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Techniques of Identifying Icing and De-Icing of Wind Turbines

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Abstract
In this paper, a variety of techniques to detect icing and de-icing on elderly wind turbines are specified. Wind turbines are often used in cold weather and they are subject to freezing. The vast majority of freezing is created on the turbine blades. This reduces the performance of wind turbine and also creates instability loads on the blades aerodynamic, fatigue and Health and increases the risk. Wind turbine associated with the stop at the end. Turbine Stop loss is a significant portion of wind energy. Dealing with the freezing and defrost systems is an aim to optimize the impact of weather on the wind turbines. Many active and passive methods have been considered for this issue and they are developing day by day.

Keywords: Wind turbine, Icing identifying, De-icing, Anti-icing.

1. INTRODUCTION

Wind energy resources in recent years due to environmental issues, has been a significant growth for electricity production. Particularly the use of wind energy in areas with cold climates has been more welcome. The wind causes immense capacity and easy access to it in these areas. By the end of 2012, according to BTM [1] areas with cold weather established more than 69 giga-watts of power generation, which is expected by the end of 2017 to reach 119 giga-watts. Frequent occurrence of icing in these areas could be irreparable losses, most notably the loss of energy import. In recent years many systems and procedures has been designed and implemented to deal with this phenomenon

Wind turbines in cold weather are directly or indirectly exposed to icing. The problems of the increased load, vibrations from the sound and noise, environmental constraints, the health and safety of people in these areas are ultimatums to stop the turbine [2]. So studying the effect of icing cold weather in areas with a more complete and accurate assessment of needs minimizes the dangers of this phenomenon. The system converts wind energy into electricity needs that adapt to the weather conditions so that productivity is better than it was in icing conditions. In conjunction with the icing of the general theory can be said that the first theory is called anti-icing, and ice formed on the opposite turbine. The second theory is called and de-icing formed on the turbine is removed. All systems should have the defrost system that can accurately identify this problem at the beginning of icing layer is much thinner and less heavily destroyed adhesion.

Nowadays little information about the performance of wind turbines in icing conditions is available. A general method for dealing with icing and defrost wind turbines are not available [3, 4]. Although the costs associated with de-icing and anti-icing systems is very high, compared to profit from increased production of turbines is

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achieved, is very small [5]. For example APPELBO turbines in Sweden between 2002 and 2003 for 7 weeks were stopped due to icing according to Statistical Database in Sweden from 1998 to 2003. The 1337 full-stop has recorded turbines for 161,523 hours. 92 turbines with a stop for icing and that for 8022 the clock was stopped due to icing. Also, according to a report in Finland between 1996 and 2001, respectively 1208, 495, 196, 581, 739 and 4230 hours for 19, 21, 29, 38, 61 and 61 turbines have been stopped due to icing [6].

2. IDENTIFY TECHNIQUES OF ICING

Many attempts have been done for icing detection in wind turbines and many of them should be improved to be practical. To detect icing on wind turbine, power curve must be constantly monitored. There must be accurate information about various stated of turbine to overcome the icing issue. On this basis must be based methods to defrost. Here we present two major methods of defrosting:

a- Direct approach: in this situation weather conditions including temperature, humidity and visibility combined with certain experiences and predicts the icing turbines [7].

b- The indirect approach: continuous measurements of changes such as mass sensors, conductance, reactance and dielectric constant of ice adhesion can be a practical method to identify icing [8].

Then the methods that have been proposed will discuss three of them:

Fig. 1.The icing phenomena of a wind turbine.

2.1. Machine Vision Technology

In this way, according to data from the primary and secondary turbine and compare those with each other as well as image processing parameters can be calculated for icing. This icing method is on the basis of full control [9]. In the field of air transport technology this method to detect ice on aircraft blades in wind tunnel tests, the results have been very good [10]. But for the implementation, this procedure shall be incurred high costs as well as the procedure for wind turbine control systems is very large and very complex. This method is based on infrared sensors installed at different locations with no wind turbine is installed wire. High-speed machine vision measurement system for measuring and reliability is very high. The system for wind turbine blades is certainly possible to do online can detect ice.

