Business from technology

Pic: Bonus 600kW, Olos fjäll, Finland

Preliminary results from project IcedBlades: Input to new IEC 61400-1 ed4

WinterWind 2013 Conference, Östersund, Sweden

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  - New design load cases (DLCs)
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Motivation
-Wind energy in Cold & Icing Climate (CIC)

- Currently 60 GW in CIC [3]
- Global wind energy in CIC ≈ 3 x global offshore! [5]
- NREL estimate: 50% of US wind fleet in CIC 2010-2030 [4]

- Problem of production losses caused by iced blades ”well known”.

- **BUT no idea, how turbine lifetime is affected by iced blades.**

- **Thesis: Premature failure of main components e.g. gearboxes & towers resulting to “hidden” financial penalties BIGGER than production losses?**

- ULTIMATE GOAL: Increase knowledge & improve wind energy reliability in CIC

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Project ”IcedBlades” goals (2/2013-12/2014)

Within the project scope updated industry standard or new simulation tools for assessing wind turbine dynamic behavior in cold and icing climates.

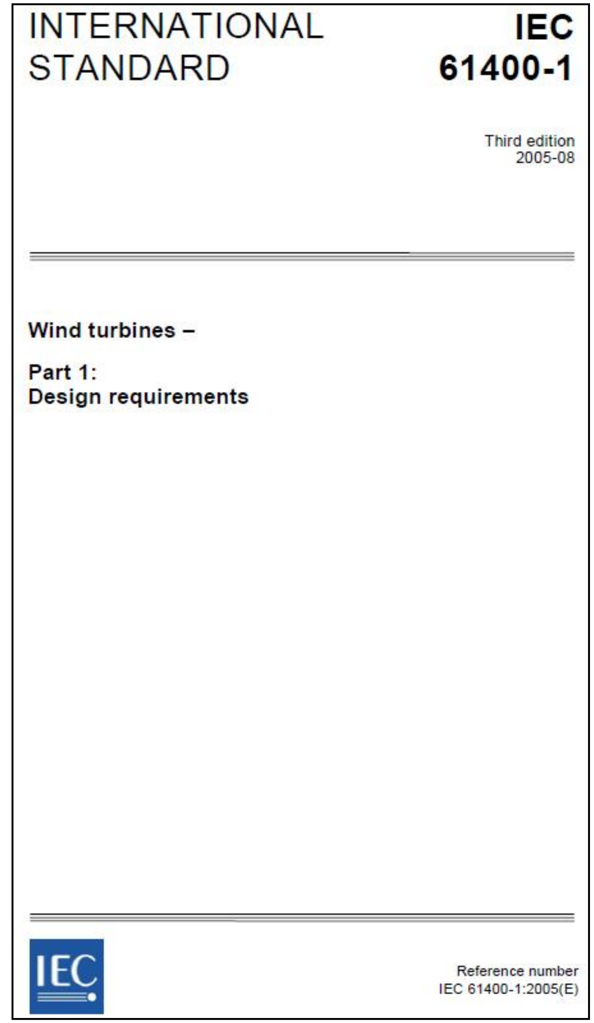
1. Predicting the power losses.
2. Understand better the dynamic loading of iced turbine rotor.
3. Developing a new technical note for icing.
4. Input for new edition of IEC 61400-1 Ed3 → Ed4.
5. Forecasting the risk of icing for single wind turbines.
6. Forecasting power production in icing conditions.

