Design of a measurement arrangement for estimating the icing duration of wind turbines prior erection

Master thesis

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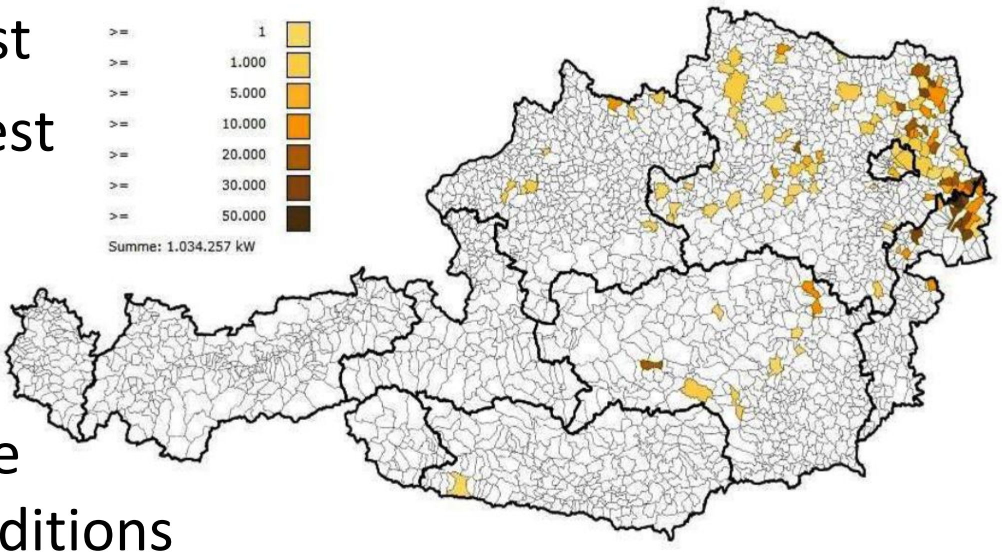
Installed wind power in Austria 2011

- Major part in the North-East
- No wind turbines in the West
- Reasons:
    - Alpine regions
    - Tourism
    - Insufficient infrastructure
    - Hard meteorological conditions



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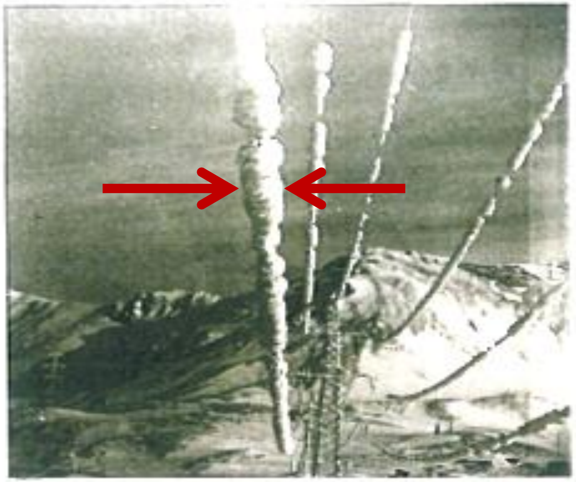
Problem description

Site „Windsfeld“ (Salzburg):

- Known high wind potential
- Known high risks for icing
- Almost no access possible during winter

Needed:

Measurement design to exactly evaluate periods during which a blade heating must be activated to prevent icing in advance.



