Underperformance analysis of wind turbines - Icing -

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Abstract. Wind energy systems are the most promising resources on green energy, it needs to follow the increase demand of electrical energy not only by the future technologies but also with improving the performances. In this work, we present a first performance study of the “Icing System” that monitors and controls the ice detection on blades, it stops the machines when the corresponded sensor detects the presence of ice on the blades, the problem is that the status “Ice Detection Stop” is activated out of consideration of the nacelle’s position and its direction, this stop cost a lot in terms of production and incomes. The turbine restart automatically when the ice is heated and after several hours of production losses. The main idea of this article is to set up a configuration on monitoring system that refers to available database and the daily registered data from the solar met mast to fix the nacelle direction taking into consideration the sunrise and sunset. Using the sun energy, the applied process will help to speed up the heating of ice on blades and minimise the impact of the stops. As result, the availability will improve as well as the annual production of energy.

1 Introduction

The O&M takes the longest period in comparison with the previous phases (development, engineering and construction), we talk about 25 years of real operations and maintenance actions that need to be performed with high international standards in reference to the selected turbine technology. The O&M team is in charge to follow up of the production and the schedule of all different types of maintenances, taking into consideration the local constraints (environmental, permits, subcontractors...). The main strategy of the O&M department is to maximize the portfolio of production and minimize the unavailability while respecting technical and environmental constraints based on the contractual clauses. [4]

The ice detection stops is one of the important issues that face the main O&M strategy and that needs to be solved or optimised in reliable manner. The ice stops the turbine in an undefined position which does not take into consideration the daily sun positions, this work presents a contribution willing to reduce the impact of the stops caused by ice and improve the production of the wind farms using the available sun energy.

This study refers to the KPIs « key performance indicators » to perform some statistics and analysis on the main data « status data » and « 10min data » based on the available data offered by the remote control system SCADA. The analysis of the problem have shown an important ratio of stops allocated to « Ice Detection Stop » especially during the winter months, the frequency of stops is higher and have an impact on the production and the availability where the owner is the only responsible. The restart of the turbines after the « Ice Detection Stop » takes several hours per turbine depending on the temperature conditions needed to the ice melting. [10]

The developed solution of this article is to combine during the ice detection, the direction of nacelle (3 blades) in front of the sunrise and sunset points to speed up the fusion of ice on blades and activate the automatic restart trough the SCADA remote control system.

The process implemented on the remote control system SCADA will refer to the available database of the activated Shadow system and the onsite database from the local solar met mast to fix the sun positions on a daily basis. As results, the real operational availability and the monthly production will increase by reducing the duration of the occurred icing stops. [1]

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2 O&M of wind farms

2.1 Operations:

We talk about the operations phase when the development, the construction is closed and the commissioning is fully succeed for the first injected KWh. The Operations phase is based on the analysis of the performances of the wind turbines (power curve, production, reactive and active power, losses, etc.) the compliance with local regulation and current technical standards (environmental or even acoustic, etc.). [5]
The scope of work that is covered by the Operations team:

- Monitoring form SCADA remote system
- Follow up of the production
- The analysis of the performances (KPIs)
- The on call duty for incidents
- The forecast (Day-Ahead prediction)
- The coordination with the grid manager
- HSE compliance plan draft and management
- Follow-up, management and coordination of HSE legal inspections
- HSE reporting on a monthly and yearly basis
- Failure analysis (Reporting)

The onsite team of the operations are fully in charge of the close follow up of the monthly production budget and the cumulative yearly budget in reference to the P50 base on the « Yield Study » at the financial closing of the project.
Below a monthly distribution of yearly production budget that need to be achieved as a fixed target:

Table 1. « Yield Study » long-term estimation.

Month	Distribution [%]
Jan	12,97
Feb	11,09
Mar	8,94
Apr	6,73
May	6,44
Jun	4,84
Jul	5,44
Aug	5,04
Sep	6,13
Oct	9,62
Nov	10,29
Dec	12,48
Total	**100,00**

The power curve of each turbine is the reference for the internal performance of the machine. The point in the real power curve must follow the theoretical curve guaranteed by the turbine manufacturer. For some specific constraints, the turbine is curtailed to fit with the local conditions of the permits or for the respect of the biodiversity activities (if applicable).

