A Proposed Research Policy for Wind Energy in Icing Climates

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***Abstract* - An analysis from a wind energy developer's point of view is presented regarding measures needed to utilize the full potential of wind energy in icing climates. The intended addressees are national energy administrations, researchers and industrial partners interested in expanding the potential for wind energy to such harsh environments. The work is based on input from developers, national and international wind energy research projects, current design standards and the international collaboration carried out in EU's COST Action 727 - Measuring and Forecasting Atmospheric Icing on Structures and IEA's RD&D Wind, Task 19 – Wind Energy in Icing Climates. So far, we've seen no commercially available de- or anti-icing systems able to cope efficiently with medium to severe icing conditions.**

I. INTRODUCTION

A few years ago it was widely believed that offshore wind energy would take off and that an extended development of suitable locations on land therefore was not needed. Due to a significantly lower cost per kWh produced on land this is no longer considered to be the case. However, iced up wind turbine blades pose a significant challenge to wind turbine manufacturers as well as wind farm developers and owners in certain cold climate regions. The main reasons for their concern are:

- personal safety issues,
- loss of production and
- influence on the expected life of components.

The adaptation of technology required to master wind energy in icing climates is currently lacking and the manufacturers are unlikely to pay much attention without market incentives or eye-opening market studies. Before the financial crises, the manufacturers saw an excellent opportunity window to increase their profit margins by

- utilizing economies-of-scale,
- improving efficiency,
- moving production to low cost countries and
- lowering the cost of capital employed by pre-charging customers.

Icing of wind turbines creates a more risky and challenging niche market. The wind energy research community has addressed the issue of icing since the early 1990's. However, due to a focus on easy to develop land based projects and large offshore windfarms, no commercial de- or anti-icing solutions currently exist for medium and severe icing conditions.

II. BACKGROUND TO THE CURRENT SITUATION

Icing of wind turbine blades causes problems listed in the introduction and the economic risk for an investor is consequently higher in icing climates in comparison with projects on the standard market. This is particularly true without proper means to remove ice from the blades as icing increases the economic risk and thereby may prevent or reduce the profitability of wind energy projects in affected areas. Figure 1 shows an example of an iced up wind turbine blade.

Figure 1: An iced up blade of a wind turbine in Northern Finland. The rime ice is collected on the leading edge on the left. Photo: Timo Laakso, VTT.

Enabling wind turbine manufacturers to develop de-/anti-icing technologies has been a long-time issue for wind energy developers of wind farms at ice-infested locations.

This paper was written taking a wind energy developer's point of view and the Swedish company "o2 Vindkompaniet" was chosen to serve as an example. It is, however, believed that the general results and conclusions herein are valid and of interest also to the other sponsors. Figure 2 indicates the industry landscape. Players that have shown an interest in icing climates have been highlighted. As indicated in Figure 3, only one manufacturer, Enercon, has, so far, shown an active interest in solving the icing issue.

While the market, technology wise, has been less farsighted than the research community, it has certainly succeeded in making some governments provide introductory measures and incentives like investment subsidies, feed-in tariffs, production tax credits, green certificates etc. These tools and measures are of little use as the technology required for utilizing wind energy in icing climates simply isn't readily available.

Figure 2: The developer o2 Vindkompaniet's potential icing climate partners among interest organizations, manufacturers, in the research community, the government sector and among customers.

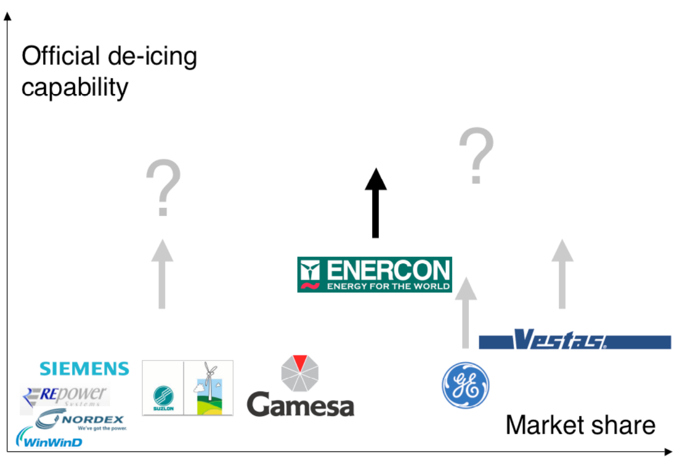

Figure 3: Official de-icing capability of selected manufacturers.