Ice on a 110 kV transmission line at Windsfeld, © Salzburg AG

State-of-the-Art

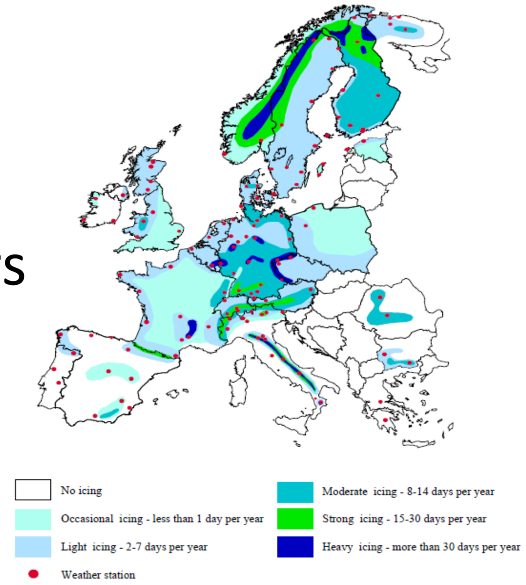
Icing maps

Not detailed enough

Comparison of anemometers

Resolution not sufficient

Synoptical methods



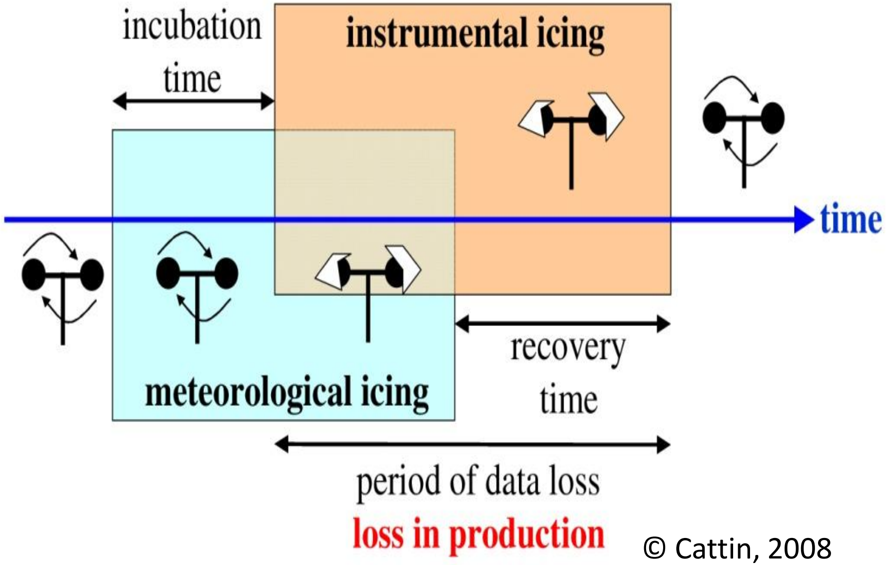
Icing map of Europe,
© Tammelin et al., 2000

Heavily iced anemometer,
© Cattin, 2008

Periods of icing, common classification

Due to high icing risks blade heating must be installed.

As access during winter is very difficult, heating should start before ice on the blades is detected (=shut down).



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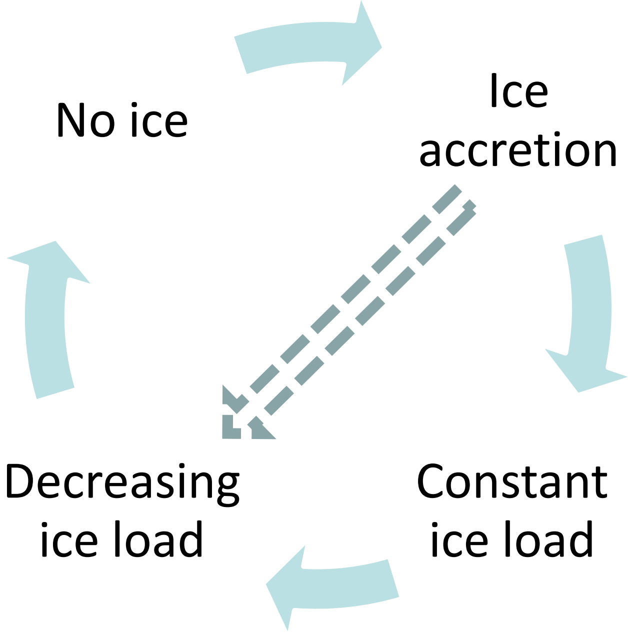
Relevant Icing Time, RIT

Definition:

Relevant Icing Time =

Meteorological Icing +

time with constant ice load



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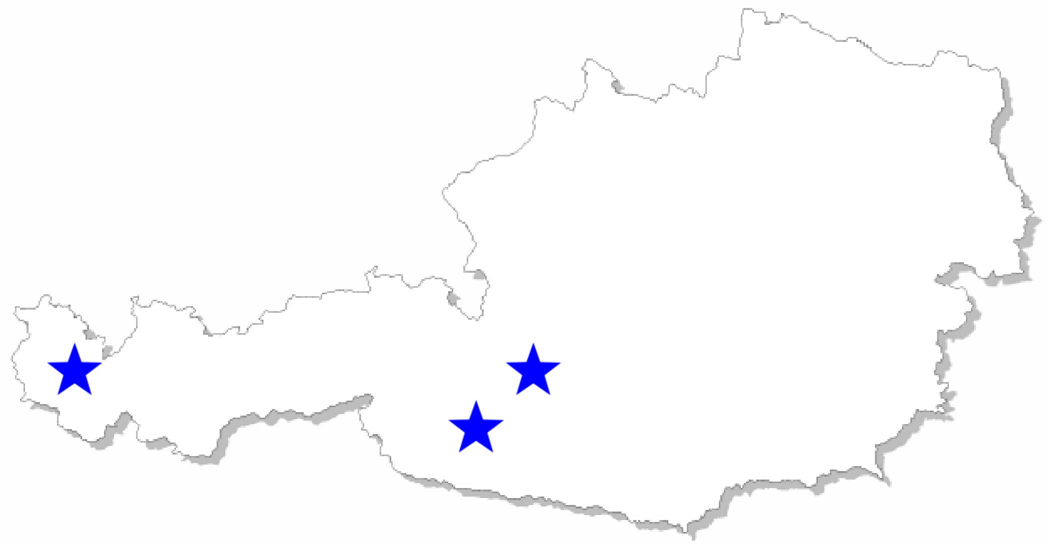
Field tests

Three measurement stations at different altitudes to evaluate standard icing detection methods as well as new ice sensors.



Sites of measurement stations in Austria

Known parameters for icing

Parameter:	Reasonable sensors for alpine test sites available:
Temperature	✓
Relative humidity	✓
Liquid water content	x
Medium volume diameter	x
Cloud base height	x
Wind speed	✓
Radiation	✓

Evaluated camera pictures as reference

- Defining absolute ice amount
  7 categories, from no ice to heavy icing
- Defining ice accretion, constant or decreasing ice load
- Defining picture quality
  3 categories, from good to poor quality

Focus not on absolute ice amount but on the development with respect to the picture before: *Increased*, *constant* or *decreased* ice mass.

Investigated detection methods

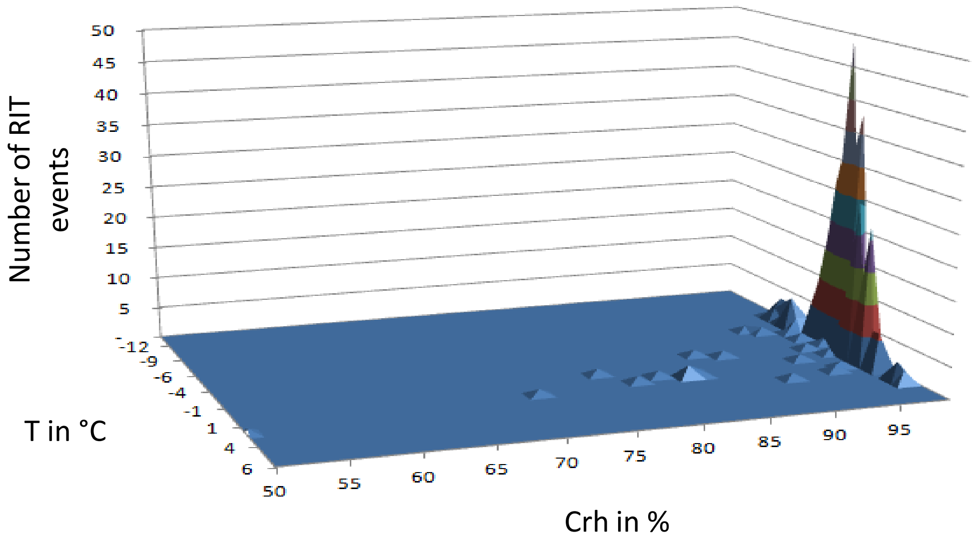
- Ice detection according to ISO 12 494
- Synoptical ice detection: T < 1 °C, rH ≥ 90 %
- Different types of ice sensors
  (no results published due to ongoing tests)

First results showed that both synoptical detection methods overestimated the RIT defined by the picture evaluation.