2.2. Frequency Monitoring Technology

Ideally when the turbine works and, it should be monitored. If the turbine blades are experience icing, the frequency changes and this can be measured directly. This means that changes in the frequency, damage to the turbine blades arrived at this method in case of icing and icing created rapid identification can be eliminated at the outset. This method of not only monitoring but also controlling the turbines can also be very good. Ice created to eliminate the heating system can be used. The changes of frequencies and monitoring online can be time-icing detect and control system with signals associated with the use of sensors and mechanisms used in the turbine leads to defrost will be after reaching the initial conditions and favorable and convenient operation turbine system will shut down. The de-icing system that is used in this method consumes a large part of production capacity. The methodology used for icing directly in air industry is in use [11].

2.3. Imbalance

By continuously measuring the vibration of the turbine blades, blades imbalance can be detected in a timely manner. There are two main reasons for imbalance:

a- icing blades

b- Aerodynamic imbalance

It can be detected by measuring the vibration which one of the two reasons above happened, but this method can be used as part of intelligent control contributed greatly to the automation of wind turbines. To measure the vibration, the strain gauge can be attached to the body as well as non-contact lasers, acoustic emission, etc. Each of these methods can be used to detect faults in different situations. Acoustic Doppler method by the Electric Power Research Institute, EPRI has been introduced in the twentieth century it was used in 3 projects [12].

3. DE-ICING TECHNIQUES AND ANTI-ICING

Following features must be included in a de-icing system to be used efficiently:

a- Low energy consumption and cost reduction

b- Part of the wind turbine control system that is leads to automation.

c- Repairs and maintenance is as readily done.

In the case of system de-icing in the whole world cases and equipment to this end, there may be ways defrost completely and economically that in general the creation and formation of ice blades in the first place to prevent the continuation techniques this order will be mentioned. These methods can be provided in two ways:

a- Passive methods

b- Active methods

The basic working method is the active energy. In the event that passive methods do not require primary energy. The methods for detected icing, anti-icing and de-icing can be used [13].

3.1. Passive Methods

These methods use any primary energy without the need to prevent the accumulation and formation of ice on the blades. The original idea for this method is based on reducing operating costs and keeping the turbine blades is devoid of any icing. Of course, this method is not without a control system and protection against lightning and electricity. Most of these methods are covered icing on the blades to deal with the physical and chemical properties of the blades may be changed. The system also stop the turbines by one of the following methods is set by EDF-EN and is being reviewed [14]. The following methods can be passive as follows:

3.1-a. Reduce the Adhesion Strength

To reduce the adhesion strength of ice There are various strategies that the greatest and most common way is to use materials known as having the lowest power of friction are including substances such as polytetrafluoroethylene (PTFE) and polydimethylsiloxane (PDMS), which has anti-adhesion are for the blades used [15, 16].

3.1-b. Disabled Heat System

The black color of the turbine blades in the freezing conditions will improve turbine performance [17]. Black color due to absorption of sunlight can be used. However, this method has certain limitations and should not be used in areas that are not repeated freezing and the air temperature is as close to zero degrees [18]. This method should also consider that in the summer due to high temperature and high absorption of light by the black and mechanical properties of the blades is changed.

3.1-c. Full-stop Wind Turbine

EDF-EN Company recently experiments in this regard as it is a new event in the icing conditions. In fact, when the turbines stop has less ice on it are shaped so that turbines can better work in less time of re-start. This is one of the most important benefits of passive control [14].

3.2. Active Methods

3.2-a. Chemical Methods

Using chemical coating can be made to lower the freezing point. The material is a thermal hysteresis between melting and freezing point make [18].

3.2-b. Mechanical Methods

These methods are mainly based on work created cracks on the ice. Which can be achieved by vibration and shaking the frozen components. The following types of mechanical will explain briefly.

- The pneumatic method

Pneumatic method is used mainly for small aircraft de-icing front edge of the wing. By working this way is then, when the amount of compressed air was freezing so as to be transmitted sequentially inside the wings [19]. The vibration caused cracks on the surface would be eating ice and lost (Figure 2). This method is a very simple operation, which fill and empty the chamber tangible changes in the structure of the aerodynamic blades creates and repairs in other words, it increases [20].

