Summary-Report

Evaluation of the Vestas De-Icing System

Performed as a part of the Austrian participation in

IEA-Wind – Task 19

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1. Introduction

This document is an abbreviated edition of the report *Evaluierung Vestas Rotorblattheizung* (Energiewerkstatt, 2019) (in German language) available on the web site “nachhaltigwirtschaften.at”, which is operated by the Austrian Ministry for Transport, Innovation and Technology.

The content of this report is the evaluation and the assessment of the Vestas de-icing system based on operational records from two wind turbines of the type Vestas V112 – 3.3 MW on a site with severe icing conditions (IEA icing class 3) in the northern part of Upper Austria at an elevation of about 1000 m. Six wind turbines of the type Vestas V90 – 2 MW without blade heating, that are situated in the immediate vicinity, serve as a base-line for comparison.

2. Data basis

The wind turbines used for this study constitute the wind farms Sternwald II and Sternwald III and are located in the northern part of Upper Austria in the municipality of Vorderweißenbach in immediate vicinity of the national border to the Czech Republic. The positions of the turbines stretch in a roughly east-westerly direction, parallel to the run of the national border, along a forested mountain ridge at an elevation of about 1000 m. The locations of the wind turbines are illustrated in Figure 1.

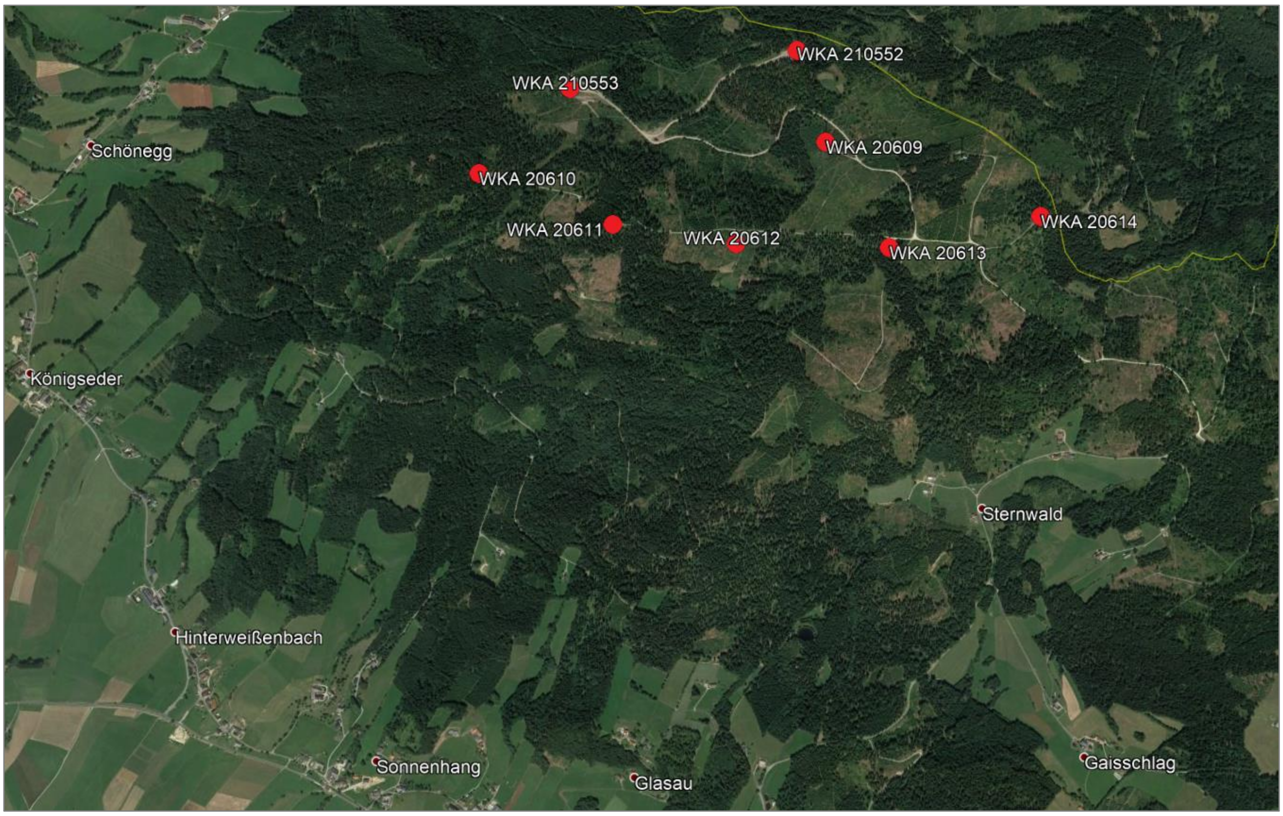

Figure 1: Situation of the investigated wind farms Sternwald II and Sternwald III. The national border with the Czech Republic is shown as a yellow line (Google Earth)