Developing the „**T-crh** Algorithm“

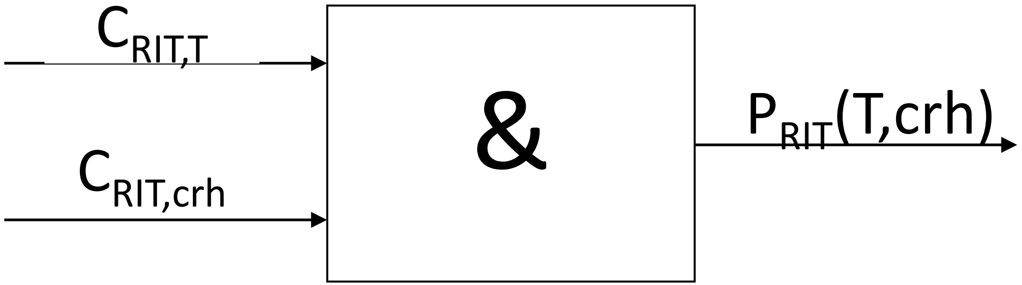
Crh: Corrected relative humidity, using the dew point temperature above ice for temperatures < 0 °C and that above water for temperatures ≥ 0 °C.

RIT occures almost only when -4 °C < T < 1 °C and crh > 95 % at the same time.



Idea of „T-crh Algorithm“

Estimation of the probability of ***RIT*** by combining so called condition curves of ***T*** and ***crh***, according to the frequency distribuation.

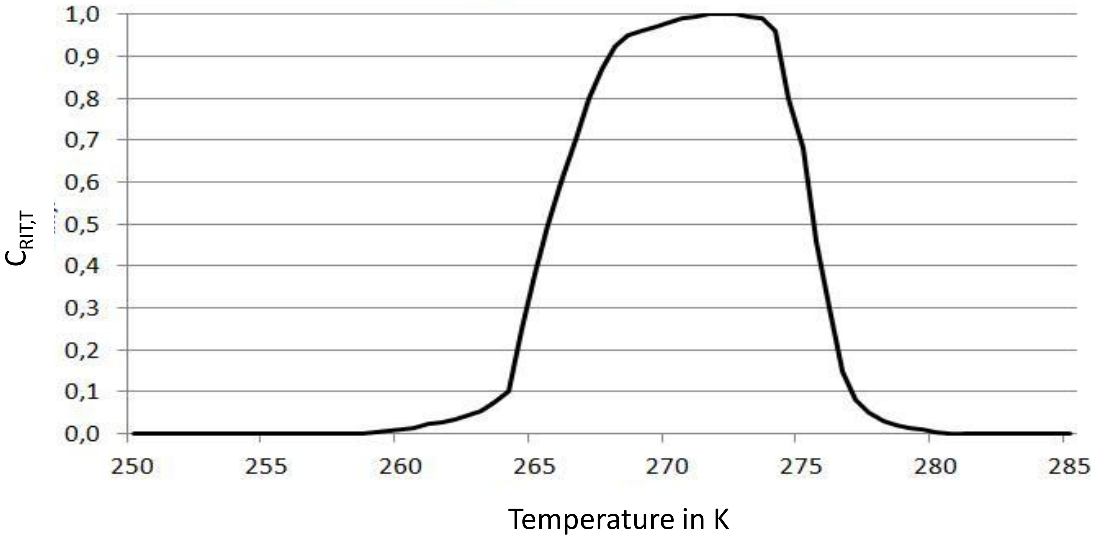


$C_{RIT,T}$: Condition for Relevant Icing Time depending on temperature
$C_{RIT,crh}$: Condition for Relevant Icing Time dep. on corrected relative humidity
$P_{RIT}(T,crh)$: Probability of Relevant Icing Time

$C_{RIT,T}$ (1.700 m a.s.l.)

Several iteration steps:

Starting with experience reports of park owners and stepwise adaption of the curve to achieve the best results.

