GAMESA solutions for Cold Climate Conditions

GAMESA Solutions for Cold Climate Conditions

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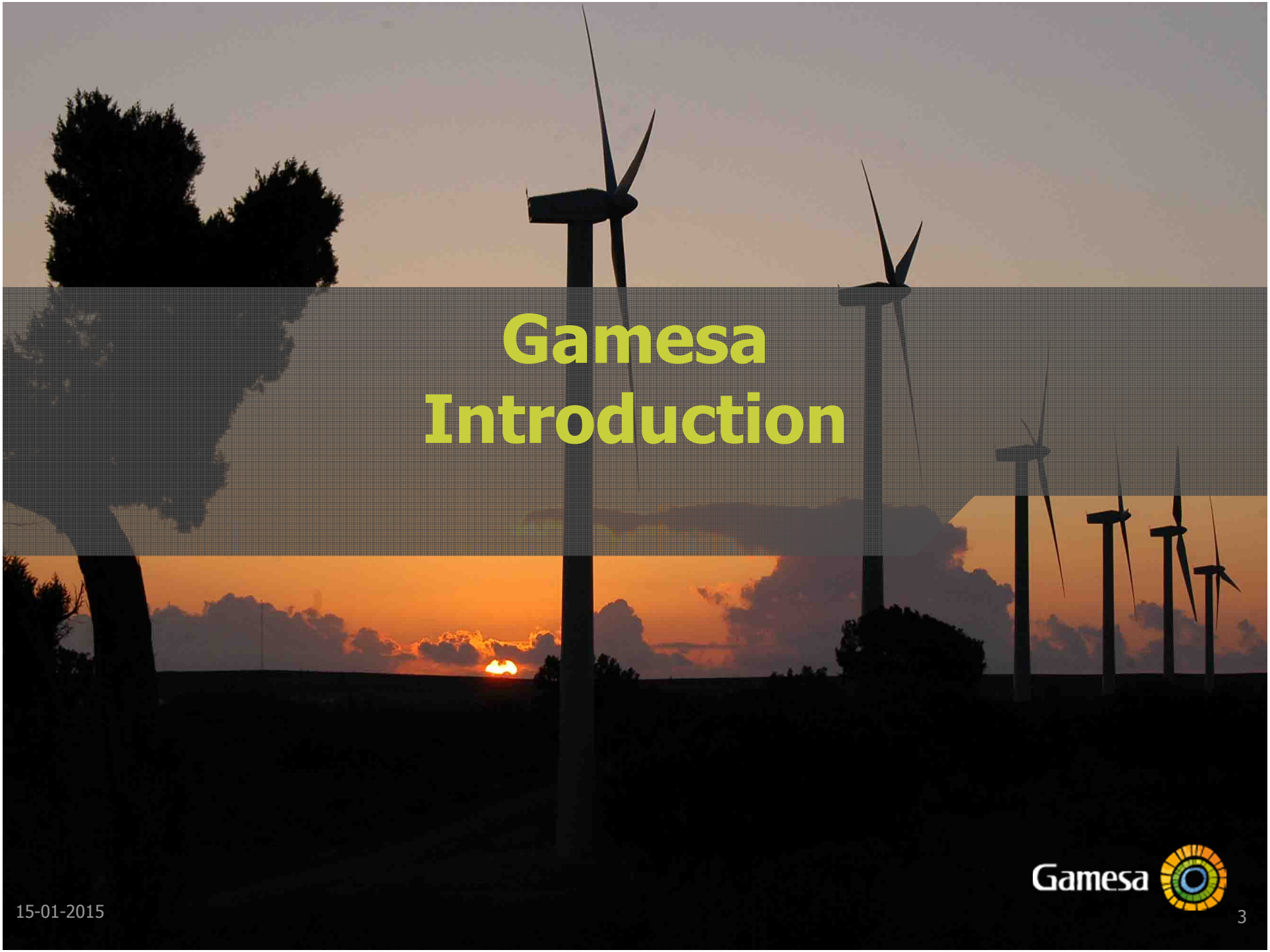

Gamesa Introduction

GAMESA Solutions for Cold Climate

Introduction

Gamesa has developed a set of ~~several tailor-made~~ ~~solutions~~ technologies for optimal adjustment to several icing environments mitigate the impact of ice formation on wind turbine performance and safeguard operation ~~during the icing events~~.

- ✓ **Anti-icing (Bladeshield™)**. General purpose passive coating reducing the ice formation on the wind turbine blades.
- ✓ **Blade De-icing System (BDS)**. An active solution for medium intensity icing sites based on hot air circulation inside blade.
- ✓ **Ice Prevention System (IPS)**. An active solution for high intensity icing sites based on blade surface heating, avoiding ice build-up during the wind turbine operation.
- ✓ **Ice specific WTG control strategy based on efficient detection.** The Ice Detection System (IDS) and Ice Mode Strategy (IMS).

