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Wind Energy Development in Harsh Environments
Subtopic 3: Design and Installation Challenges

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Design and Installation Challenges

1. Design Standards and Certification
2. Environmental Considerations
3. Turbine suitability
4. Cold weather packages and cold weather turbine shutdown
5. Material specifications
6. Foundations and Civil design
7. Electrical
8. Turbine transportation, installation and operation

Turbine Design Standards and Certification

International Standards

- International Electrotechnical Commission (IEC): IEC 61400-1 Wind Turbines – Part1: Design requirements
- Germanischer Lloyd (GL) Guideline for the Certification of Wind Turbines

Canadian Standards

- Canadian Standards Association (CSA): CAN/CSA-C61400-1:08
- Suggested deviations from the IEC standard
- External conditions such as wind speed and temperature
- Electrical and building code standards

Certification of Wind Turbine Designs

- Design, type certifications and Statement of Compliance
- GL, DNV, TÜV Nord, etc
- CSA standards only been used a guide as turbines not currently certified to them
- Requirement for turbine [structural] design certification in Canadian projects is typically from Owners and Lenders to ensure project lifetime

Environmental Considerations

The IEC wind turbine design classes consider the following

- Long-term annual wind speed
- Extreme gust wind speed
- Turbulence intensity
- Extreme wind direction change
- Extreme wind shear
- Temperature range

Wind turbine class	I	II	III	S
V_{ref} (m/s)	50.0	42.5	37.5	Values specified by designer
A	0.16			
B	0.14			
C	0.12			

IEC 61400-1 ed. 3. Subclass A, B and C refer to turbulence intensity

Other Environmental Considerations

IEC 61400-1 suggests consideration of the following:

- **Temperature ***
- **Humidity ***
- **Air density ***
- Solar radiation
- **Rain, hail, snow and ice ***
- Chemically active substances
- Mechanically active particles
- **Salinity ***
- Lightning
- Earthquakes

** Newfoundland and Labrador considerations*

Environment Canada: source for extreme wind speeds and temperature

Environmental Conditions Related Issues

Loss of turbine performance and availability from:

- Power demand from heating
- Blade and anemometry icing
- Maintenance difficulties
- Access disruption to turbines and substations

Increased turbine loading from higher air densities

Safety concerns such as falling ice – turbine setback distances

Corrosion

Is your turbine suitable?

Important to assess site meteorological conditions beforehand

Guidelines from GL *Wind Turbines for Extreme Temperatures (cold climates)*:

- Definition of a cold climate (and when a cold weather package is required) is less than -20^{o}C for more than 1 hour in 9 days per year

Additional certification requirements such as:

- Corrected air density for load calculations
- Appropriate material selection
- Consideration of thermal expansion stresses
- Heaters for components
- Protection of electronic devices