- Repulsive methods

Including methods of waste that can be used for removing ice, electromagnetic and piezoelectric pulses can be noted [20]. Repulsive systems are largely composed of a spiral coil inside a metal enclosure (Figure 3). When the coil current flows, there is a magnetic field and cause deformation of the metal surface and loss of ice on its surface [21].

- The ultrasonic method

The main idea of this method is based on the gap between the two levels of adhesion. Therefore this method is usable extent. In this method using ultrasonic waves at the junction material creates a tension. The benefits of this approach are low cost, low power and high speed start to icing noted [21]. It is expected the ultrasonic method can be used to icing turbine blades. More recently, the company DELCE-UT studies and research done on the defrost system is based on the plans for 2020 are expected to be operational this system [22]. Figure 4 shows the test de-icing DELCE-UT.

3.2-c. Thermal Methods

Other solution to prevent the ice forming on the surface of the blades is keeping the temperature above freezing level. This is the basis of thermal methods which requires a heat generator. To these must be a source of energy for heat generation is required. Of course, the carbon fiber and electrical sensors must be protected against lightning [23].

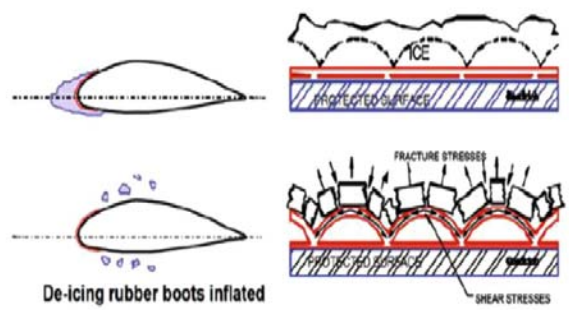

Fig. 2. Pneumatic method principle [19].

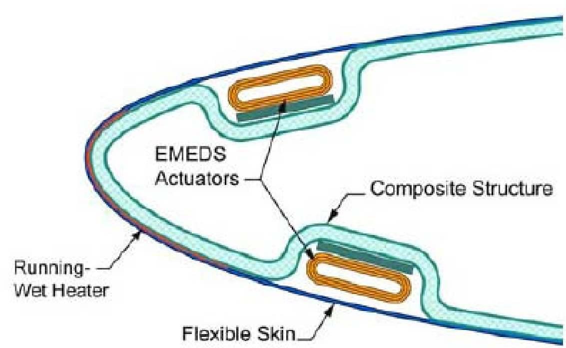

Fig. 3. Icing repulsion [20].

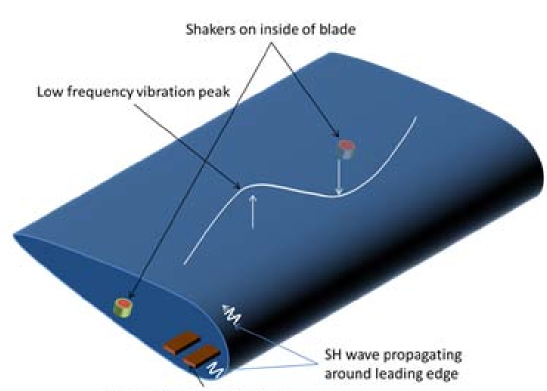

Fig. 4. De-icing with ultrasonic testing [22].

- The injection of hot air

Many of the techniques defrost completely failed to overcome this problem as one of the largest and most efficient methods used to deal with this phenomenon is the direct injection of hot air into the blades. Principles and practice of this method in the form of (5) is visible. The first method was tested on aircraft wings. Unfortunately, a large part of the heat generated is wasted in this way [24].