All previous technologies can be complemented in order to achieve the best possible result.

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Anti-icing (BLADESHIELD®)

ANTI-ICING Coating

DESCRIPTION

- High resistant single layer hydrophobic coating based on HSPUR paints.

MAIN CHARACTERISTICS

- Anti-icing solution using current Gamesa paints, based on nanotechnology to achieve hydrophobicity.
- A coating for partial / whole blade, combining high durability and functionality.
- Applicable both in manufacturing facilities (Airless spray gun) and in field (Roller/Brush) for retrofitting exsiting windfarms.
- Alone or in combination with active systems, minimize energy consumption to assure de-icing.
- Future developments aimed at its application to all blade types (non Gamesa, infusion, other paints, etc.).
- Patent pending.

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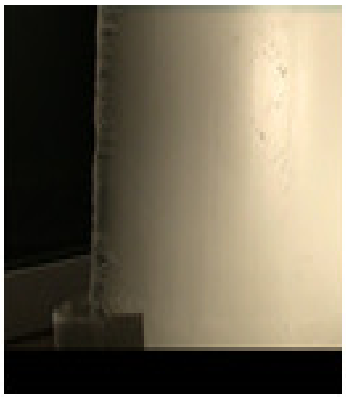
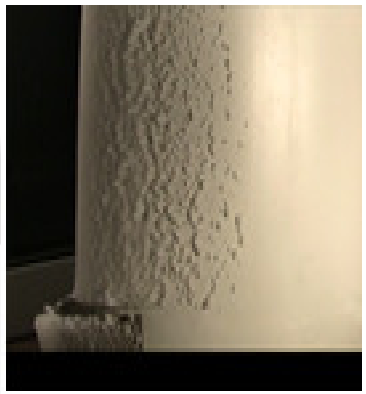
ANTI-ICING GAMESA SOLUTION

Validation tests at medium scale level: Wind tunnel

Demonstrator fabricated and painted with anti-icing coating



Anti-icing - **OK**



Reference – **NO OK**

IT IS OBSERVED A SIGNIFICANT DELAY OF THE ICE FORMATION WITH ANTI-ICING SOLUTION.

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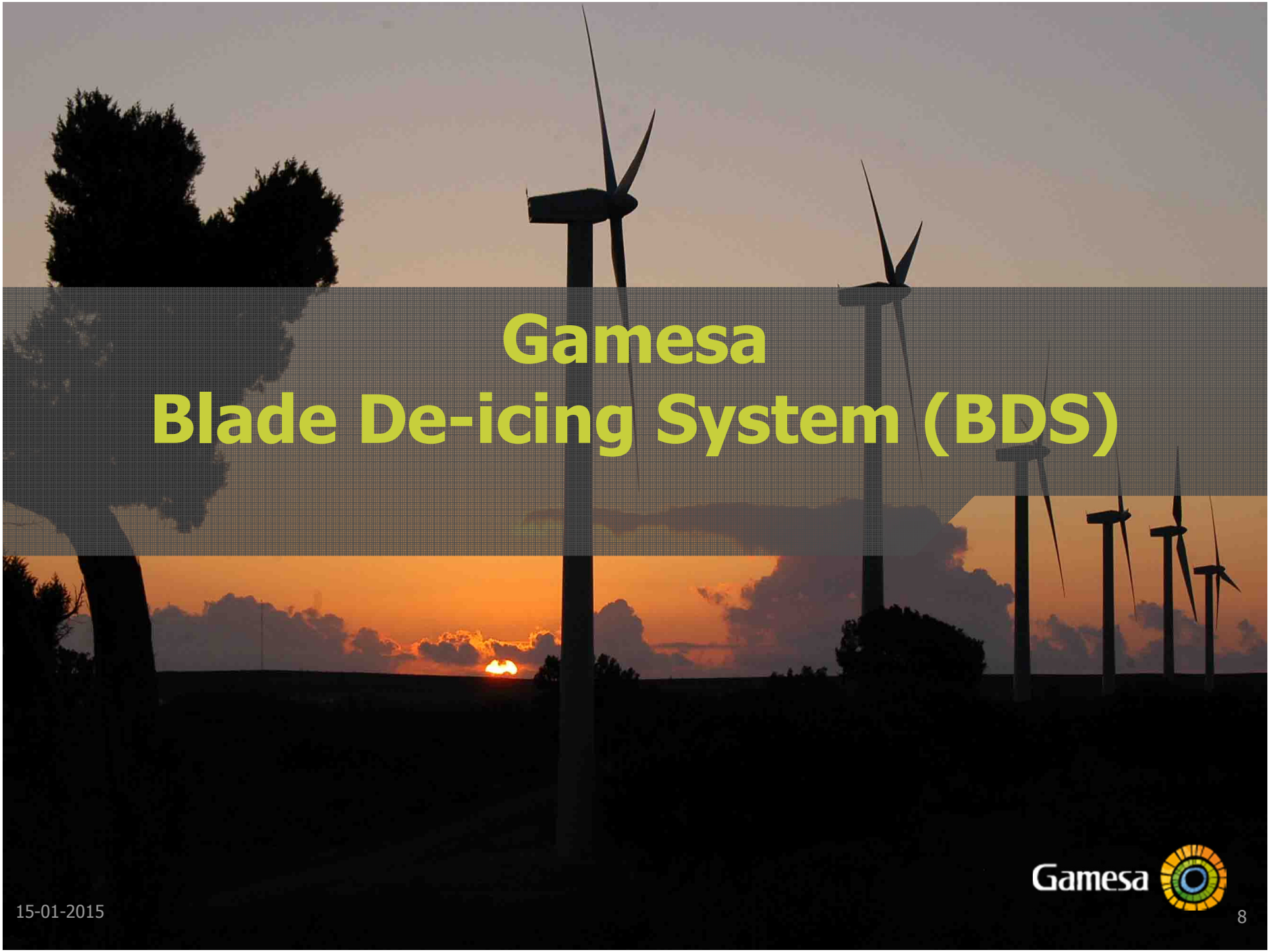