[1] For more details on IcedBlades see [1]

IcedBlades in revision of IEC 61400-1 ed3->ed4 “Wind turbine - Design requirements”

- IEC 61400-1 is the international standard for the design of onshore wind turbines [2]
- Main emphasis on turbine reliability and personal safety
- Focusses on external conditions, mechanical loads, control and protection system, site assessment
- Smaller chapters on mechanical and electrical components, material strength

- Schedule: New ed4 committee draft for voting (CDV) ready in Q1/2014


INTERNATIONAL STANDARD

IEC 61400-1

Third edition 2005-08

Wind turbines –

Part 1:
Design requirements

Reference number
IEC 61400-1:2005(E)

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New text to IEC 61400-1 about CIC* -Ambient conditions-

- Cold climate = IC and/or LTC
  - Icing Climate (IC)
    - = Sites with icing events
    - Using IEA TASK 19 definition
  - Low Temperature Climate (LTC)
    - = Below normal operational limits
    - Definition from GL Technical Note 067 rev4 (2011) on cold climate

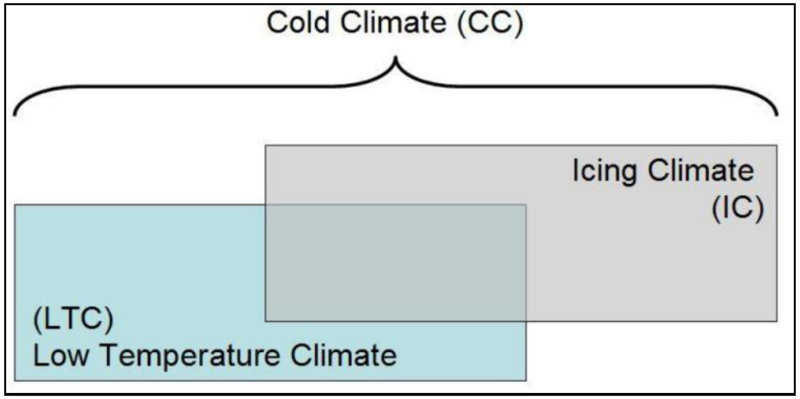

Figure 1. Definition of cold climate, low temperature climate and icing climate. [3]

*: CIC = Cold & Icing Climate

New text to IEC 61400-1 about CIC*
-Environmental conditions-

- Input from IEA TASK 19 [3]
- Meteorological and COMPONENT icing
- Icing climate = icing classes
- Icing will be defined as icing frequency

Table 1. Icing classes PRELIMINARY

Icing class	I	II	III
Icing time for fatigue load cases (limits for days per year)	60 (60>t≥30)	30 (30>t≥10)	0 (10>t)
A C	LTC		
B C	Normal environmental conditions		

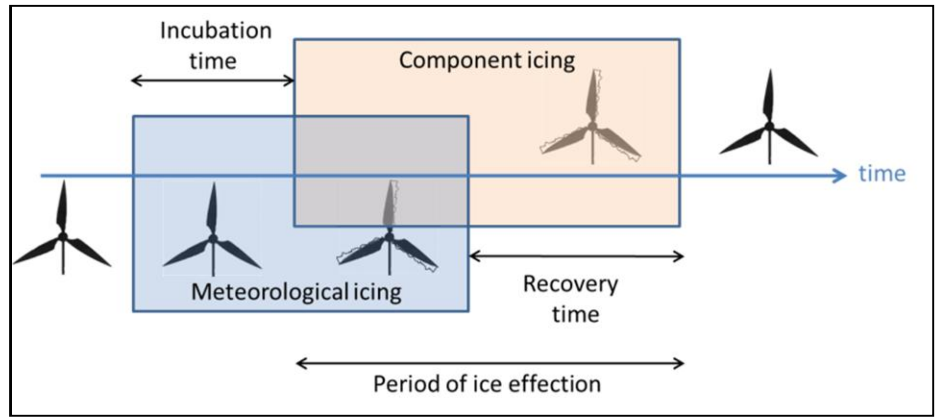

Figure 2. Definition of meteorological icing and component icing. (modified from [3])

- For example: a turbine could be wind class IIA and icing class IB = **Class IIA IC IB**

*: CIC = Cold & Icing Climate

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New text to IEC 61400-1 about CIC* -Structural design-

