OFFwind Highlights No. 12 – JUNE 2025

DE-ICING SOLUTION ON OFFSHORE WIND TURBINE BLADE USING AIRLAYER METHODS.

Winter should be the best season for electric production from wind turbines. But ice accumulation on blades leads to low aerodynamic performances, decrease in production and safety hazards.

During winter, the production of wind turbines electricity from wind turbines should be at its peak. The combination of stronger winds and higher air density, resulting from temperature drops, exerts more force on the blades. Unfortunately, in Nordic winters, harsh climate condition counteracts this provision. Ice accretion alters the aerodynamic performance of the blades, leading to power losses and safety concerns for the local population and technicians.

In the present day, various anti-icing and de-icing methods are used and/or available to mitigate the impact of ice on electricity production.

Available methods

Passive methods

Passive methods include anti-icing coatings that reduce ice adhesion strength, facilitating easier ice removal or preventing ice accumulation. Photothermal coating are also used. They absorb light and convert it into heat energy to melt surface icing. The passive de-icing systems include flexible blades can shed ice by the natural bending capability of its surface and blade pitching which use the radiation energy to remove the ice by pointing directly at the sun.

Active methods

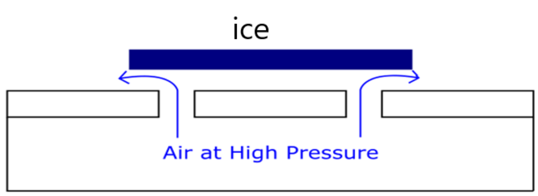
The active methods require activation by sensors of external anti-icing and de-icing system. Anti-icing systems use electrical resistance to heat the outer surface of the blade to maintain it above freezing temperature and preventing ice from adhering. Maintaining the surface above freezing temperature can also be achieve by using microwave and a microwave reflective material to cover the blade, the use of hot air through the hollow structure of the blade to heat the surface all the way to the tip of the blade where quantity of ice is higher. Chemicals sprays are also used as antifreeze solution, like ethanol or glycol. Their role is to mix with the water droplet on the surface to reduces their possibility of freezing.

Those anti-icing systems can also be used as de-icing system when the ice is already formed on the surface. By heating the surface, the ice is melting which creating a layer of water between the surface and the ice and allows to clean the blade from attached ice. Ultrasonic and electro-impulsive de-icing would use high frequency waves produced by piezoelectric actuators to break ice bonds on the surface. Aeronautic constructor uses pneumatic de-icing technics on aircraft; it consists of expansion tube place on the surface edge of the blades. Once the ice reaches about 6 to 13mm, the tubes are inflated with compressed air to break the ice layer that will fall with the gravity, once done the tubes are deflated awaiting a new circle of icing. (Li, o.a., 2022)

Lastly, the air layer system is a system that is tested and discussed in this highlight.

Air layer theory

The air layer theory comprises an airflow originating from inside the blade, propelled through rows of small holes near the leading and trailing edges of the blades to generate a layer of clean and heated air that has an anti-icing property. The droplets are repealed before reaching the surface, and the heated air would prevent the few droplets that reach the surface to form ice.



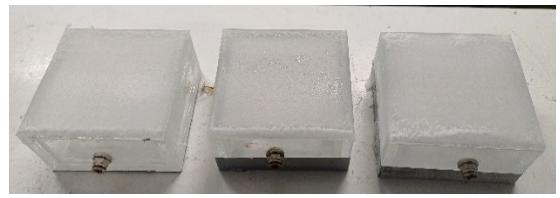
Picture 1. Illustration of the airlayer system

Moreover, this system can be utilized as a de-icing method. In the case that some droplets reach the surface, freeze and accumulate, the air pressure is used to push and break the accreted ice.

In this highlight, the ice adhesion is measured based on the air pressure required to break the adhesion and the surface area.

Test boxes

The test is made in an airtight box made of acrylic plastic PMMA (10 mm thick) with an air input and a pressure gauge to control the build in pressure.
The holes on the testing surface are placed every 10mm in a square pattern.
Different surfaces sample materials are being tested during this project, PMMA, flamed sprayed polyethylene (FSPE) and fiberglass with a gelcoat paint which is similar to the surface of the wind turbine blades.



Picture 2. PMMA boxes for air layer de-icing method before test covered in fresh ice.

Ice removal tests

The ice accretion is done in the icing wind tunnel (IWiT) at the Tampere University ICE laboratory. A wind tunnel operates on the principle of creating a controlled and uniform flow of air over a stationary object to study its aerodynamic properties. Placed in subzero environment, the wind tunnel allows to reproduce the icing condition of the winter Nordic wind condition. Combined with a water spray, it create mix glaze and allows ice accretion onto a surface to be studied.

The conditions are set at -10°C and 80% humidity, with a windspeed set at 18m/s.

Picture 3. Icing Wind tunnel at Tampere University ICE lab.

The layer of ice is 2 mm thick. The sample must wait for a minimum of 1 hour at -10°c for the ice to settle.

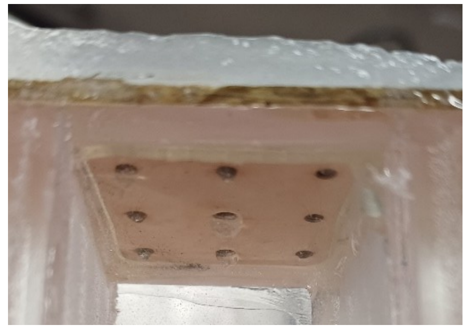
Picture 4. 2mm Ice layer on surface before test

The air pressure applied to the box to remove the ice from inside out is controlled by a digital pressure gauge with an increased pressure by 0,1bar per seconds.

Picture 5. Digital pressure gauge with manual adjustment valve, d=0,001MPa.

Results

Different size boxes have been tested, It has been observed that the smaller box with the surface of 5x5cm had the tendency to explode. The strength of the ice adhesion being higher than the strength of the glue that hold the surface sample to the box. This is due to the mix glaze ice leaking through the fewer holes of the sample and creating an anchor point for the ice increasing the ice adhesion.



Picture 6. Anchor point on the iced sample on small box (5cmx5cm)

The tests were considered successful when the ice separated from the surface even partially and the pressure was recorded.

Table 1. Average ice breaking pressure measured

Surface	Pressure (bar)
Gelcoat paint	1,2
FSPE	1,2
PMMA	0,6

The pressure required to break the ice on the studied surface are around 1 bar. It is noticed that the ice layer tends to break but stays attached to the surface. But we are convinced that the movement of the blade and the gravity will play their part in the de-icing methods too. To confirm this hypothesis, more tests on-site shall be conducted.

AUTHOR:

Julien Walser

Project researcher

Novia University of Applied Sciences, Vaasa

julien.walser@novia.fi

Interreg Aurora

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LAPIN LIITTO

MERINOVA TECHNOLOGY CENTRE

LULEÅ UNIVERSITY OF TECHNOLOGY

NOVIA UNIVERSITY OF APPLIED SCIENCES

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