The selected site is, in several ways, well suited to the evaluation of the Vestas de-icing system. First, it shows a comparatively high number of icing events placing high demands on the performance of the blade heating and allowing for meaningful statistics. And, second, the wind farms in this area also contain a number of turbines without a de-icing system. This comparison among a larger number of wind turbines – two with, and six without blade heating and sited in immediate vicinity – gives a broad statistical basis and thus allows the deduction of well-based conclusions.

The operational records for the evaluation come from the six turbines of Sternwald II and from the two turbines of Sternwald III. An overview of the individual turbines together with their main properties is compiled in Table 1.

Wind farm	Ident No.	Turbine type	Coordinates (WGS84)		Hub height	Blade heating	Errect-ed
			X (Ost)	Y (Nord)	[m]		
STERN II	20609	Vestas V90 – 2 MW	14° 14' 1,3"	48° 34' 53,7"	105	No	2005
STERN II	20610	Vestas V90 – 2 MW	14° 13' 37,5"	48° 34' 55,6"	105	No	2005
STERN II	20611	Vestas V90 – 2 MW	14° 12' 36,7"	48° 34' 51,9"	105	No	2005
STERN II	20612	Vestas V90 – 2 MW	14° 13' 0,2"	48° 34' 46,0"	105	No	2005
STERN II	20613	Vestas V90 – 2 MW	14° 13' 21,7"	48° 34' 43,8"	105	No	2005
STERN II	20614	Vestas V90 – 2 MW	14° 13' 48,5"	48° 34' 43,3"	105	No	2005
STERN III	210552	Vestas V112 – 3.3 MW	14° 14' 15,0"	48° 34' 46,9"	140	Yes	2016
STERN III	210553	Vestas V112 – 3.3 MW	14° 13' 32,7"	48° 35' 6,6"	140	Yes	2016

Table 1: List of wind turbines with turbine type and geographical data.

The observation period for the evaluation of the blade de-icing system includes the periods from 01.01.2017 to 01.05.2017 and from 01.10.2017 to 01.05.2018. Where applicable, results have been evaluated for a reference period of one winter season for a straightforward interpretation.

3. Description of the wind turbines

Table 2 compiles the main specifications of the wind turbines considered in this report. General arrangement drawings of the turbines (to the same scale) are provided in Figure 2 and Figure 3.

Wind turbine		VESTAS V90 – 2 MW	VESTAS V112 – 3.3 MW
Type	[-]	Upwind machine with blade pitch control	
Rotor type	[-]	Three blade rotor, horizontal axis	
Rotor diameter	[m]	90.0	112.0
Swept area	[m²]	6362	9852
Rated power	[kW]	2000	2975[1]
Rotational speed	[rpm]	variable: 8.2 to 17.3	variable: 6.2 to 17.7
Cut-in wind speed	[m/s]	3	3
Cut-out wind speed	[m/s]	23	25
Hub height	[m]	105	140
Rotor tilt angle	[°]	6	6
Rotor conus angle	[°]	2	4
Blade material	[-]	Glass fiber reinforced epoxy resin and carbon fiber	
Blade length	[m]	44	54.65
Blade de-icing system	[-]	none	Hot air

Table 2: Main parameters of the wind turbines Vestas V90 – 2 MW und Vestas V112 – 3.3 MW

[1] Permanently de-rated from 3.3 MW to 2975 kW.