- The direct heating surface

This method for direct heating by radiators that warm air into the blade and the blade surface is removed. Such a system is installed and operated by Enercon in Switzerland [17]. Battisti et al. [25] to de-icing blade surface with a layer of warm air over the blades were prevented from freezing. This means that clean air is hot and the inside blades through holes in a row in the embedded blades were driven out. The air layer on the surface of the blades caused by stray drops prevented from meeting them on the blade and tiny drops that fall on the surface to melt. There are advantages to this method: The shape and surface of the blade does not change so the aerodynamic of the blades and the lightning risk is not changed. The holes on the blades bring warm air into the shell structure and the thickness of larger turbines has a high thermal resistance to keep the blade free from freezing. In the event of failure of one of the significant imbalance on the rotor blade heating systems apply. An inductive load acts differently than other blades. Yukon Energy Turbine such a case occurred in 1996 [26]. Defrost technology using thermal system requires electrical energy consumption is generated from the turbine. According to the latest research conducted for large turbines need to be at least 25 percent of the turbine and also for small turbines to 6 to 12 percent of its production capacity [27].

- Heat resistance

For this method, according to the form (6) three different structures could be considered [28]:

- Out of blades: The heating system is installed out of the blade. Its function is essentially the thermal resistance and mechanical properties of a device which is attached to link. Some experiments show that these properties are very sensitive to temperature when temperature increases the possibility of cutting the fins. It also must be protected against lightning.
- Between the blades and resin: This structure is not compatible with feathers turbines because the uncertainty this way, heat is your own resin as well as the impact of the thunder. Siemens and NORDEX studied this method in cold weather conditions recently [29, 30].
- Between the blade and the outside of the resin: The structure of this method is similar to the above method, but the basic idea of how to find more than hot air injection method. As previously mentioned, the company ENERCON in a warm infusion of warm air that was used by a significant portion of the heat generated is wasted instead; this method can be used to generate heat sensors, electrical enclosure.

- Microwave heating

In 1982, Hansman suggested the use of microwaves to prevent freezing, which will deal with water droplets electromagnetic energy to transport them and melt [31]. The system can easily be avoided wasting energy. The only concern this way, the risk of human health and other living creatures. The issue is also being investigated by LM WIND POWER turbine blades that can be used to de-icing [28].

- Infrared heating

This heating method in this way releases the energy that from a distance and for absorption by the blades need not install any receiver on the blades. So there is no roughness and protrusions on the surface of the blade. Because of its infrared radiation is very strong absorber ice, choice of materials for the manufacture of blades should so that the sufferings of infrared fire must prevent the blades. This method can also be used to prevent freezing and de-icing [32].

3.2-d- Active the Pitch Control

Major energy loss occurs when turbine control uses stall. This is the case even when icing is very low due to the aerodynamic structure of icing. An example of turbine operation by pitch controlling in the icing conditions in the form (7) is visible [33].

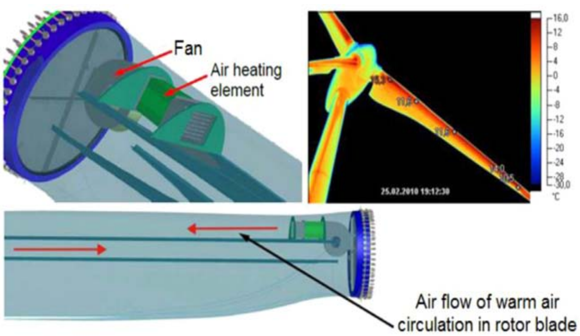

Fig. 5. The heating by injection of hot air [23].

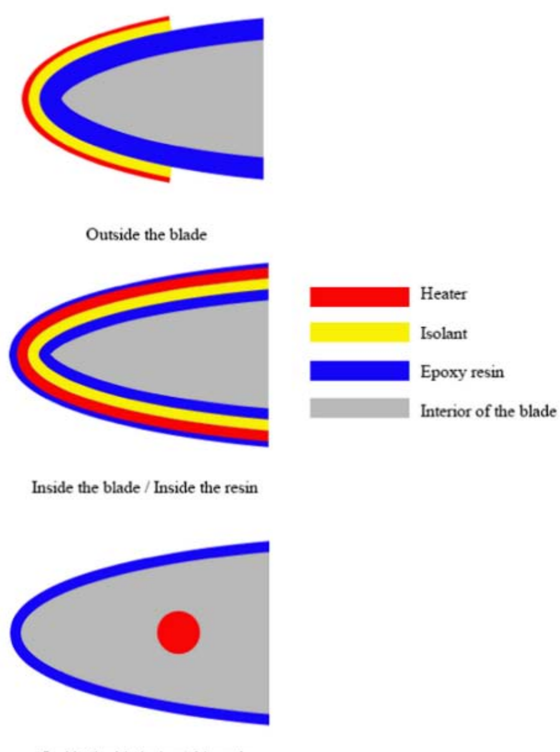

Fig. 6. The structure of thermal resistance [28].