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Blade De-icing System (BDS)

Blade De-icing System (BDS)

Remove ice accreted on blades to recover ITS aerodynamic performance, and hence energy production

De-icing System Overview

- **Concept** → Blowing hot air inside the blade conducts towards the tip. Air returns back for reheating system. Heat flows from the inner blade side to the outer blade side, thus melting the ice.
- **Components** → The system comprises a fan and a heater, located at blade root.
- **Power** → power consumption is 80kW per rotor, when the deicing system is ON in all 3 blades.
- **Control** → PLC switches several heating levels to minimize the power consumption.
- **Time to detach ice** → Depends strongly on the icing and temperature conditions on site.
- **Third party patent infringement free.** System implemented in each market has been studied to guarantee infringement free.

Blade De-icing System (BDS)

System Description

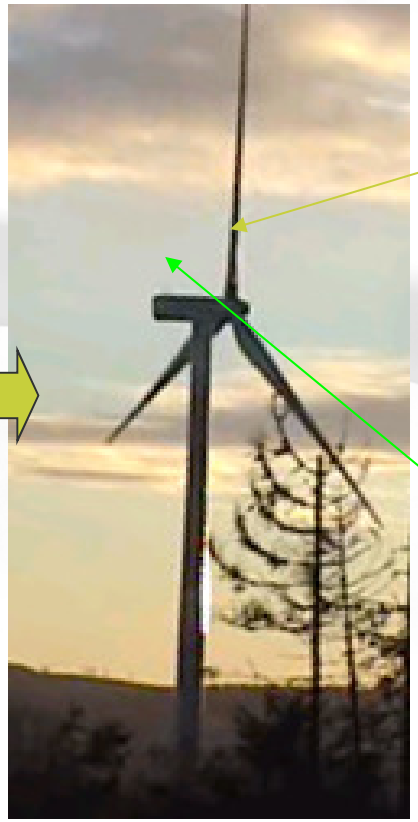
On field validation

Different components are installed at the wind farm to monitor the ice accumulation and de-icing system performance:

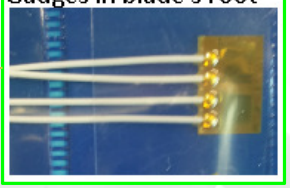
Thermographic camera

To Gamesa Servers via SCADA

PCs for logging DAS data



Gauges in blade's root



Barometer

Webcam pointing at instrumented WTG

WTG seen from webcam

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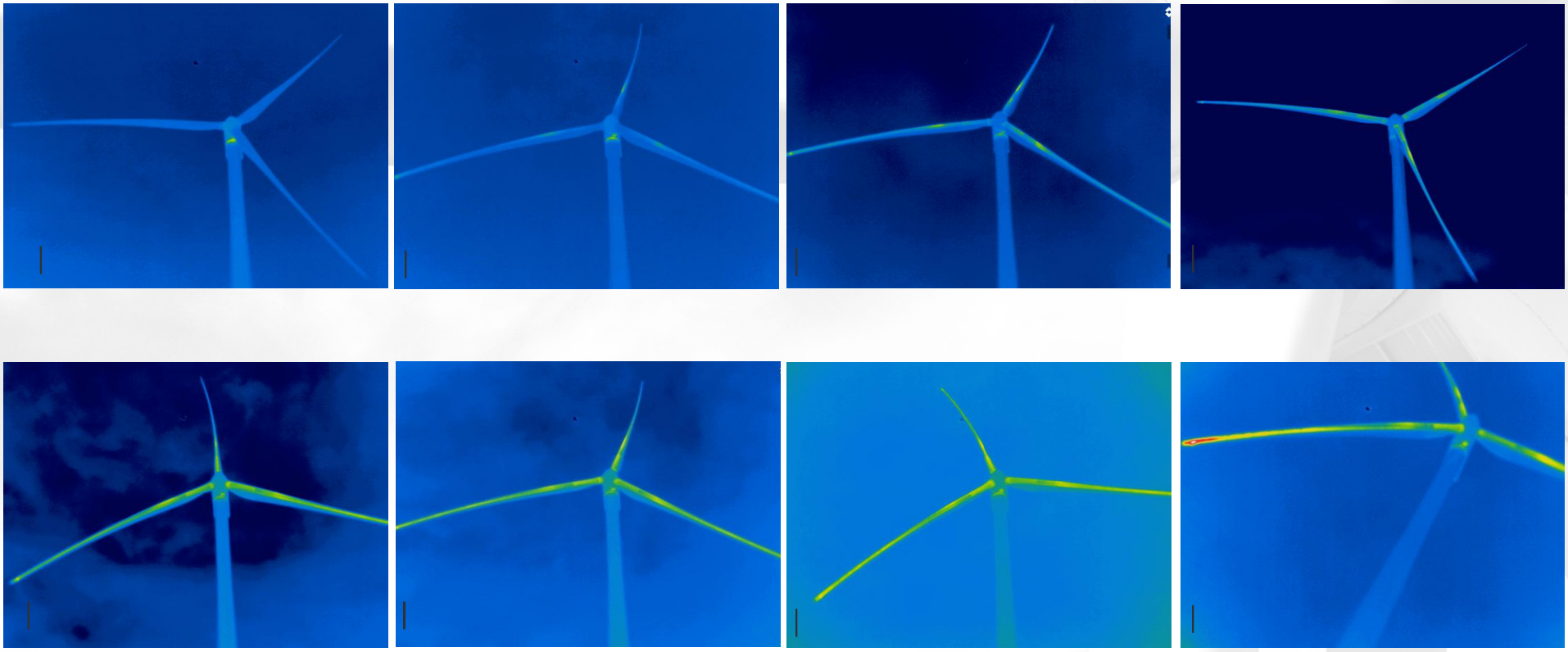
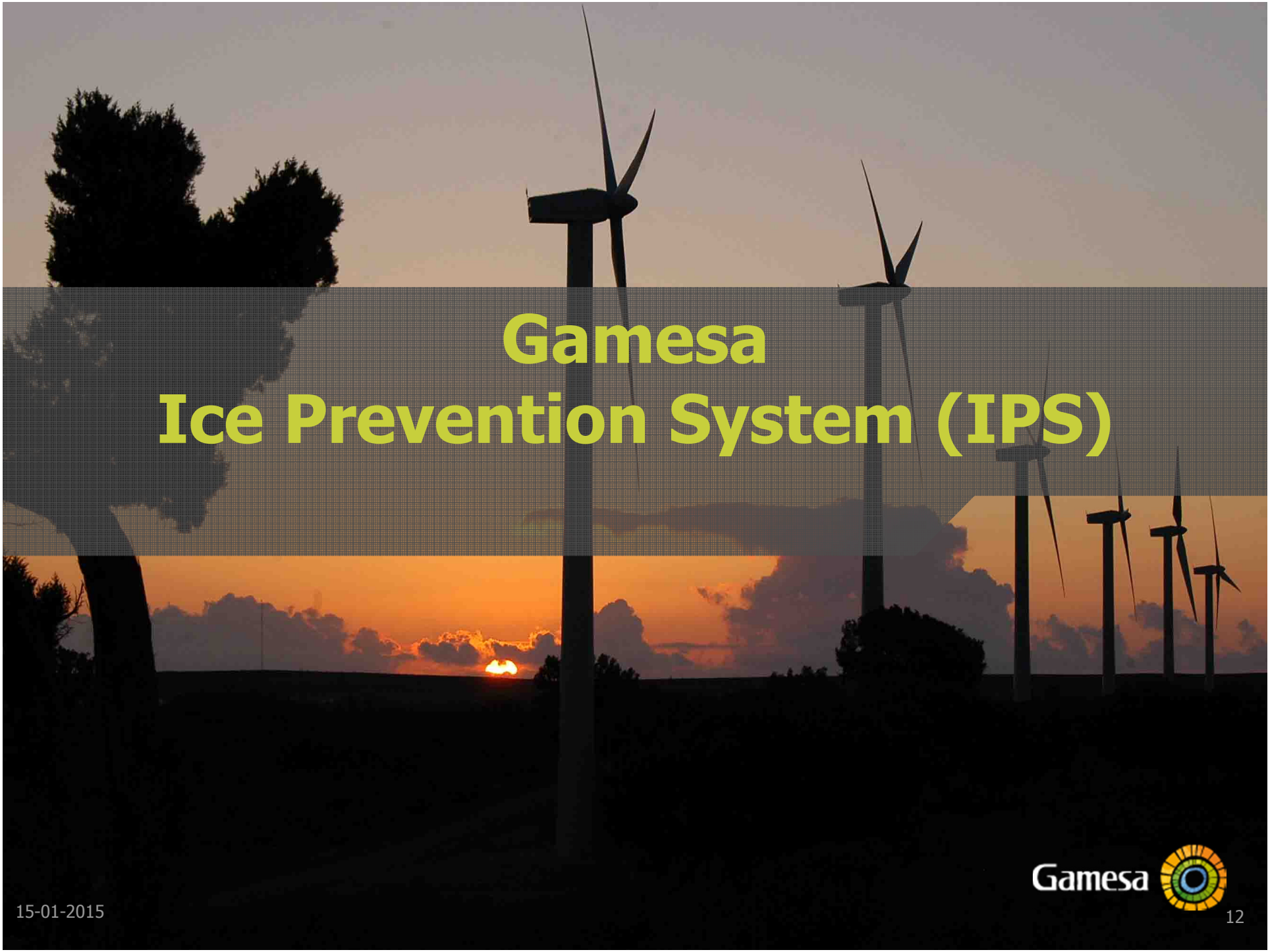
Blade De-icing System (BDS)