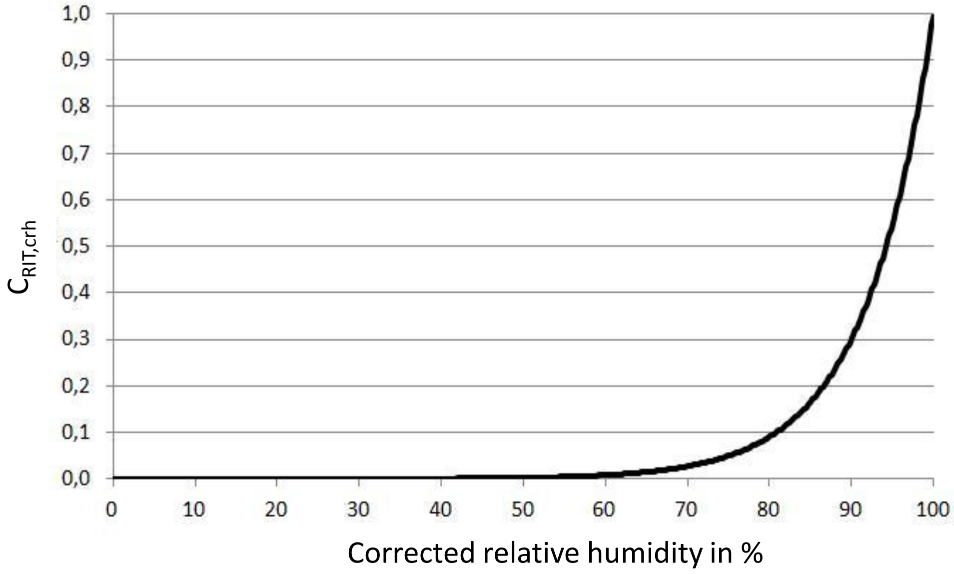


$C_{RIT,crh}$ (1.700 m a.s.l.)

e-function:

$$C_{RIT,crh} = e^{a*(crh-b)}$$

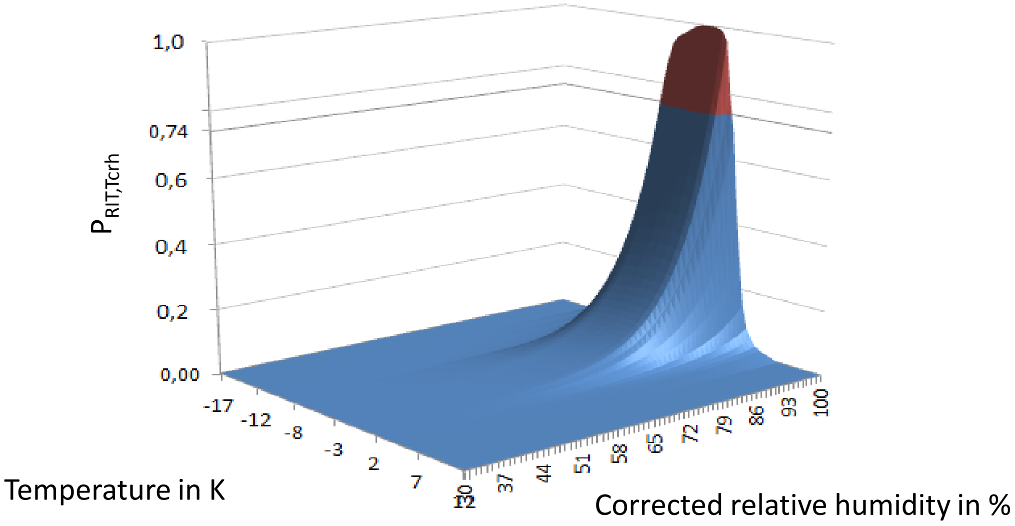
a and *b* are constants.