- Rotor blade icing shall be considered for aerodynamic changes and for the blade ice mass
- Icing frequency will be input for fatigue calculations
- Low temperatures result to low air densities

Table 2. Applied temperatures and air densities for standard cold climate conditions

Temperature	Air density
$\theta_{mean,year}$ = 0°C	1.292 kg/m^3
$\theta_{min\ operation}$ = -30°C	1.317 kg/m^3
$\theta_{1year,min}$ = -40°C	1.317 kg/m^3

*: CIC = Cold & Icing Climate

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New text to IEC 61400-1 about CIC*
-New design load cases-

- Major input from project IcedBlades [1]
- New DLCs (ultimate & fatigue loads):
  - New simulation parameters:
    - If IC then aerodynamic penalties for blades AND/OR
    - If LTC then increased air density (Table 1 prev. slide)
  - DLC1.6: Power production with iced blades**
  - DLC6.X: Parked (standstill or idling) with iced blades
  - DLC7.1: Parked plus fault conditions with iced blades

*: CIC = Cold & Icing Climate

**: Lehtomäki et al. Vibration and load measurements of two MWscale turbines operating in icing conditions WinterWind 2013

New text to IEC 61400-1 about CIC* -Site assessment in CIC-

- Input form IEA TASK 19 & COST 727
- Site assessment in CIC:
  - Site icing conditions need to be assessed
  - New informative annex on:
    - Guidelines for ice detection measurements
    - Calculation of rotor icing from meteorological icing with fig 3 & 4
    - Meteorological modeling

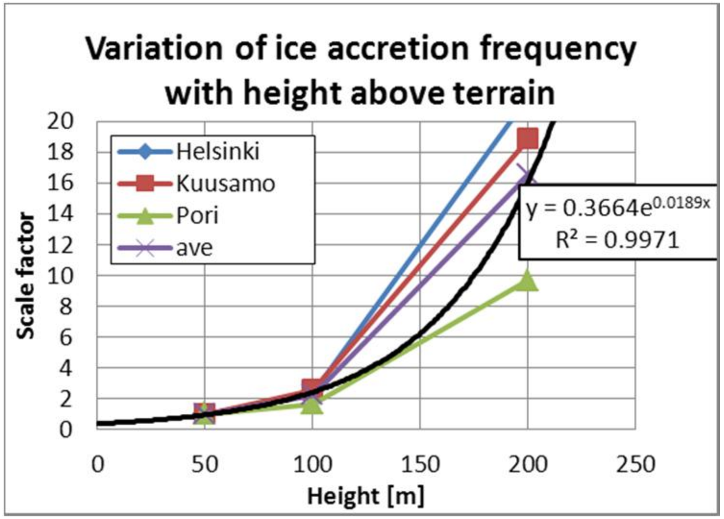


Figure 3. Icing frequency profile (scale factor set to 1 at 50m) PRELIMINARY

$$SF = e^{\left(0.0189\left(\left(hh+\frac{2D}{32}\right)-mh\right)\right)}$$

D = rotor diameter [m]
hh = hub height [m]
mh = measurement height [m]

