in windmills

In wind power generation in cold regions, ice accretion is affected by the aforementioned loss of power generation. Currently, technologies to prevent ice accretion **(anti-icing)** or to remove ice **(de-icing)** have been developed, ranging from those in the testing stage to those in use for many years[5] - Measures against ice accretion in windmills are introduced below.

4-1.Heating method ®

Many of the measures used in actual operation are heating methods that control ice by heating the blades. Heating methods include pumping hot air into the blades and installing electric heaters on the blade surfaces. Some electric heaters can be installed in some existing windmills, but it is said that heating type ice control devices are difficult to apply to existing windmills.
A special heating method is to irradiate microwaves on specially painted blades. Because microwave irradiation is performed from outside the windmills, it is relatively easy to defeat existing windmills. However, this method is still in the development stage and has not been applied to actual windmills.

4-2.Mechanical method

Mechanical method refers to a method of deicing that destroys ice by applying an external force. Deicing work performed by an operator in a suspended state or removing ice on a blade with a rope, etc. is classified as mechanical method. While ice can be removed reliably, there is a risk of the operator being involved in an accident.

4-3.Physicochemical method

Physicochemical method is a method of preventing ice accretion or reducing the amount of ice accretion by applying a functional paint to the blades. Since the only work required is to paint the blades, it is easy to apply it to existing windmills. Ultra-water-repellent paint showing low ice accretion is the mainstream. However, in windmills, there are few examples of field tests applied to actual machines, although development in laboratories is ongoing.

5. Examples of anti-ice accretion measures with ultra-water-repellent paint

This paper presents an example of applying ultra-water-repellent paint to a specific area of the blades of a wind turbine operating in a mountainous area of Greece as an anti-ice accretion measure. The use of the wind turbine generating electricity is shown in Figure 4, and the area of paint on the blades is shown in Figure 5.

HIREC100, manufactured by **NTT-AT**, was used as the super-water-repellent paint, and since the painting work was carried out in **October 2017**, the data for **6** months from **November 2016** to April **2017** was used before painting, and the data from **November 2017** to April **2018** was used after painting.

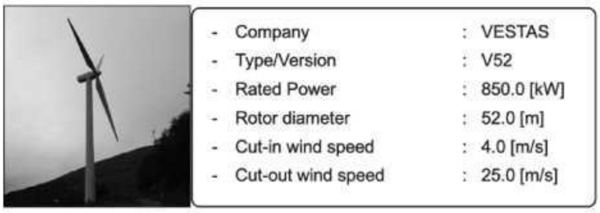

Figure **4.** Windmill specifications

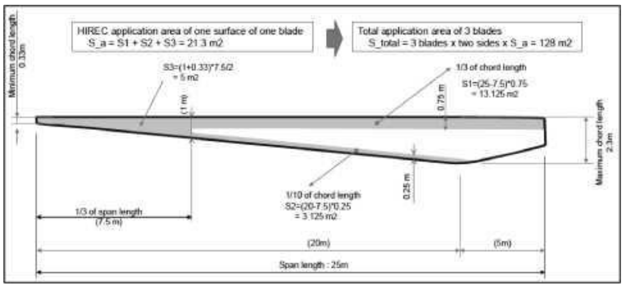

Figure **5.** Coating range on blade

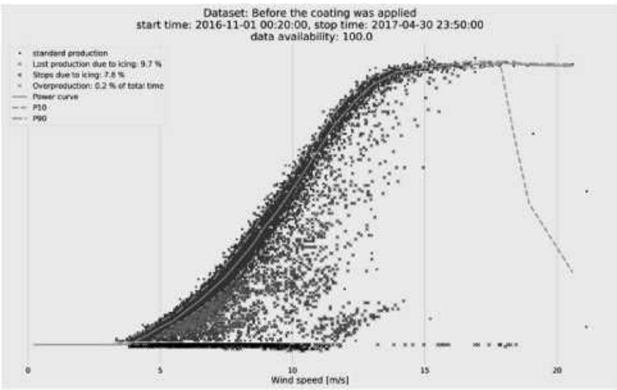

Figure **6. TILM** calculations for the first half of the painting year

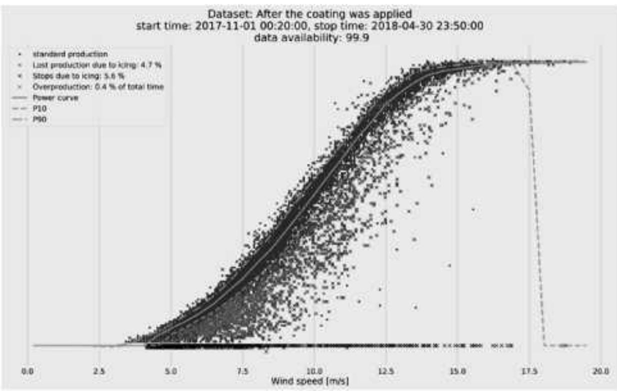

Figure **7.** Results of **TILM** calculations for the second half of the painting year