System Description

On field validation

- All results and empirical measurements have been as expected.
- Thermal imaging camera images in sequence of the de-icing system operation at a temperature of -8º C.:





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Ice Prevention System (IPS)

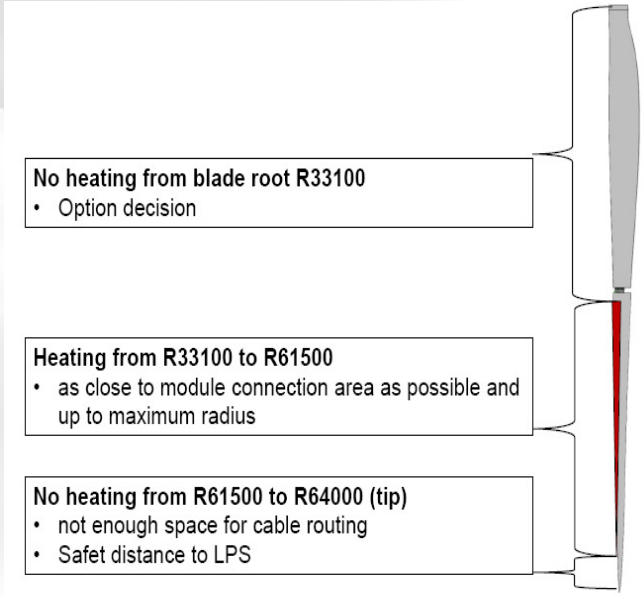
Ice Prevention System (IPS)
Objectives and System Description

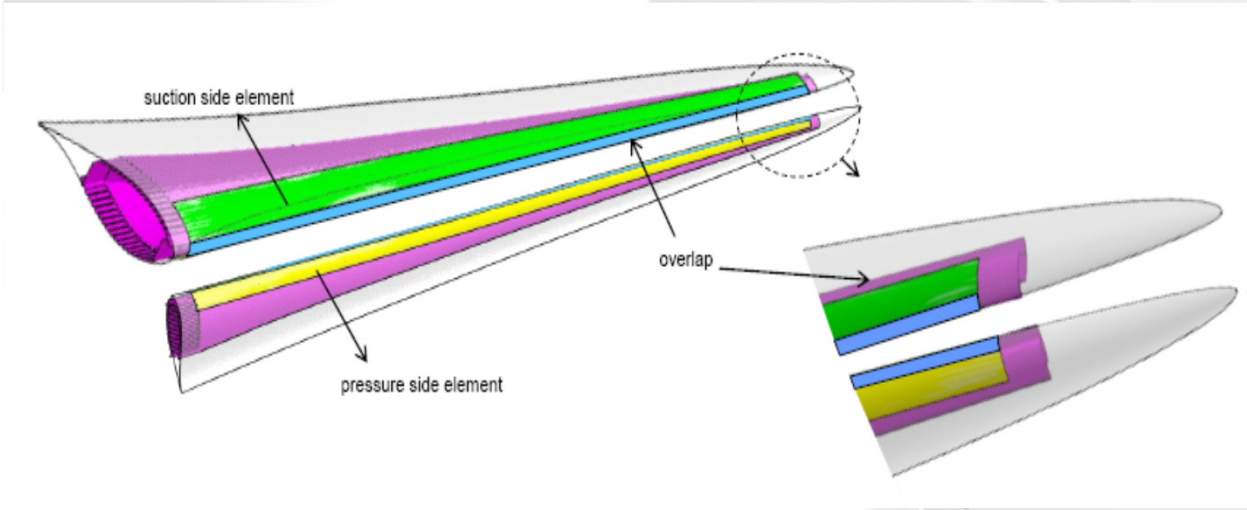
IPS Main Objective:

