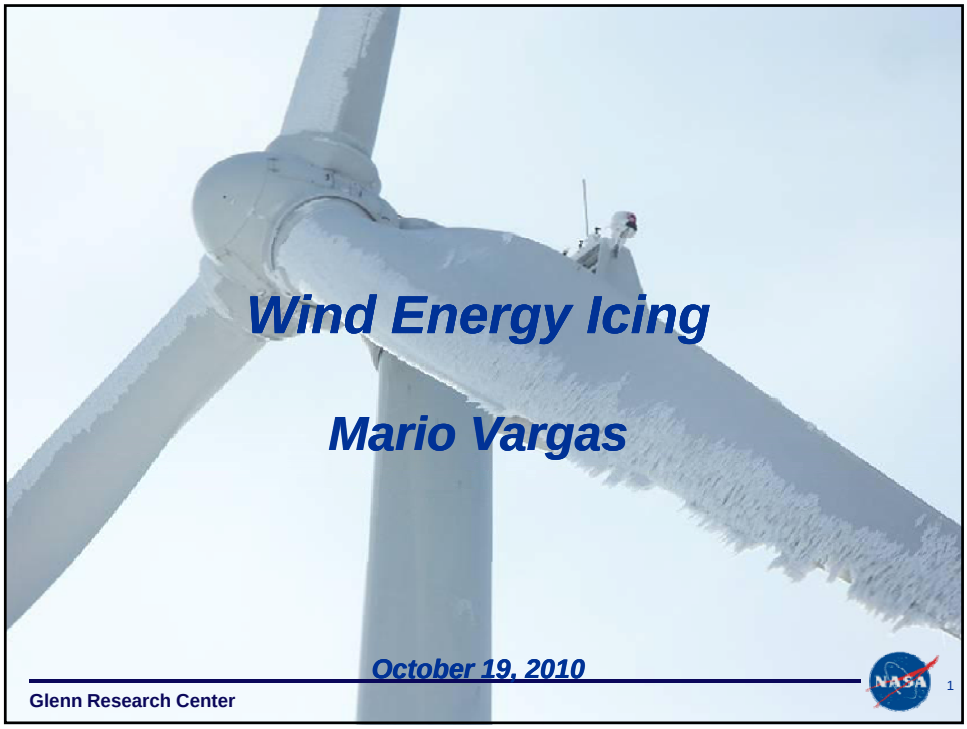


Wind Energy Icing

Mario Vargas

October 19, 2010

Outline

- Cold weather effect on wind turbines
- Wind turbine problems due to icing
- Icing Branch areas of expertise in Aircraft Icing
- Icing Branch areas of expertise applicable to Wind Energy Icing

Cold Weather Effect on Wind Turbines

Cold Weather Effect on Wind Turbines
Major Concerns

- Low temperature effect on wind turbine components
- Impact of snow
- Impact of ice accretion on the rotor blade and on structures and surfaces

"Ice accretion represents the most significant threat to the integrity of wind turbines in cold weather"

(Dalili et al., 2009)

Wind Turbine Problems due to Icing

Wind Turbine Problems due to Icing
Types of Icing

- In-cloud icing
  - Super-cooled water droplets impinge on a surface
  - Glaze ice, rime (soft and hard) ice and mixed ice
- Precipitation icing (rain or snow freezes after striking a surface)
  - Freezing rain, wet snow
- Frost (water vapor solidifies directly on a cold surface)

Wind Turbine Problems due to Icing
Aerodynamic Effects

- Ice accretion on turbine blades nearly always decreases power production
  - Power losses due to change in the shape and roughness of the blades affects their aerodynamic characteristics (Marjaniemi and Peltola, 1998; Jasinski W.J. et al.,1998)
  - At locations with high icing incidence the power loss is typically in the range of 20-50% (Talhaugh L. et al., 2007)
  - Complete stoppage of the turbine in severe icing conditions
    - Significant production losses as records from Sweden and Finland indicate (Jasinski et al., 1998)

Wind Turbine Problems due to Icing
Aerodynamic Effects

- Delayed stalls
  - Rime ice may assume the shape of a leading edge flap
  - Increase lift coefficient delaying aerodynamic stall to a higher angle of attack
  - Increase in maximum power beyond rated limits with damage to turbine components