III. INDUSTRY INCENTIVES

As been stated before, for projects in medium to severe icing conditions where de-/anti-icing systems are needed there's currently no proven commercial solution available. The tools and measures proposed in Figure 5 are examples of actions that should be considered to support an accelerated development of adapted technologies. These are:

1. Increase the demand ability
2. Initiate a pull via a blade manufacturer
3. Updated research policy (this report)
4. Encourage 3rd party solutions
5. List, find and evaluate available technical solutions
6. Carry out market studies
7. Contact Canadian utilities
8. Contact other Canadian wind energy organizations

The bottom line is to increase the buyer's relative purchase power to get the necessary attention from the industry. It is believed that local sales organizations operating on markets where a large number of projects in icing climates might be sold may be able to attain corporate attention.

One example of the use of large purchase power was the round of bids to Hydro Quebec (HQ) for 2000 MW of wind energy, of which some will be built in icing climates. HQ's approach in this matter is such that the company will a) not own any wind farms, b) pass on favorable offers from manufacturers to developers, c) purchase the power produced at a fixed price, d) require no maintenance to be carried out during three winter months and e) penalize producers that are unable to periodically deliver a contracted amount of energy.

An alternative to the last requirement could have been to demand 95% technical availability including icing. It is, however, due to the inherent lack of adapted technology, questionable if any manufacturer would have been able to make an offer under such circumstances. The manufacturers participating in the HQ bidding in Sep. 2007 were REpower, GE and Enercon, [4].

IEA's cold climate expert group in R&D Wind - Annex XIX, has published a State-of-the-Art report, [5], as well as recommendations for developers, [6]. Figure 5 shows an analysis of considerations to make regarding de-/anti-icing assuming a thorough understanding of the icing situation on the selected location. Examples of incentives and alternative players are also given. But do we really know how to effectively select locations in icing climates?

IV. ESTIMATING THE FULL POTENTIAL OF WIND ENERGY IN ICING CONDITIONS

The main criteria governing the selection of sites, not considering icing, are the cube of the wind speed and the grid connection cost. The wind speed, the grid connection cost and the conflicting interests are rather well known and/or easily accessible while icing introduces a whole new set of requirements. A sound utilization of wind energy in icing climates will require attention to be paid to fields shown in Figure 4. The targets of the analysis shown are to map the technical and net potential of wind energy in icing climates as well as to enable consistent energy assessment measurements to be carried out in such environments. The details can be found in COST Action 727 reports [7] and [8].

A research policy supporting the deployment of wind farms in icing climates needs to cover at least:

- Wind energy and icing assessment
- Micro-siting of turbines and grid in icing climates
- Selection of wind turbines and optional equipment
- O&M in icing climates
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Examples of issues, with reference to the first two items above, which need to be addressed for a developer to be able to assess the regional and local energy production in icing climates, are:

1. Standard for classifying site-specific icing
2. Sensors classified with respect to icing
3. Icing frequency maps
4. Energy production deficiency maps
5. Reliable ice detectors
6. "Best" suited ice detector for the type of icing of interest (icing?, intensity, persistence, type, load)
7. Selection of ice detectors
8. Icing and humidity
9. Liquid water content of air (LWA)
10. Droplet size distribution (MVD)
11. Should cup or ultrasonic anemometers be used in icing conditions?
12. Iced-up support structures, how to mitigate?
13. Measurement masts tend to break
14. Can Sodar and Lidar wind speed measurements be made bankable in complex terrain and in icing conditions?
15. Environmentally friendly power supplies for measurements at remote locations are inherently lacking
16. No proven weather prediction models covering local icing conditions

This stage of the research strategy aims at finding the best locations by developing the required modelling tools and equipment.