- Maintain aerodynamic blade performance, and hence energy production, by avoiding ice presence on the key parts of the blades in order to ensure efficient operation.

IPS System Description:

- Electrical circuit heater in outboard blade LE, composed by two carbon fiber dry layers.





Ice Prevention System (IPS)

Objectives and System Description

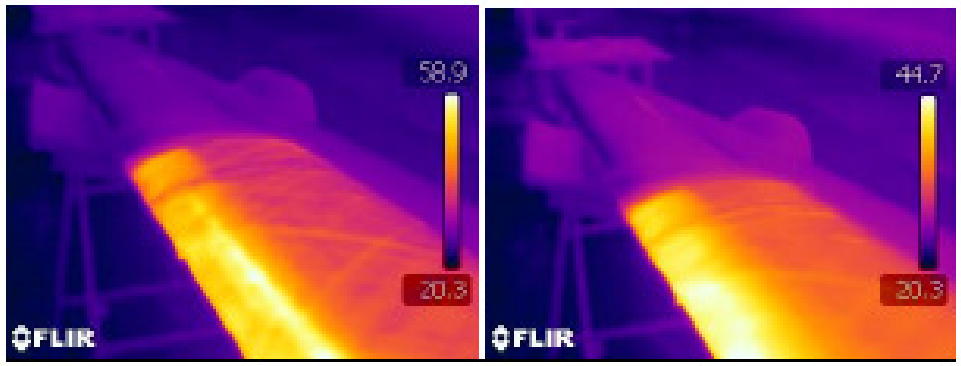
Lightning Protection System (LPS) Validation:

LPS requirements accomplished thanks to:

- Know-how of LPS design for Gamesa's carbon fiber blades.
- Validation of the combinded operation of the LPS with Ice Prevention System at laboratory.

System Validation:

- Thermal capacity tested successfully on an actual blade.