The limited points in the following real power curve that refers to : P Ø [kW] = 0 kW at wind speed values over 3 m/s refer to the Icing Stops « Ice Detection Stop » :

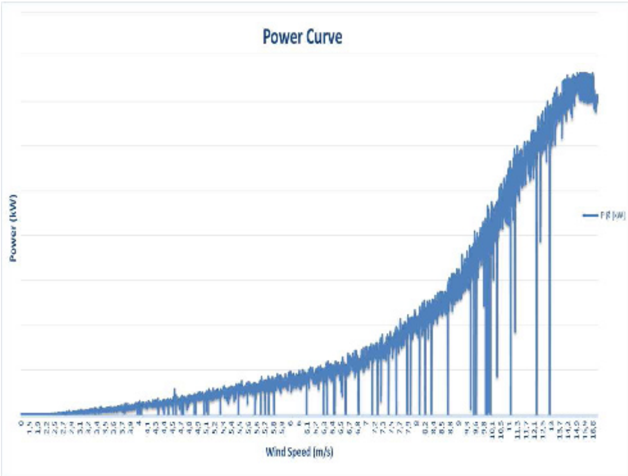

Fig. 1. « 10 min data » SCADA system

2.2 The Maintenance:

A wind farm contains more than the turbines, there is an important internal infrastructure (PDL, substations, 33 and 225KV lines that need to be maintained and cared in reference to international standards. The WTGs needs five types of interventions on the predictive maintenance plan [3]:

- Mechanical & Electrical maintenance
- Grease maintenance
- Over speed maintenance
- Master maintenance
- Visual inspection and check

The maintenance schedule in normal interventions reserves the priority to the wind conditions, generally when the average forecasted wind speed is over 6 m/s it is prior to postpone its interventions on site (except for the over speed test). [9]
The figure below shows the Pareto analysis of all registered downtimes and stops with the allocated duration in minutes. It appears that most stops were ordered by the remote control system and are caused by local constraints and obligations.
For this period analysis over than 80% of the stops are the Icing stops.

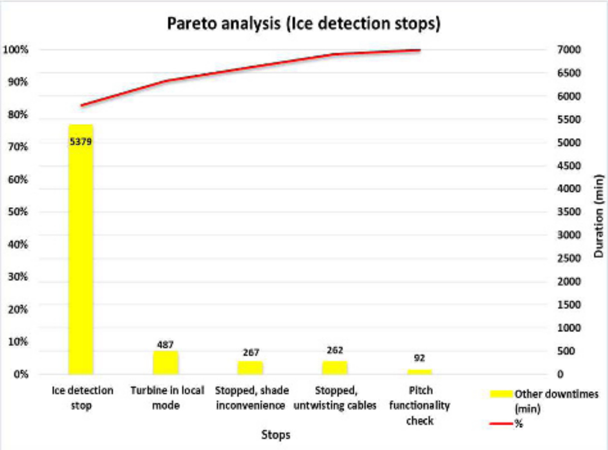

Fig. 2. Pareto analysis.

3 Icing system:

3.1 Ice detection:

The default settings of the implemented ice detection systems reflect the most current technological standards and the greatest available and possible technical safety. Thus in compliance with all local applicable legal requirements [7].
For some technical reasons, the ice detection systems can not fully and in a safety manner preclude the risk of ice throw around the platform or the access roads [2]. Means that even when using the predefined and configured default parameters, the risk of ice shedding remains unavoidable.
The O&M team is aware that modifications to the operating parameters may increase the risk of ice throw shedding and create greater hazards compared to the default settings. In particular, fragments and ice chunks created by ice on the blades may be flung for large distances. This can cause injury and property damage.[6]

Fig. 3. Detected ice on blades.

Determines if possible or not the wind turbine is allowed to restart automatically at a sufficiently high temperature. This setting exclusively applies to the ice detection system. Determines also whether the ice detector should only be active when the WTG is stopped.

Determines at which wind speed and up to which wind speed the ice detector system should or supposed to be become inactive.

Determines at which calculated rate of wind energy converters on the wind farm having detected ice formation the WTG has to be stopped. Wind farm ice detection may only be activated when all WTGs on the wind farm generate information. In particular, does not activate wind farm ice detection on mixed wind farms with older control systems that do not come with this function.

3.2 Nacelle position during Icing:

During the time where the Ice detection alarm is applicable, the WTG receive to order to stop the production with no order of the nacelle stop direction (green points on the figure below). Determines whether or not the nacelle should be oriented in a specific direction during ice buildup at wind speeds of up to 7 m/s, the WTG may not be aligned with the wind. This may cause damage to the WTG.