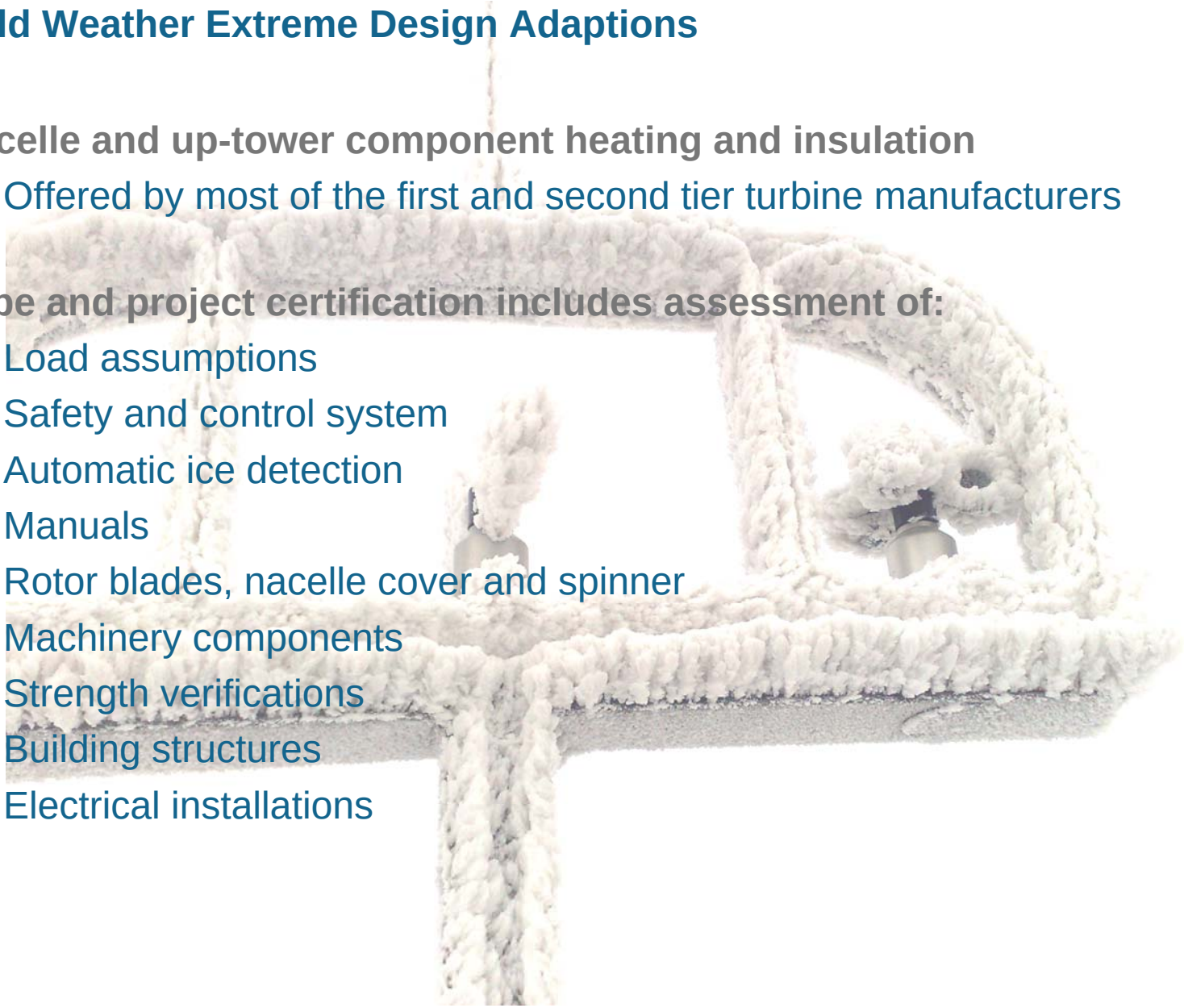
Cold Weather Extreme Design Adaptions

Nacelle and up-tower component heating and insulation

- Offered by most of the first and second tier turbine manufacturers

Type and project certification includes assessment of:

- Load assumptions
- Safety and control system
- Automatic ice detection
- Manuals
- Rotor blades, nacelle cover and spinner
- Machinery components
- Strength verifications
- Building structures
- Electrical installations



What are cold weather packages?

International standards for turbine design (IEC and GL) specify minimum normal ambient air temperatures of:

- -10°C operational
- -20°C stand-still

Not sufficient for the most of Canada

Cold weather packages extend operational and stand-still range of turbine, typically down to normal ambient temperatures of:

- -30°C operational
- -40°C stand-still

What are cold weather packages?

Heating for components such as:

- Nacelle space
- Yaw drive and pitch motors
- Gearbox (through external oil heater for start-up)
- Generator stand-by
- Slip ring
- Controller and control cabinet
- Battery

Power consumption from heating can range up to 200kW to 300kW per turbine for conditions below -20ºC

What are cold weather packages?

Special alloyed materials for:

- Ductile iron for hub and machine frame
- Tower steel
- Main and planetary shafts

Nacelle sealing/insulation

Low temperature lubricants

Heated anemometry

Others features such as:

- Ice detectors
- Blade heating by hot air recirculation or heating elements (Enercon)

Cold weather shutdown strategy

Turbine will shutdown in low temperature conditions - strategies include:

- Cut-off for ambient temperature
- Reduced power output for temperature range (curtailment)

Some components typically must be heated:

- Nacelle temperature > -30^{o}C to -20^{o}C
- Controller temperatures > 0^{o}C
- Hydraulic oil > +10^{o}C
- Gearbox oil > +30^{o}C and bearings > +25^{o}C
- Generator windings and bearings > +15^{o}C

A start-up time period as well as parasitic power is required to achieve a minimum component temperature

Grid outage: start-up time may be significant (e.g. 12 hours)

Material Specifications

Additional tests required if temperatures lower than corresponding standards

For example a toughness 27 J Charpy impact test at -40ºC.