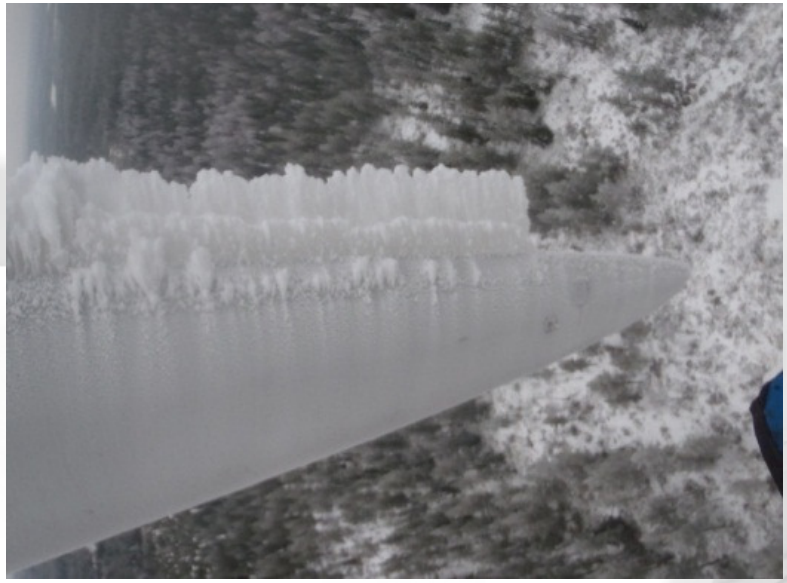


Ice Prevention System (IPS)
Objectives and System Description

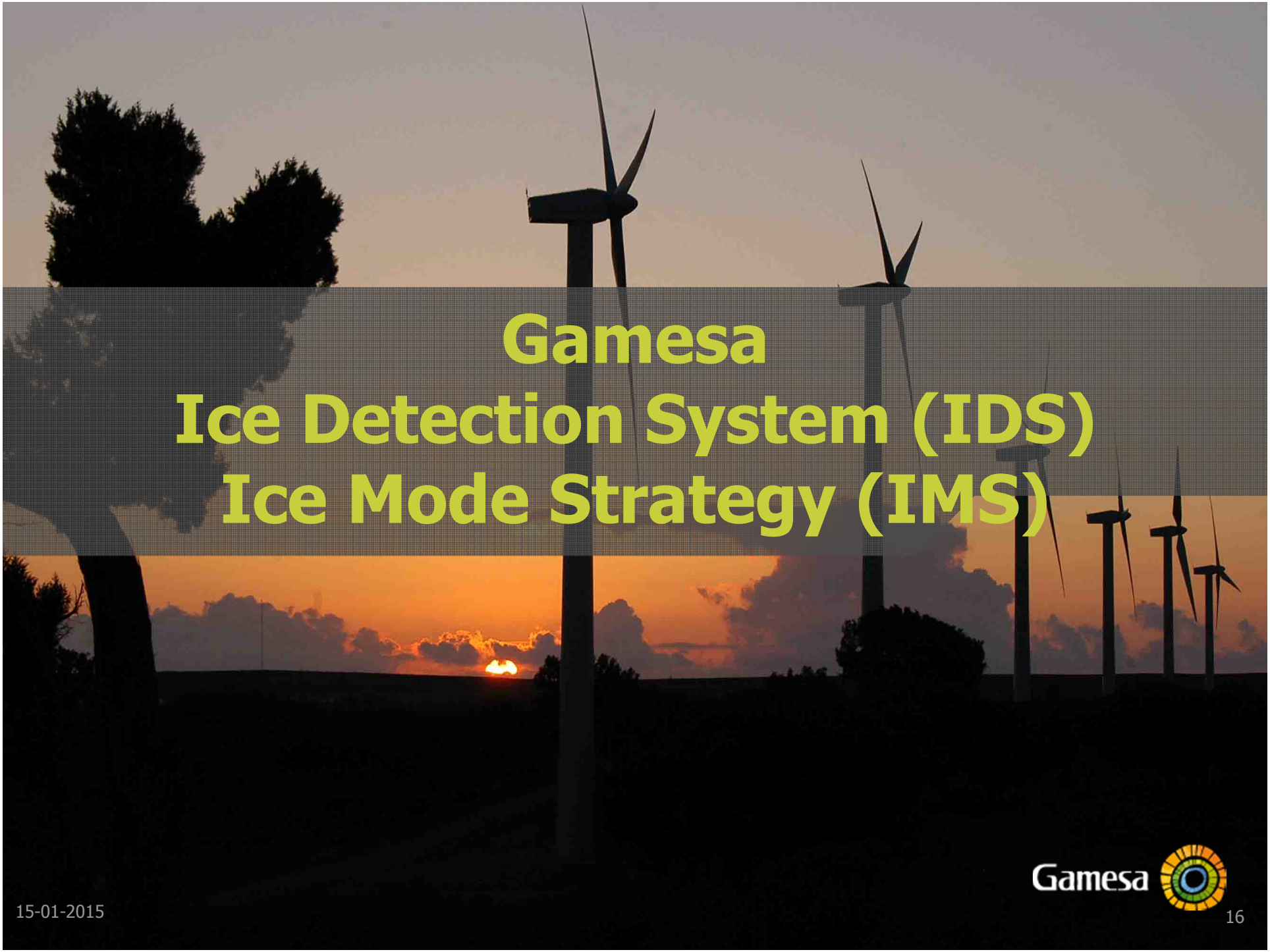
Prototype Validation:

- IPS Validation will be fully completed during next winter 2014-15 on prototype installed in Tornio, Finland, on one G10x Modular (Segmented) Blade Rotor of the G10X-5MW.

G10x-5MW WTG at Finland site



Ice conditions on a G10x-5MW Blade (with IPS switched off) at Finland site



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Ice Detection System (IDS)
Ice Mode Strategy (IMS)

Gamesa G10X: IDS & IMS

Ice Detection System (IDS)

- **COMBINATION OF DIFFERENT TECHNIQUES TO DETECT ICE ACCRETION ON BLADES:**
  - **Ice sensor:**
    - Ultrasound-based ice detector provides information about arctic conditions suitable for ice formation.
  - **Environmental conditions:**
    - Temperature, humidity, pressure, … are computed in order to determine environments leading to a taxonomy of ice type formation.
  - **Operational performance:**
    - Overall performance is suboptimal due to ice accretion on blades.
    - Performance is monitored through several wind turbine control variables.
  - **Component Eigen modes:**
    - Mechanical and structural properties of the wind turbine components vary due to ice and temperature.
    - Specific Eigen frequencies are monitored with blade load sensors, tower accelerometer, etc.