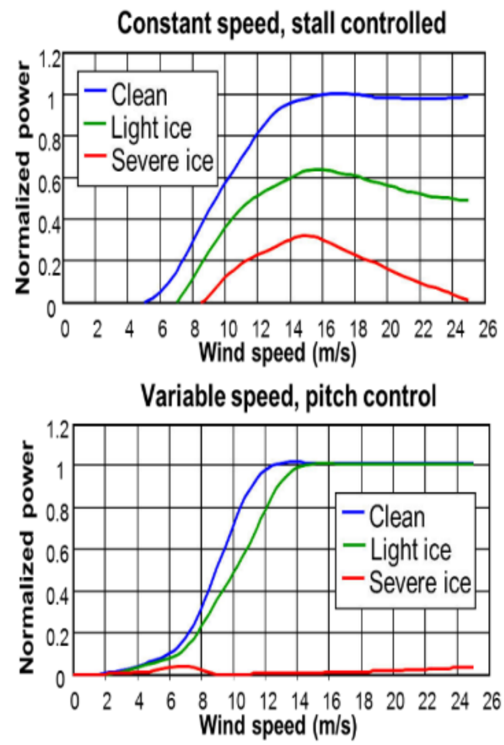

Fig. 7. The effect of frost on the curve be controlled by stall (above) and the control Pitch (bottom) [33].

This method is practically freezing not help but contribute significantly to compensate for power lost is against icing. For maximum power produced by pitch controlling it is necessary to have precise knowledge of the structure of the airfoil in these weather conditions.

4. CONCLUSION

Based on research conducted in this paper as well as other research in this area has been in recent years, yet a reliable system to deal with de-icing and defrost in the wind industry does not exist in the market. But to enhance the reliability in for this purpose is the need for further testing to provide a safe and reliable system designed and used. Also, in conjunction with blade protection against lightning and also deal with icing there is also the perfect cover for blades that can cover both cases. For the defrost-heating system which is used in most cases, the system may leave a devastating impact on the aerodynamic blades. Also in connection with the defrost system when the action takes place, in most cases, large pieces of ice to fall. Another point which should be noted is that prohibiting icing one of the blades may be difficult and causing an imbalance in the turbine and serious damage to importing the means to deal with such situations should an alternative system for defrosting system considered. And at the end of the discussion regarding the issues mentioned, to improve the performance of wind turbines in such circumstances should be necessary and sufficient conditions for the design of all turbines that can cope with this issue be considered.

REFERENCES

[1] ApS, B.C., International Wind Energy Development: World Market Update 2011. 2012: BTM consult ApS.

[2] Dalili, N., A. Edrisy, and R. Carriveau, A review of surface engineering issues critical to wind turbine performance. Renewable and Sustainable Energy Reviews, 2009. 13(2): p. 428-438.

[3] Dierer, S., R. Oechslin, and R. Cattin, Wind turbines in icing conditions: performance and prediction. Advances in Science and Research, 2011. 6(1): p. 245-250.

[4] Ilinca, A., Analysis and mitigation of icing effects on wind turbines. 2011: InTech Open Access Publisher.

[5] Ronsten, G., et al., State-of-the-art of Wind Energy in Cold Climates. IEA Wind Task XIX, VTT, Finland, 2012.

[6] Jasinski, W.J., et al., Wind turbine performance under icing conditions. Journal of Solar Energy Engineering, 1998. 120(1): p. 60-65.

[7] Fikke, S.M., et al., COST 727: atmospheric icing on structures: measurements and data collection on icing: state of the art. 2006: Meteo Schweiz.