Turbine part	Material	Standard	Temp [ºC]	Grade/spec
Castings	Spheroidal graphite iron (ductile iron) ferrite grades	EN 1563	>-20ºC >-40ºC	400 350 (special 400)
Fabrications and Towers	Structural steel all grades	EN 10025	>-20ºC >-40ºC	J20 grades Special purchase or Chinese grades Q345E or higher grades
Blades	Glass fibre reinforced plastic (GFRP)	GL guidelines	Special tests	
Forgings	Medium alloy steel	EN 10083	Special tests	e.g. 34CrNiMo6
Flanges and welds		ASTM 572-694 EN S355 NL	-50ºC	F42 and F50 Charpy 50 J and 100 J

Electrical

CSA and ESA standards

- Design requirements
- Electrical connections
- Insulation and bonding
- Industrial control equipment

- Regional electrical codes and safety requirements
- Balance of Plant (BoP) designed to Canadian standards
- Suitable setbacks from turbines if overhead lines are chosen
- Design of arc flash and insulator needs consideration
- Maintenance strategy after high winds, snow and ice storms

Electrical installations

General
- Definition of thermal areas
- Temperature range for each area
- Confirmation of component manufacturer / sub-supplier
- Measurements or tests

Transformers and windings of generator and motors
- Are not under voltage when measured temperature is less than minimum allowable
- Heating requirement prior to a restart
- Test of heating within prototype testing

Electrical Cabinets
- Low temperature capability review of all installations
- Heating designed to maintain minimum temperature defined under all circumstances
- Analysis or tests

Bearings
Slip ring
Storage devices
Cables and lines

Foundations and Civil design

Canadian national and provincial building codes

Concreting in cold weather

- Thermal blankets and heaters
- Monitor concrete temperature
- Air-entrained concrete mix
- Heated mixing water and aggregates
- Monitor temperatures of surfaces in contact with fresh concrete
- Non-frozen sub-grade
- Finishing and curing to minimize cracking

Tower anchor bolts in cold weather

- Tower steel and connecting bolts may have toughness criteria (Charpy Impact)
- Common anchor bolt ASTM material specifications do not have criteria
- Low toughness may reduce fatigue life and implies brittle failure
- Annual ping testing (strike top of bolt with ball peen hammer) will identify extreme loss of tension or fracture

Foundations and Civil design

Grout shoulder extending onto vertical face of tower flange

Foundations and Civil design

Differential thermal expansion between tower flange and grout causes grout spalling

Foundations and Civil design

Water infiltration causes freeze- jacking of grout, undermining tower flange

Foundations and Civil design

Severe anchor bolt corrosion inside tower

Turbine transportation, installation and operation

Environmental Considerations (weather windows)

- Temperature
- Wind speed
- Wind-chill
- Snow and ice build-up
- Rain
- Visibility (fog and blizzards)

Working considerations (IEC)

- Operators instruction manual
- Work procedures plan
- Emergency procedures plan, specifically:
  - Icing conditions
  - Lubrication defects
- Snow and ice clearance plan for turbines and movement about site
- Working conditions and legislation during construction
- Operations and maintenance strategy considering weather windows
- Cranes, hoists and lifting equipment