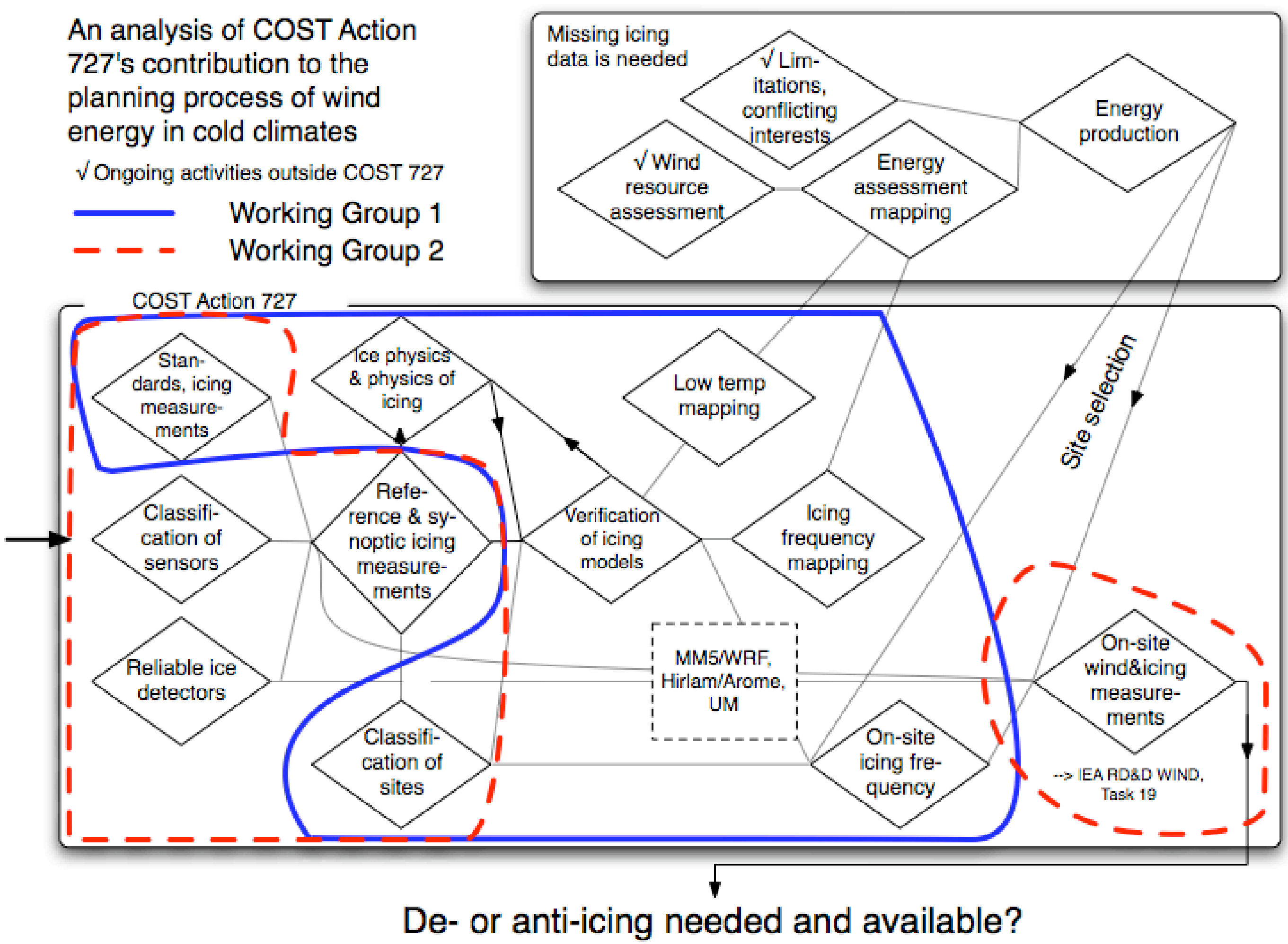

Figure 4: Measures needed to enable the full utilization of wind energy in icing climates and responsibilities of COST Action 727 Working Groups.

The selection of wind turbines and optional equipment implies that adapted technologies are readily available, Fig 5.