[8] Mughal, U., M. Virk, and M. Mustafa. Dielectric based sensing of atmospheric ice. in 38th International Conference on Application of Mathematics in Engineering and Economics. 2012.

[9] Yang Yongyue , Deng Shanxi , and H. Gequn, The technology of intellectualized vision for blades measurement. Acta Energize Solaris Sinica, 2003. 02(018).

[10] LIU Song-lin, GUO Jiang-xing, and C. Jie, Study on Vision Measurement Method for the Freezing Process of Airplane Sensor Parts. Beijing Surveying and Mapping, 2009.

[11] Amirat, Y., et al., A brief status on condition monitoring and fault diagnosis in wind energy conversion systems. Renewable and sustainable energy reviews, 2009. 13(9): p. 2629-2636.

[12] Lian-suo, G.Y.-q.L.J.A., Review on noncontact measurement technologies for turbine blades vibration. JOURNAL OF NORTH CHINA ELECTRIC POWER UNIVERSITY, 2006 (3): p. 54-58.

[13] Ibrahim, H., et al., Optimisation par contrôle d'un système de dégivrage électrothermique d'une pale d'éolienne. 2015.

[14] Wadham-Gagnon, M., et al., Ice Detection Methods and Measurement of Atmospheric Icing.

[15] Karmouch, R. and G.G. Ross, Superhydrophobic wind turbine blade surfaces obtained by a simple deposition of silica nanoparticles embedded in epoxy. Applied Surface Science, 2010. 257(3): p. 665-669.

[16] Karmouch, R., et al. Icephobic PTFE coatings for wind turbines operating in cold climate conditions. in Electrical Power & Energy Conference (EPEC), 2009 IEEE. 2009. IEEE.

[17] Seifert, H. Technical requirements for rotor blades operating in cold climate. in VI BOREAS Conference, Pyhatunturi, Finland. 2003.

[18] Laakso, T., et al., State-of-the-art of wind energy in cold climates. IEA annex XIX, 2003. 24.

[19] Mayer, C., et al., Wind tunnel study of electro-thermal de-icing of wind turbine blades. International Journal of Offshore and Polar Engineering, 2007. 17(03).

[20] Mayer, C., Système électrothermique de dégivrage pour une pale d'éolienne: simulations en soufflerie réfrigérée et impact sur la puissance produite. 2007: Université du Québec à Rimouski.

[21] Goraj, Z. An overview of the deicing and anti-icing technologies with prospects for the future. in 24th International Congress of the Aeronautical Sciences. 2004.

[22] DeIce-UT. Summary description of project context and objectives. Accesed:10.08.2016; Available from: http://www.deice-ut.eu/publications/.

[23] Tammelin, B., et al. Icing effect on power production of wind turbines. in In Proceedings of the BOREAS IV Conference. 1998.

[24] Battisti, L., Wind Turbines in Cold Climates: Icing Impacts and Mitigation Systems. 2015: Springer International Publishing.

[25] Battisti, L., P. Baggio, and R. Fedrizzi, Warm-air intermittent de-icing system for wind turbines. Wind Engineering, 2006. 30(5): p. 361-374.

[26] Maissan, J.F., Wind power development in sub-arctic conditions with severe rime icing. Northern Review, 2002(24).

[27] Tammelin B, C.M., Holttinen H, Morgan C, Seifert H, Sa ¨ntti K., Wind energy production in cold climate (WECO) (Photo courtesy of Kranz). Publishable report; 1996–1998. p. 1-38.

[28] Fakorede, O., et al., Ice protection systems for wind turbines in cold climate: characteristics, comparisons and analysis. Renewable and Sustainable Energy Reviews, 2016. 65: p. 662-675.

[29] Siemens blade de-icing, in Brochure de présentation. 2011.

[30] Nordex, Anti-icing - Higher Yields in cold climates. 2015.

[31] Hansman, R.J., Microwave ice prevention system. 1982, Google Patents.

[32] Ryerson, C.C., Assessment of superstructure ice protection as applied to offshore oil operations safety. 2009.

[33] IEAWIND, Wind Energy Projects in Cold Climates. 2012.