Nacelle position at icing determines which position in degrees (0°= North) the nacelle turns to during icing when positioning is activated. Setting range Standard Operator/owner request 0 – 359° -
A shorter detection time does not affect the sensitivity of the ice detection system. For an automatic restart during icing or for a restart after icing by means of the blade heating system, the counter for status is reset as defined for each.

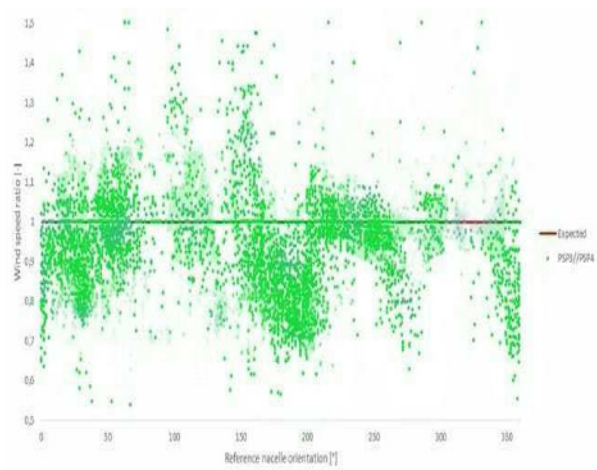

Fig. 4. Nacelle directions during icing stops.

In the figure above the green points represents the registered nacelle direction of all turbines in comparison with the average expected direction for a limited period, the recorded directions are random without any consideration of the sunrise or sunset points. The automatically restart takes several hours of delay waiting for the dissolving of ice.

3.3 SCADA configuration:

To set a final position in front of the sun set the Scada need to refer to the registered data of Shadow stops witch include detailed information about the exact point of the sun. This database is available on Scada system and updated depending on the available data.

In addition, the received signal from the solar met station contains many data including the irradiation and the sun position on daily basis. [8]

The script refer to the available and certain to communicate the position (see the Sequential Function Chart below):

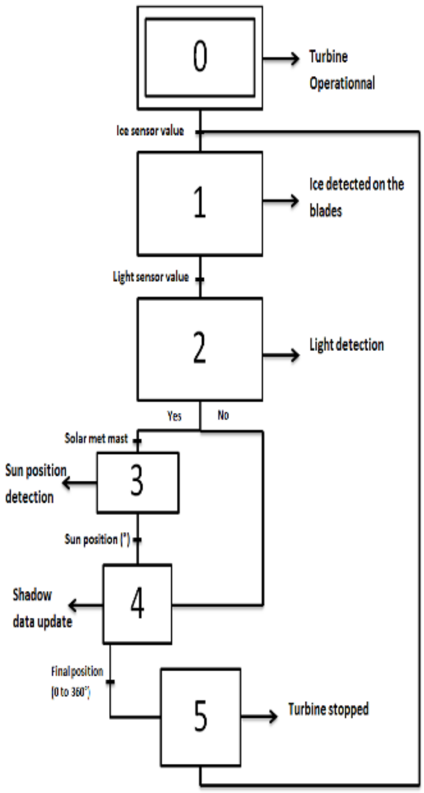

Fig. 5. Sequential function chart.

On the SCADA server and the FTP, the configuration is possible for the operator trough the opened parameters that allow some specific updated on the stop/start times and duration. It is also possible to upload a specific protocol of operations in common collaboration with the manufacturer.

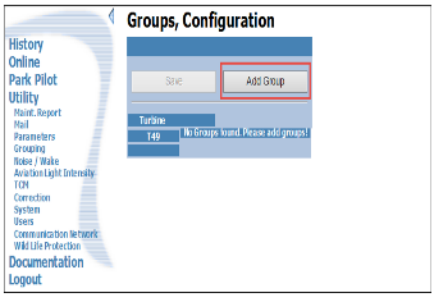

Fig. 6. SCADA protocol for configuration.

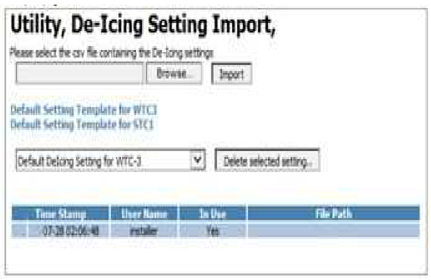

Fig. 7. SCADA protocol for configuration.