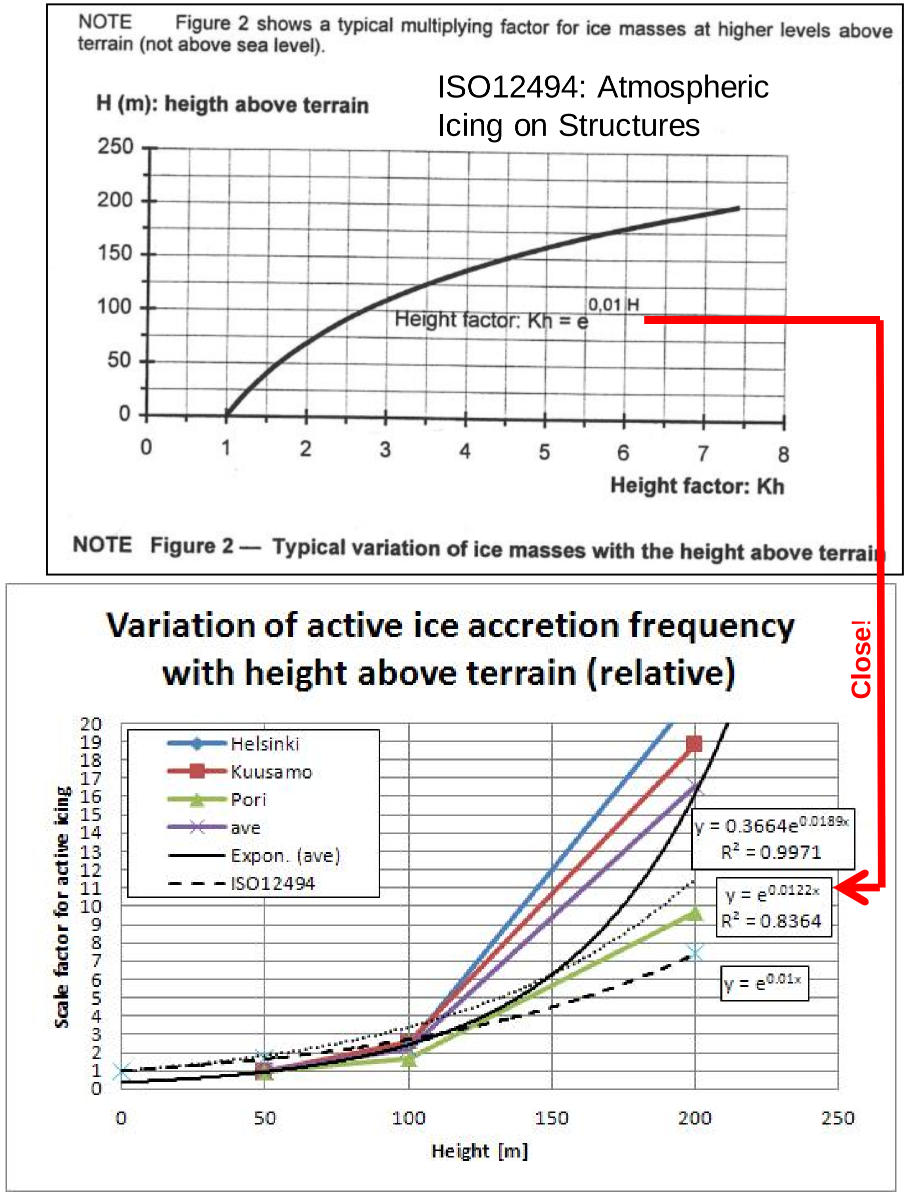
Figure 4. Transferring with a scale factor (SF) of measured active icing time to icing effecting the rotor PRELIMINARY

*: CIC = Cold & Icing Climate

New text to IEC 61400-1 about CIC* -Site assessment in CIC-

- Average icing vertical profile can be simplified to an exponent formula (some finetuning still needed)

- Current IEC average icing profile formula close to ISO12494 formula



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New text to IEC 61400-1 about CIC*
-Site assessment in CIC-

- Example 1: if site long term measurements (min 1yr) at 100m above terrain level result to 100h/a of active icing, how much:
  a) active icing and
  b) component icing is at 150m?

