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Ice protection systems for wind turbines in cold climate: characteristics, comparisons and analysis

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A B S T R A C T

The impact of icing on wind turbines and energy production in northern regions is a severe problem. Therefore, emphasis on developing ice mitigation systems has become a significant part of the wind energy conversion systems. These systems use various technologies and have different specifications, sometimes with no clear indication of their efficiency. Since the effect of cold climate on wind turbines is complex, not every ice protection system is suitable for a given wind farm. Therefore, the aim of this work is to compare the existing ice mitigation solutions and provide an indication on their efficiency. In this paper, we first review the most recent standards set by experts, and the major issues associated with wind energy in cold climates. Then, we present the ice protection techniques found in the literature, and then highlight the recent research on the optimization of the systems. Finally, we present an analysis of the current market, compare ice protection techniques and systems, based on various criteria, and measure the additional costs generated by ice mitigation.

Contents

Abbreviations: IWAIS, International Workshop on Atmospheric Icing of Structures; IEA, International Energy Agency; IPS, Ice protection system; WEC, Wind energy converter; IE, Icing event

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1. Introduction

In times of growing need for renewable energies, wind energy projects in cold climate areas are becoming more popular, due to the high wind potential and the availability of land. According to BTM's latest World Market Update [1], the installed capacity in the cold-climate market was expected to be 69 GW at the end of 2012, and an additional 50 GW by 2017 [1]. Icing events are frequent in those regions and can have devastating effects. Over the years, several ice protection systems have been designed in order to overcome these effects. The aim of this paper is to present a thorough comparison of the existing ice protection systems.

Wind energy in cold climate is threatened by the various direct and indirect effects of icing – increased loads and vibration and, as a result, shorter component life. In addition, higher noise levels and associated environmental restrictions, health and safety risks and, therefore, forced shutdown of wind turbines. Finally, the aerodynamic properties and generating power of iced wind turbine blades are heavily affected (Fig. 1) [2,3].

Hence, the impact of icing in cold climate regions needs to be evaluated in order to minimize the uncertainties and risks involved. Thus, wind energy conversion systems need to be adapted in order to operate in icing conditions. Two schools of thought have emerged for ice mitigation. The first strategy, called anti-icing, consists of preventing ice build-up at the surface of the blade. The second, called de-icing, consists of removing the ice layer from the surface of the blade. All the de-icing techniques require accurate ice detection systems, which can be very problematic since this type of ice measuring devices are only reliable within a limited range of icing intensity. The advantage of anti-icing is that the turbines do not have to be stopped during icing events. However, in some cases stopping the wind turbines to remove the ice can be more advantageous. Many de-icing techniques are currently in use in the aviation, road, and electric power transmission industries. In this paper, the term icing refers to the formation of any type of ice on an object resulting from the freezing of water.

In order to achieve our goal, in the first section we will first present the recent standards on the subject of icing in cold climates. In the second section, we will elaborate on the effects of icing on wind farms. The third section will then focus on the ice protection techniques, both active and passive. The fourth section will discuss the studies conducted on the optimization of ice mitigation systems. And finally, the fifth section will present a market analysis, a cost assessment, and a comparison of ice protection techniques and systems.

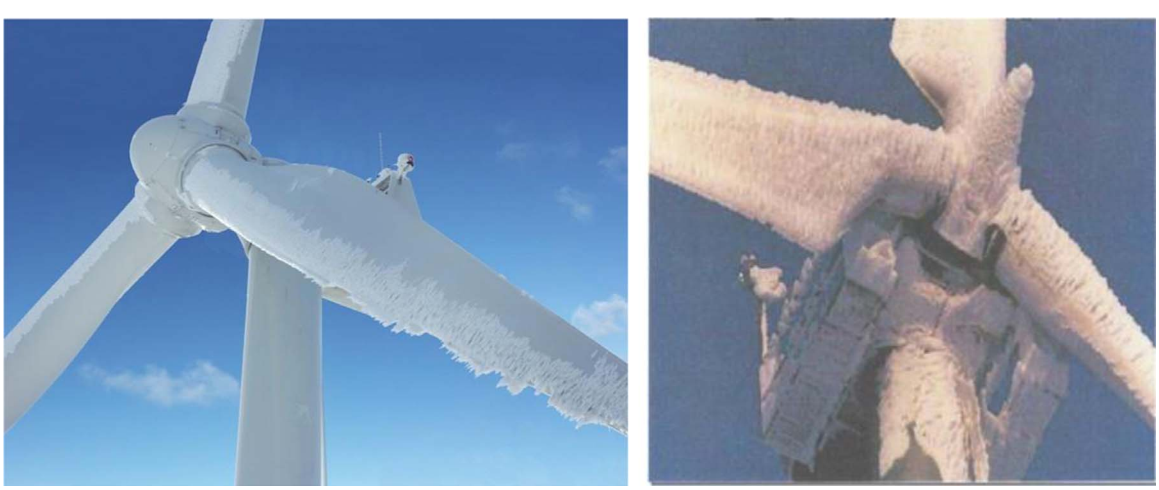

Fig. 1. Impact of icing on wind turbines [3].