Figure 6 shows the results of the analysis for the 6 months before the application of super-water-repellent paint, and Figure 7 shows the results for the 6 months after the application of the paint. Although the time stamp is set at every 10 minutes, the start time of the analysis is delayed by 20 minutes for both the pre-painting and post-painting results due to data defects. The time taken for the analysis was 4343.5 hours, and the internal icing period was 357.5 hours, about 8.2% of the pre-painting time, and 328.8 hours, about 7.6% of the post-painting time. The power loss due to icing was 61.6 MWh, which is about 9.7% of the total power generation of 516.6 MWh, before the painting time, and 49.5 MWh, which is about 7.8% of the loss due to the shutdown time. On the other hand, the loss due to icing was 39.0 MWh, which is about 4.7% of the total power generation of 736.8 MWh, after the painting time, and the loss due to the shutdown time It was 10 MWh, or 5.6%, and although pure comparison is difficult because the same wind turbine was not observed during the same period, the improvement in power generation loss during operation during the icing period before and after the blade painting is considered significant.

The ultra-water-repellent paint has been shown to reduce power generation loss due to icing, but there is still room for improvement as a complete ice control measure, and the durability of the paint is another issue.

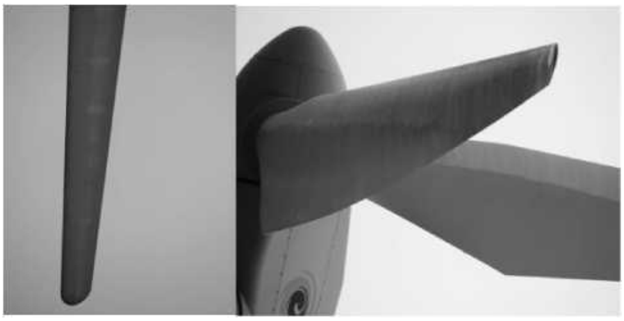

Figure **8.** Observation of the paint on the blade

It was confirmed that the paint film had peeled off at the leading edge where water droplets directly collided, and the damage to the paint film was noticeable at the tip of the blade. If the paint film had peeled off, the effect of the functional paint could not be achieved, resulting in a greater loss of power generation due to icing. As can be seen in the photograph on the right in Figure **8**, contamination of the paint film by impurities also leads to a reduction in the effect. When applying functional paint to windmills, it is necessary to consider not only the effect of the paint film but also the need for repainting.

6.**Summary**

This paper summarizes the effects of ice accretion on the rising demand for wind power generation in cold regions, and examines the power generation loss using the data of wind power facilities actually operating in cold regions. Furthermore, it introduces the ice accretion measures currently available, and verifies the effect of the physicochemical method of ice accretion measures using super-water-repellent paints. Although the target of comparison is the same wind turbine, quantitative evaluation is difficult because the timing is different. However, considering the calculation results of TILM, we believe that the reduction effect of power generation loss by super-water-repellent paints can be confirmed. In the inspection after a year, the erosion and dirt of the paint surface were confirmed, and in addition to the investigation of durability, it is necessary to continue to evaluate the economy.

As for anti-icing measures for windmills, most of the ones used in actual operations are heating systems, and while development of others has been advanced, there are still a number of cases that have reached the point of field testing applied to actual windmills. This is due to the time constraints that require extensive installation work to be carried out during the summer months, and the problems of contracts and guarantees with windmill manufacturers and management companies. A closer cooperation among windmill manufacturers, operating agencies, and research institutes is essential for the development of anti-icing measures for windmills in the future.

References

1) IEA Wind, "2010 Annual Report",2010
2) IEA Wind TCP Task 19, ^Performance WarrantyGuidelines fOr Wind Turbines in Icing Climate s",2018
3) Shigeo Kimura, "Effects of Icing on Wind Power and Countermeasures," Journal of the Japan Gas Turbine Society Vol. 40 No. 2, 2012
4) T19 Ice Loss Method: https://community.ieawind.org/task19/t19icelossmethod
5) IEA Wind Task 19, "Available Technologies ofWind Energy in Cold Climates," 2016
6) Rene Cattin, "Wind turbine blade heating-can it payeven more?," Winterwind2012, Skelleftea, Sweden