Icing class	IEC simu	IEC range
III	**0**	0-9
II	**30**	10-30
I	**60**	31-60

Answer: a) $\frac{sf(150m)}{sf(100m)} = \frac{0.3664e^{0.0189\times150m}}{0.3664e^{0.0189\times100m}} = e^{0.0189(150m-100m)} = 2.57 \rightarrow 2.57 \times 100\frac{h}{a} = 257\frac{h}{a}$

b) $component = rotor\ icing = 2 \times active = 2 \times 257\frac{h}{a} = \mathbf{514}\frac{h}{a}$ → II

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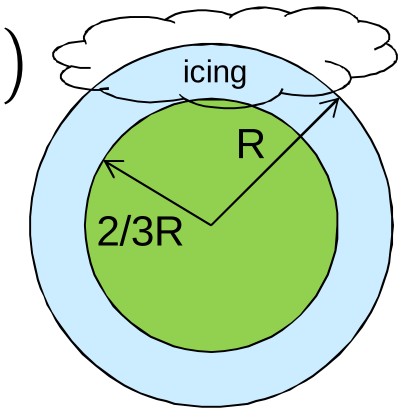
New text to IEC 61400-1 about CIC*
-Site assessment in CIC-

Transferring measured active icing time to effective rotor icing time (assuming that icing is most relevant on outer 1/3 of rotor)

$$SF= e^{\left(0.0189\left(\left(hh+\frac{2D}{3\,2}\right)-mh\right)\right)}$$

D = rotor diameter [m]
hh = hub height [m]
mh = measurement height [m]



Scale factor =1 at 50m

<u>Example 2:</u> Long term site icing measuremets (min 1yr) at hub height (hh=mh=100m) result to 120h/a of <u>component icing</u>. What does this mean for a turbine of D=100m with hub height hh=100m?

Answer: $component\ icing = rotor\ icing \rightarrow$

SF= $e^{\left(0.0189\left(\left(100m+\frac{2\times 100m}{6}\right)-100m\right)\right)} = 1.88 \rightarrow 1.88 \times 120\,\frac{h}{a} = \mathbf{226}\,\frac{h}{a} \longrightarrow$

Icing class	IEC simu	IEC range
III	**0**	0-9
II	**30**	10-30
I	**60**	31-60

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New text to IEC 61400-1 about CIC*
-Control, protection, mechanical and electrical systems-

- No existing CC standards to refer to
- CC conditions need to be considered as well for
  - effects by varying air density on wind turbine dynamics
  - safety critical energy storages, e.g. in the hub
  - sensor readings and data processing
  - start-up procedure from minimum ambient operation temperatures
  - maintain minimum oil temperature in the gearbox before power transmittion
  - appropriate materials in the electrical components
  - possible grid return after grid loss at minimum standstill temperature

*: CIC = Cold & Icing Climate

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Conclusions

- Demand: Huge market potential for cold & icing climate wind energy
- Problem: Uncertanties in operating with iced blades that may reduce the lifetime of main wind turbine components -> Risk: BIG financial penalties!
- Solution: Revision work of IEC 61400-1 “Wind turbine - Design equirements” ed3->ed4 will have **MAJOR IMPROVEMENTS IN THE RELIABILITY AND SAFETY FOR WIND TURBINES OPERATING IN COLD & ICING CLIMATE**

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References

[1] Lehtomäki, V. et al., *IcedBlades - Modelling of ice accretion on rotor blades in a coupled wind turbine tool,* WinterWind 2012 conference, Skellefteå, Sweden

[2] IEC 61400-1:2005 ed3, *Wind Turbines – Part 1: Design requirements,* International Electrotechnical Commission, 3, rue de Varembé, PO Box 131, CH-1211 Geneva 20, Switzerland

[3] IEA WIND TASK 19, EXPERT GROUP STUDY ON RECOMMENDED PRACTICES: 13. WIND ENERGY PROJECTS IN COLD CLIMATES, 1. EDITION 2011, Approved by the Executive Committee of IEA Wind May 22, 2012.

[4] Baring-Gould, I. *US Wind Market Overview,* WinterWind 2011 conference, Umeå, Sweden

[5] IEA TASK 19, *WIND ENERGY IN COLD CLIMATES: Cold Climate Challenges,* EWEC 2011 conference, EWEA side event Brussels, Belgium March 16th, 2011

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Thank you!

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