Setting range	Standard	Operator/owner request
0 – 359°	-	

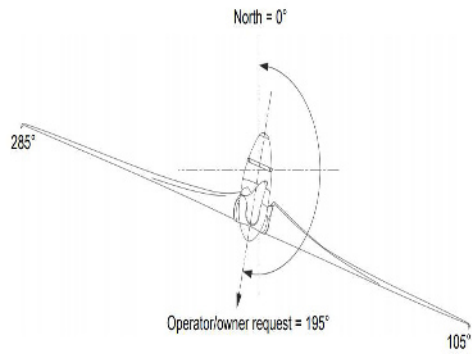

Fig. 8. Uploaded directions of turbine nacelle.

3.4 Results:

The simulated results in the figure below shows the reel and final nacelle directions after the configuration of the sequential function chart on the SCADA remote control system. The green points represent the directions of the nacelle in reference to the local inputs.
The red line shows the theoretical directions that must be applicable after the configuration, the uncertainty between the reel and the theoretical values range approximately from 5 to 10%:

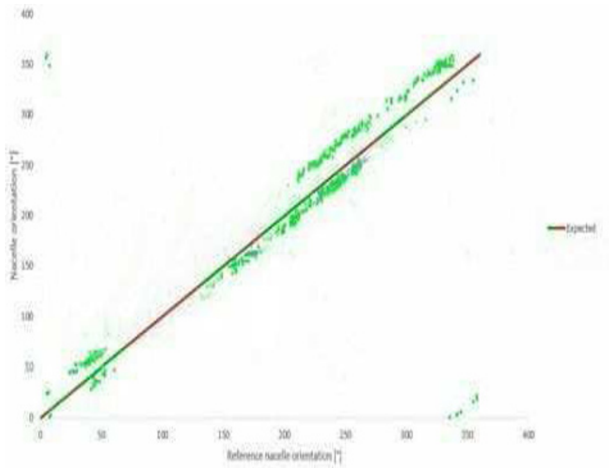

Fig. 9. Real nacelle directions.

3.5 Comparison and interpretation :

The results in figure 9 confirms that experimental results of the nacelle direction (green points) are so closed to the reference nacelle direction needed for the implementation of the process (red line). Therefore the nacelle direction before the implementation of the system shows and random of directions that are so far from the needed and referenced directions.

The appeared results will have a considerable impact on the availability of turbines during the winter months and as consequence, the production volume of the wind farm will increase in line with the added rate of availability. [11]

We estimate that the applied solution will reduce the unavailability allocated to “Ice Detection Stop” depending on the irradiation and the meteorological conditions on plant zone. This improvement of availability can be added to the contribution of other key performances (bats curtailment, noise curtailment, shadow stops…) in the total yearly operational availability of the wind farm.

3.6 The automatic restart after Icing:

The configured script on the SCADA ddetermines whether or not the wind turbine is allowed to restart automatically at a sufficiently high outside temperature. This parameter applies exclusively to the power curve method.
The ice sensor detect that there is no ice accumulation on the three blades.

Determines whether or not the wind turbine should attempt to restart at 6-hour intervals while ice is still forming. This parameter can only be activated when automatic restart after icing is activated.

4 Conclusion

Improving the performances of wind farms and ensuring their proper functioning over time is the main objective in a growing market, which is becoming more and more demanding and competitive. While striving to achieve these goals at the lowest cost during years of operations, the managers in charge of the O&M have always faced a variety of problems and difficulties, from planning issues to managing different underperformance indicators.

We have proposed a solution for one of the key performance indicators « Ice detection stops » that become a major factor that have an impact on the yearly availability and the production of wind farms, the solution based on the optimization of undetected unavailability where it is possible to overcome by working on related key factors. Using the sun energy to speed up the dissolving of ice on turbine blades by working on the nacelle positions and directions in reference to available database or to the onsite sensors (solar met mast).
It is known that a short increase in the yearly availability of multiple turbines can generate important incomes to the owner and to the SPV in charge or the O&M. The proposed solution will have an indirect impact on the local needs of electrical energy especially during the winter month where the consumption is higher and the price is important.
It is possible to conduct the same analysis for other key indicators (shadow, bats curtailments or noise limitations) to minimize their impact and reduce the generated curtailments of the total capacity.

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