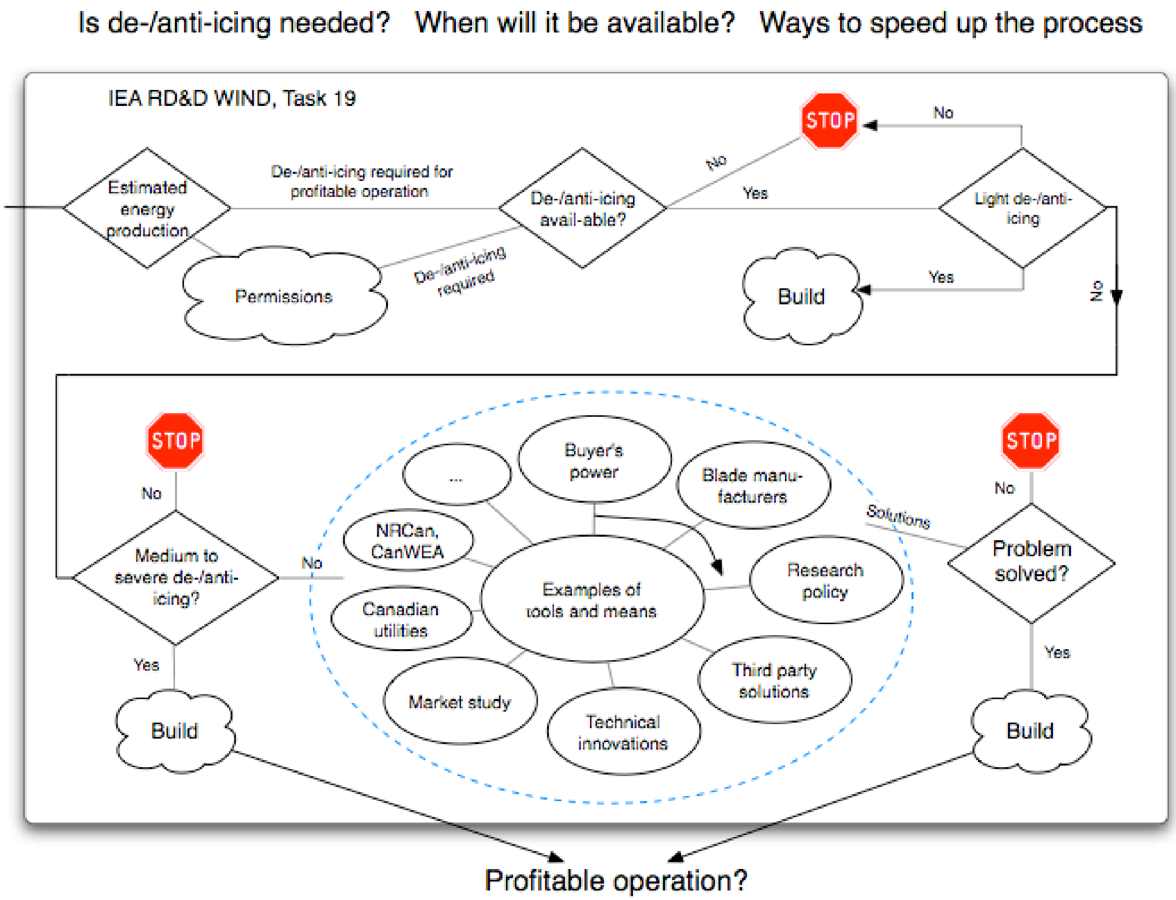

Figure 5: Considerations to be made regarding the need for de-/anti-icing equipment assuming a thorough understanding of the icing situation on a selected site. Examples of tools and means to achieve de-/anti-icing capability are also shown.

The main reason for carrying in out the above is to keep the wind turbines in operation, Figure 6.

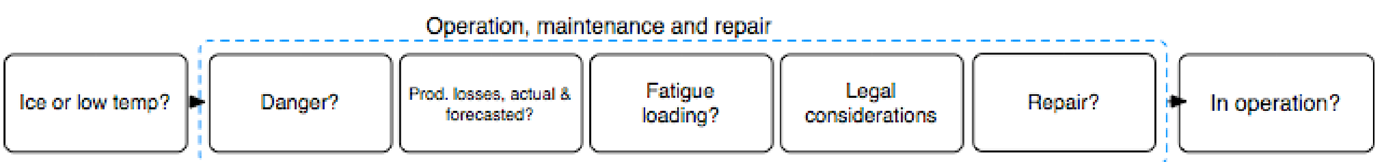

Figure 6: Once in operation, the owner of a wind farm needs to consider personal safety and comfort issues, loss of production, influence on the expected life of components, site access and the actual repair work being possible to carry out due to harsh weather conditions

V.

This work was made possible by the support from the wind farm developer o2 Vindkompaniet, the utilities Vattenfall and Skellefteå Kraft, [1], the Swedish Energy Administration through COST Action 727 and IEA RD&D Wind Task 19, [2] and its research advisory board Vindforsk II, [3].

VI. References

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