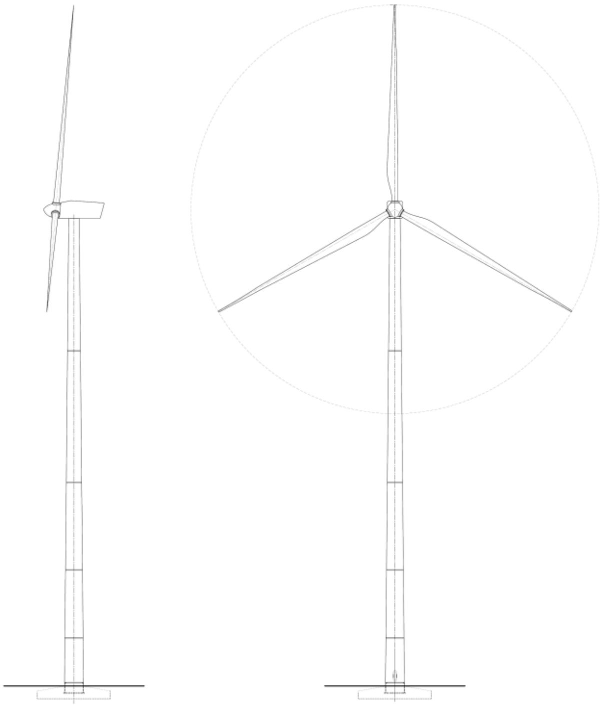

Figure 2: Wind turbine Vestas V90 – 2 MW with a hub height of 105 m.

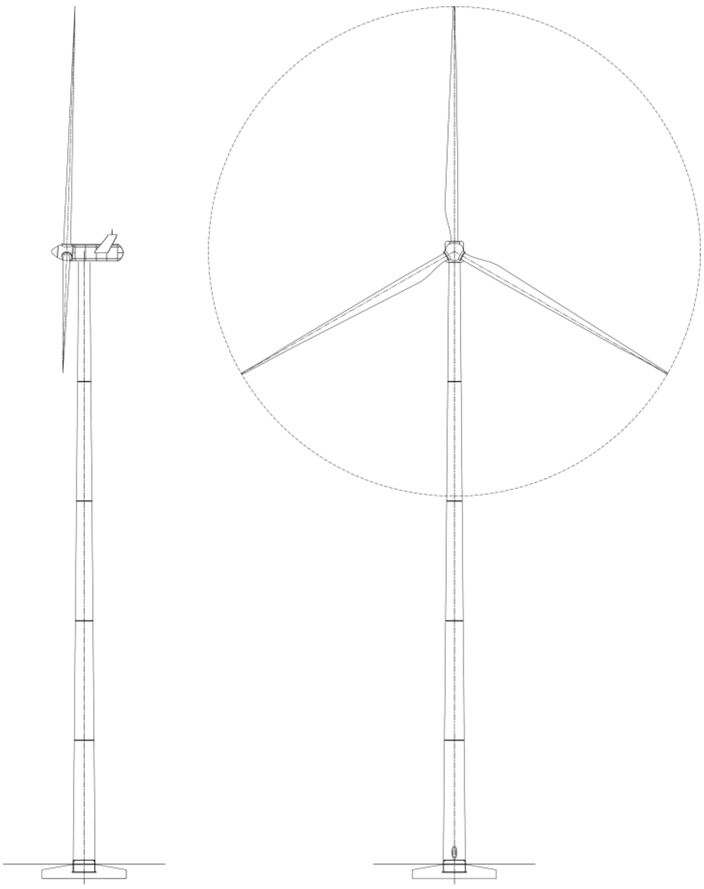

Figure 3: Wind turbine Vestas V112 – 3.3 MW with a hub height of 140 m.

3.1. Ice detection system

Ice detection in both types of wind turbines (V90 and V112) is achieved, independent from the installation of a blade de-icing system, through the power curve method and an additional BLADEControl ice detection system on each turbine.

3.2. Description of the de-icing system

The two Vestas V112 – 3.3 MW wind turbines from the wind farm Sternwald III are equipped with the Vestas de-icing system that is optionally available for this turbine. The following description of the de-icing system is based, in addition to turbine-specific information, on the document „*Allgemeine Spezifikation Vestas Enteisungssystem V112-3.3 MW 50/60 Hz*“ (Vestas Wind Systems A/S, 2015).

The Vestas de-icing system (VDS) is a hot air system for the active removal of ice from the surface of the rotor blade. The system consists, for each blade, of a hot air installation (HAI) in the root section of the blade as well as a system of air ducts which distributes the hot air to the blade sections that are to be heated. The blade heating system is designed to de-ice the blade surface along the full span in the outer third of the rotor. For the inner two thirds of the rotor, the heating predominantly acts in the area along the leading edge of the blade. Each HAI unit contains two heating elements and three axial fans. The maximum power per blade is 50 kW, rated power is 35 kW. Access for maintenance is from the hub. Power supply for the blade heating comes from the electrical auxiliary system of the wind turbine. A special power transmission system establishes the electrical connection from the nacelle to the hub. For activation of the transmission system, the rotor must be braked and locked. Control and monitoring of the de-icing system is fully integrated in the turbine control system. Apart from the additional blade heating procedure, the standard operational modes of the wind turbine remain unaffected.