Operations

Turbine commissioning

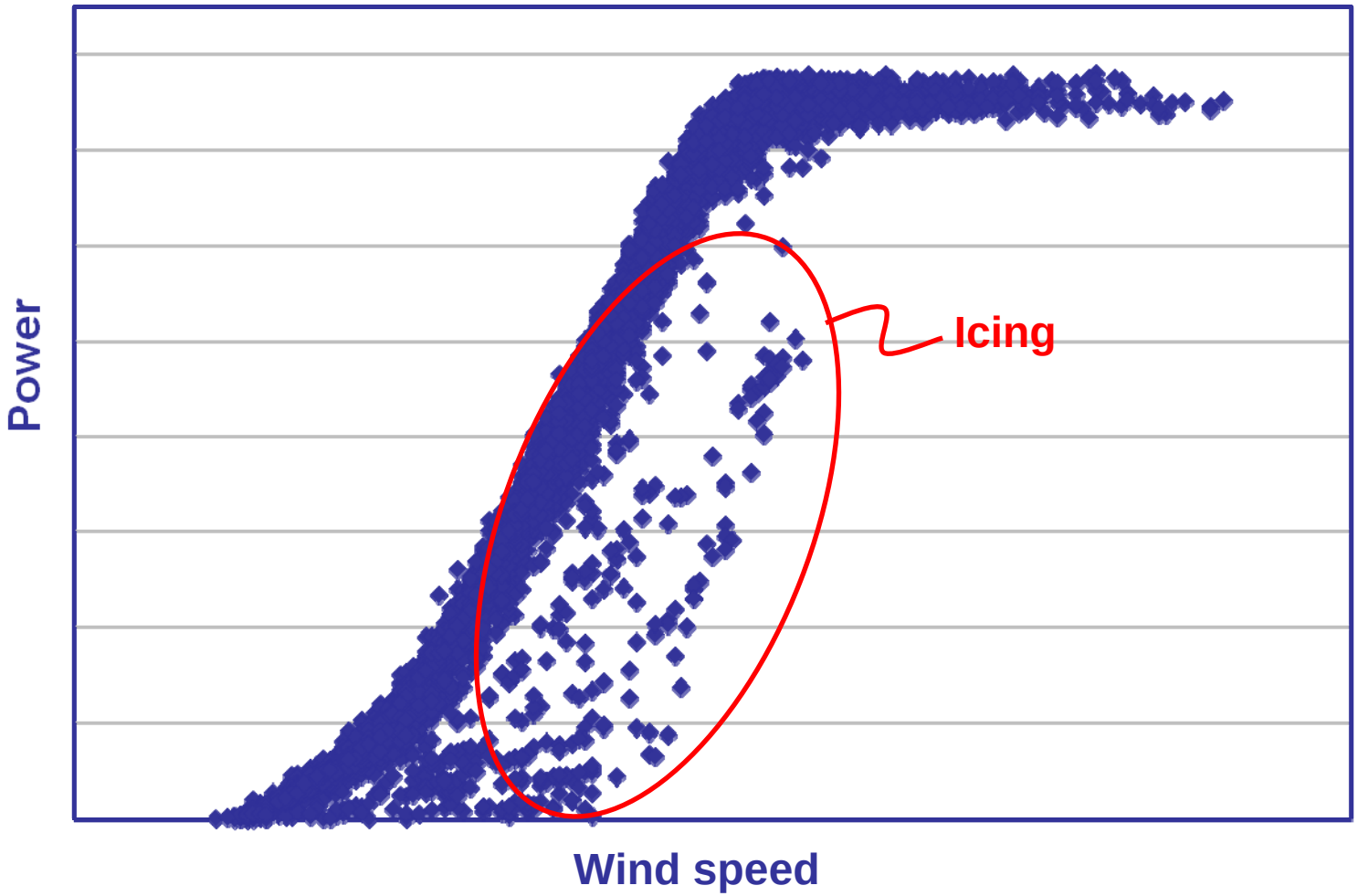
- Summer versus winter

Providing site access to turbines and substations

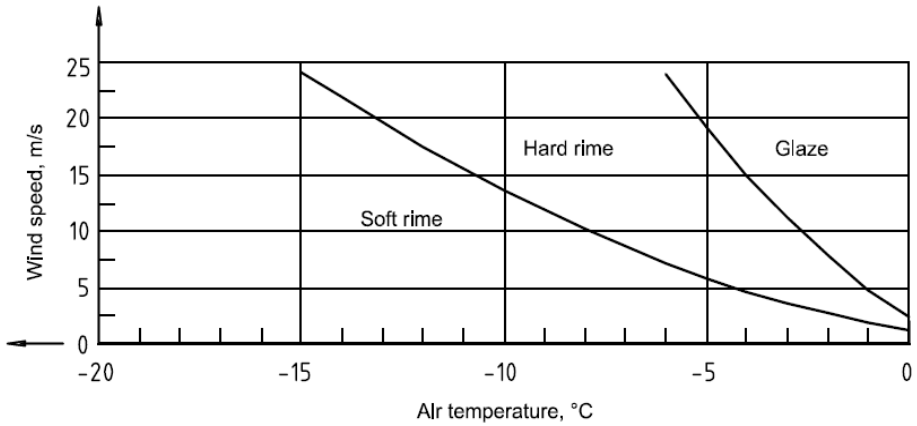
Minimize cold weather maintenance

Safety procedures for falling ice

Operational experience

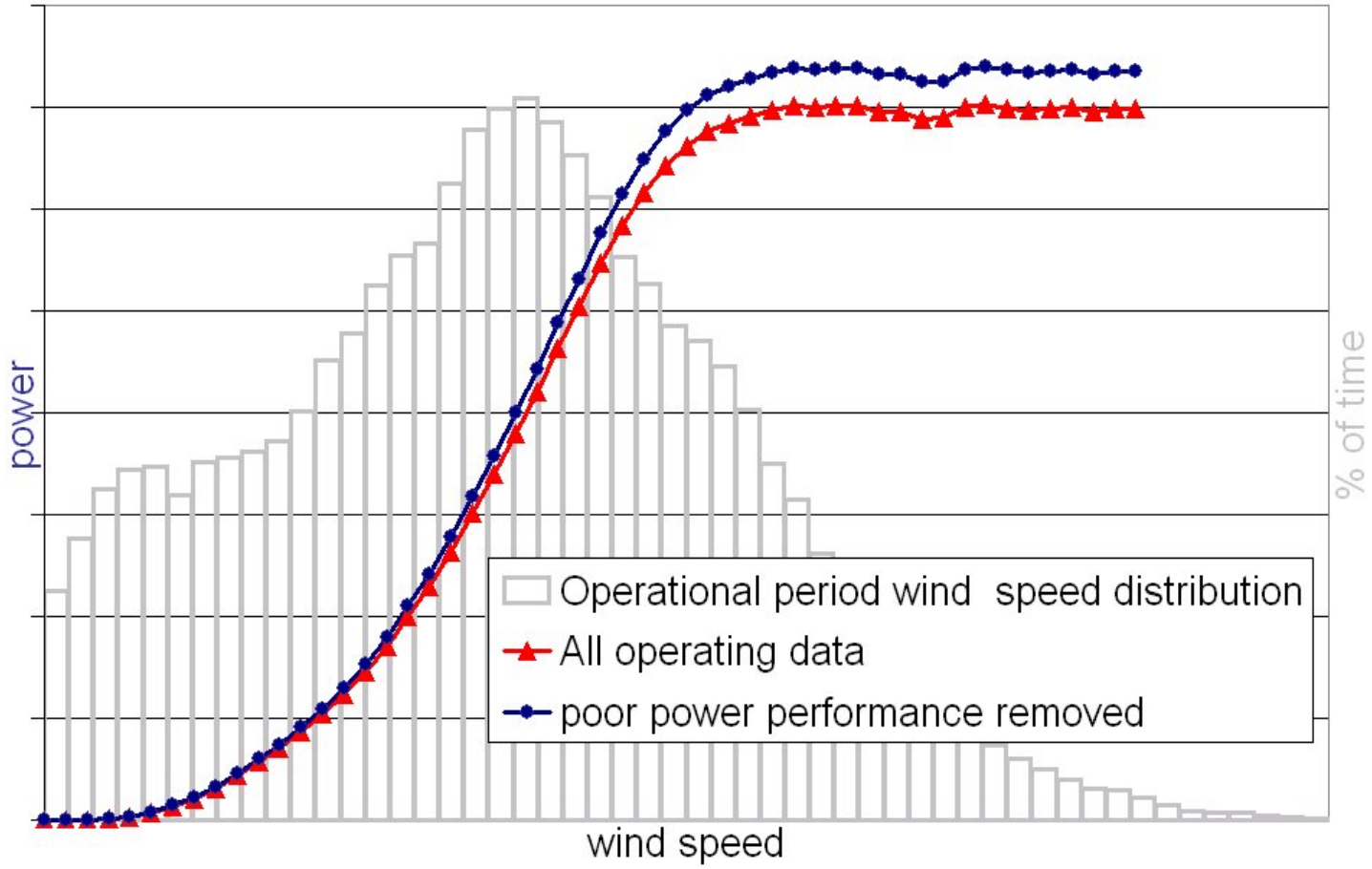


Operational experience



Operational experience

How much energy has been lost?



Design and Installation concluding thoughts

- Important to consider design basis, regulations and environmental conditions
- Cold weather conditions affect structural integrity, construction and operational performance
- Wind turbine technology is available:
  - Designs for cold and windy sites
  - Material specifications
  - Matching of cold weather package to site based on track record
- Civil and electrical design solutions are also available
- Optimise operational performance and maintenance
- Still room for innovation in design and installation

Thank you

Onshore & Offshore Wind

Wave & Tidal

Solar PV & CSP

Experts in renewable energy

www.**gl-garradhassan.**com