Wind Turbine Problems due to Icing
Mass Imbalance

- Increases the loads imposed on all turbine components (Talhaugh et al., 2007)
- Asymmetric masses cause a mass imbalance between the blades
- Excitation of edgewise vibrations
- Resonance may occur due to the changed natural frequencies of the blades

Wind Turbine Problems due to Icing
Safety Risk

- Ice thrown from rotating blades is a serious safety issue
  - Public roads, housing, power lines, shipping routes
- It is an ice adhesion problem
  - Large pieces can strike the rotor blade and damage it
- The Wind Energy Production in Cold Climates project collected data and gave an equation for a rough estimate

$$d = 1.5\,(D + H)$$

d = distance thrown
D = diameter of the rotor
H = height of the nacelle

Wind Turbine Problems due to Icing
Icing Effect on Instrumentation and Controls

- Anemometers, wind vanes and temperature sensors can be affected by ice
  - Wind errors as high as 30% (Laakso et al., 2003), which affect the yaw and power controls

Additional Technologies Required when Operating Wind Turbines in Icing

- Ice protection systems
- Ice accretion modeling
- Ice detection
- Remote sensing of icing conditions

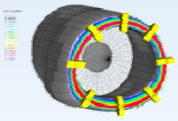
Icing Branch Areas of Expertise in Aircraft Icing

Aircraft and Engine Icing Research

Icing Tunnel Research

- Icing Physics
- Ice Accretion Aerodynamics
- Scaling Methods
- Experimental Methods
- Ice Protection
- Ice Accretion Modeling
- Rotorcraft

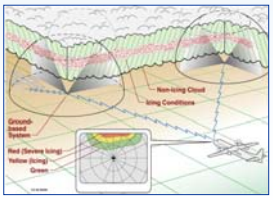
Computational Tools



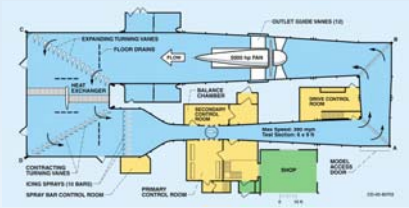
Flight Research

Experimental Methods and Databases

Aircraft Ice Protection



Current Research Assets



Icing Research Tunnel (IRT): ice accretion, ice physics, and icing scaling studies, new ice protection/detection/sensing methods, validation databases, test methods

Droplet Imaging Flow Tunnel (DrIFT): imaging/optical/ droplet test techniques development

Vertical Icing Studies Tunnel (VIST): study of micro-physical icing phenomena: water transport, heat transfer, roughness modeling, boundary layer flow, phase change kinetics

Current Research Assets

Twin Otter: atmospheric research, natural conditions flight testing, iced flight aerodynamics– non-swept wing

Remote Sensing Ground Site: for developing and assessing remote icing condition detection algorithms

S-3 Viking, Icing Research Aircraft (IRA): atmospheric research, natural conditions flight testing, iced flight aerodynamics

Icing Simulator: tool for developing methodologies for iced aircraft controls

Aircraft Icing Areas of Expertise Applicable to Wind Energy Icing

Aircraft Icing Areas of Expertise Applicable to Wind Energy Icing

- Icing Physics
  - Physical mechanisms that lead to the formation of glaze ice, mixed ice, rime ice
  - Roughness formation and effect
  - Supercooled Large Droplets (SLD) – freezing rain
- Ice Accretion Aerodynamics
  - Aerodynamic performance degradation due to roughness and ice accretion formation

Aircraft Icing Areas of Expertise Applicable to Wind Energy Icing

- Ice Accretion Modeling
  - Computational modeling of ice accretion formation and ice protection systems
  - LEWICE 2D and LEWICE 3D
- Scaling
  - Extending scaling methodologies to new airfoil configurations

Aircraft Icing Areas of Expertise Applicable to Wind Energy Icing

- Experimental Methods
  - Experimental techniques for testing in icing tunnels
  - Icing tunnel testing of airfoil configurations
- Ice Detection
  - Instrumentation needed for ice detection and measurement of icing meteorological conditions
  - Remote sensing techniques for measurement of icing conditions

Aircraft Icing Areas of Expertise Applicable to Wind Energy Icing

- Rotorcraft
  - Wind tunnel testing
  - Ice accretion simulation, development of computational tools

End of the Presentation