- **ICE TYPE AND MASS IS DETERMINED BY THE SMART COMBINATION OF ALL THESE FACTORS.**

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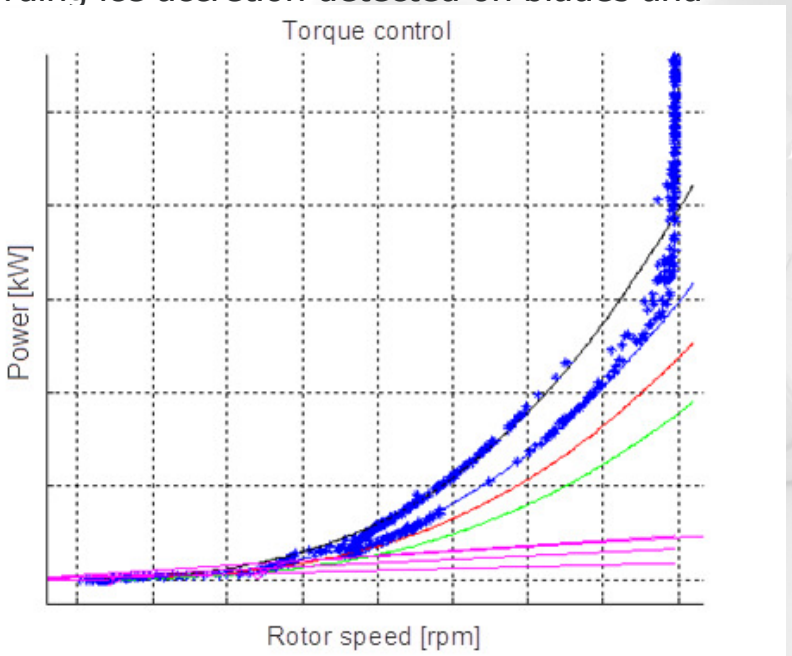
Gamesa G10X: IDS & IMS

Ice Mode Strategy (IMS)

- **CONTROL ADAPTATION TO DIFFERENT ICE CONDITIONS AND TYPES:**

  - **Start-up optimization:**
    - Low performance of iced blades makes standard start-up logic not suitable on icing conditions.
    - Standard start-up logic is modified according ice accretion detected on blades and environmental conditions.

  - **Torque control adjustment:**
    - Torque demand is adapted dynamically to icing conditions allowing to achieve the optimum energy productionj set point for every specific icing condition.



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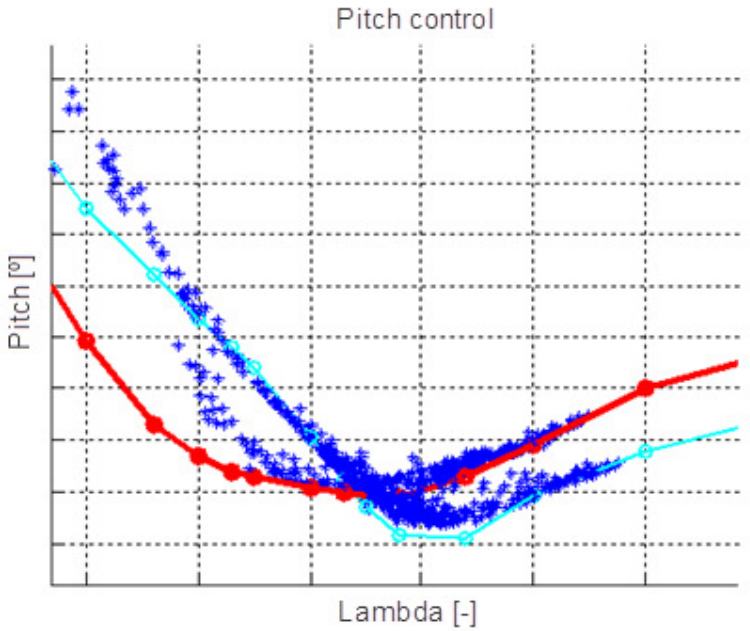
Gamesa G10X: IDS & IMS

Ice Mode Strategy (IMS)

- **Pitch control modification:**
  - Standard pitch set points are not suitable for iced blades where aerodynamic profiles change.
  - Specific pitch laws are designed for each ice taxonomy is determined.



- **Active ice removal techniques:**
  - Special techniques based on pitch dynamics are implemented aiming to actively detach ice on blades.

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Gamesa G10X: IDS & IMS

Summary

- **Gamesa wind turbine controller integrates advanced ice detection algorithms:**
  - Ice Detection System (IDS)
- **Gamesa wind turbine controller automatically adapts to ice detected:**
  - Ice Mode Strategy (IMS)
- **Different ice classes and accretion levels are categorized to optimize control strategies application.**
- **IDS & IMS aimed to minimize energy production loss due to ice.**
- **G10X wind farms in Finland are equipped with a IDS & IMS controller with successful results.**

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Thank you!

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