Operation of the blade de-icing system

A blade de-icing cycle can be started either automatically by the ice detection system or through manual intervention. A full heating cycle last for two hours and consists of a period of 90 minutes of active heating followed by a 30 minutes cool-off time before power production recommences. The purpose of the cooling time is to allow a dissipation of the high temperature peaks before the dynamic loads are re-applied to the blade structure. As described above, the rotor is stopped for de-icing. Heating of all three blade occurs simultaneously.

According to information from the wind farm operator, the blades are usually ice-free after a blade heating cycle. Should the meteorological icing conditions persist after de-icing, new ice may form leading to a further ice-shutdown. In automatic operation, three such icing/de-icing cycles are allowed within 24 hours, though, by manual activation, more frequent de-icing is possible.

4. Results and conclusions

This section summarizes the main results and conclusions with regard to the operation of the blade heating system. Obviously, these results depend on the particular type of wind turbine and, most importantly, on the specific icing conditions at the investigated site. A straightforward generalization of these results to other sites and types of wind turbines is therefore not possible. For the classification of the icing conditions at the investigated site *Sternwald*, the recorded icing events of the V90 turbines without de-icing systems may be used. That way, one arrives at 35 to 45 icing events per year and total duration of instrumental icing of 9% to 12% of the year. In the classification system of (IEA Wind, 2011), this corresponds to the IEA icing class 3.

Total duration of blade icing: The evaluation of the operational records shows, that for this site, the blade de-icing system reduces the ice-related turbine downtime from, on average, 908 hours per year by 57% to about 387 hours per year.

Number of icing events: The total number of icing-related turbine stops is for turbines with blade de-icing with 106 events more than twice as high than for turbines without blade heating. This is caused by repetitive cycles of blade de-icing followed by new ice formation during longer periods of persistent meteorological icing conditions. Thus, for turbines with blade heating, the average duration of the ice-related shutdowns is only 3.6 hours, of which the blade de-icing procedure alone (that usually takes place during the icing-shutdown) takes 2 hours. For the turbines without blade de-icing, the average duration of icing-shutdowns is about 24 hours.

Production losses: The production losses due to icing have been computed with two different methods; with and without a 0.4 m/s correction to the wind speed measurements during shutdowns (for details see full German-language version of this report (Energiewerkstatt, 2019)). The final result is, that the utilization of the Vestas blade de-icing system leads to a reduction of the production losses due to icing between 44% (conservative estimate) and 51% (best estimate). For the investigated site, this corresponds to an increase of the annual energy yield equivalent to 116 (conservative) and 151 (best estimate) full load hours. These numbers already include the energy consumption of the blade heating system.

General observations and conclusion: Operation of the Vestas blade heating system usually leads to an ice-free rotor blade, even though subsequently new ice may form under continuing meteorological icing conditions. The total energy balance of energy production and energy expended for blade heating is generally clearly positive, also for phases with repeated cycles of de-icing and new ice formation and at moderate wind speeds. Only for a small number of blade heating cycles, subsequent energy production was not possible, either because wind died away after de-icing, or because the heating power was insufficient to overcome the heat removal from the blade dependent on ambient temperature und wind speed. In such events, the energy used for the blade heating is obviously lost. However, the reduction in total energy yield from this is comparatively small, and, for lack of predictability, hardly avoidable. Overall, for the investigated site, the limited heating capacity of the blade de-icing system represented no serious limitation. For about 87% of the time when icing occurred, wind and temperature conditions were within the specified operational limits (Vestas Wind Systems A/S, 2015) of the de-icing system.

The results of this study, specifically the reduction of icing-losses by about 50%, can also serve as a basis for an economic evaluation of blade de-icing systems. Such an evaluation is, however, only sensible with reference to a specific project, i.e. a particular wind turbine and a particular site.

Finally, it should be noted, that the results presented in this report are based on a limited data set and that some idealized assumptions have been made in the analysis. This includes small-scale variations in the local conditions and differences between the two types of considered wind. While every effort has been made to provide robust results, one should bear in mind that all numbers and conclusions also contain a certain measure of uncertainty.

5. References

Energiewerkstatt. (2019). *Evaluierung Vestas Rotorblattheizung.*

IEA Wind. (2011). *Expert Group Study On Recommended Practices 13. Wind Energy Projects In Cold Climates, 1. Ed.*

Vestas Wind Systems A/S. (2015). *Allgemeine Spezifikation Vestas Enteisungssystem V112-3.3 MW 50/60 Hz.*