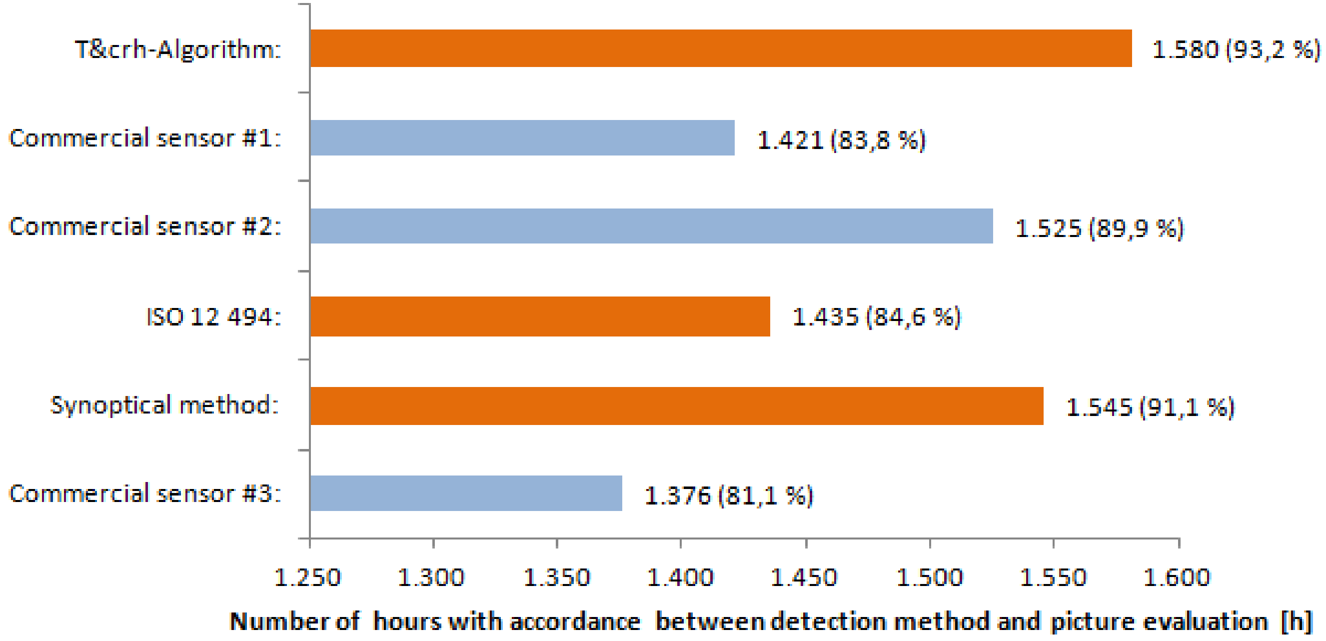
Outcome of T&crh-Algorithm

Multiplication of $C_{RIT,T}$ and $C_{RIT,crh}$ gives P_{RIT} .

Additionally a threshold for RIT must be defined.



Evaluation results



Interpretation

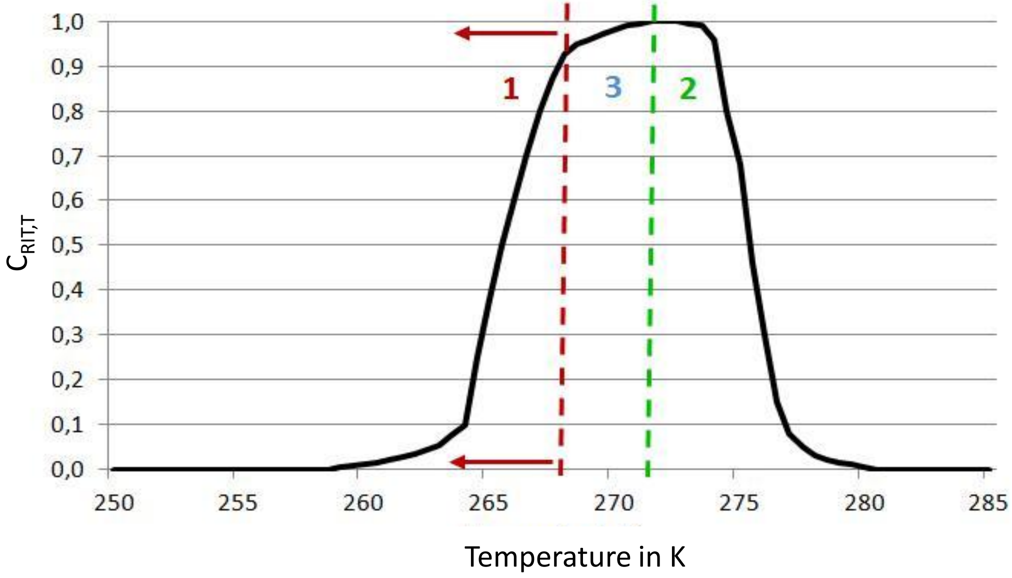
- Availability of data and high data quality is crucial
- Different detection methods achieve different performance levels and detect different periods of RIT
- Picture evaluation (reference) is often subjective
- Empirical approach

- But: Good results for T-crh-Algorithm
- If the method prooves reliable, no more picture evaluation necessary
- T-crh detects RIT often 40 min before ice is visible → blade heating controls?

Adaption of T-crh-Algorithm to different altitudes

Depending on altitude:
Horizontal displacement of the left part of the curve (1) and threshold adaption.
Constant figures for (2), linear completion in (3).

Promising results for two more test sites.



Site evaluation „Windsfeld“

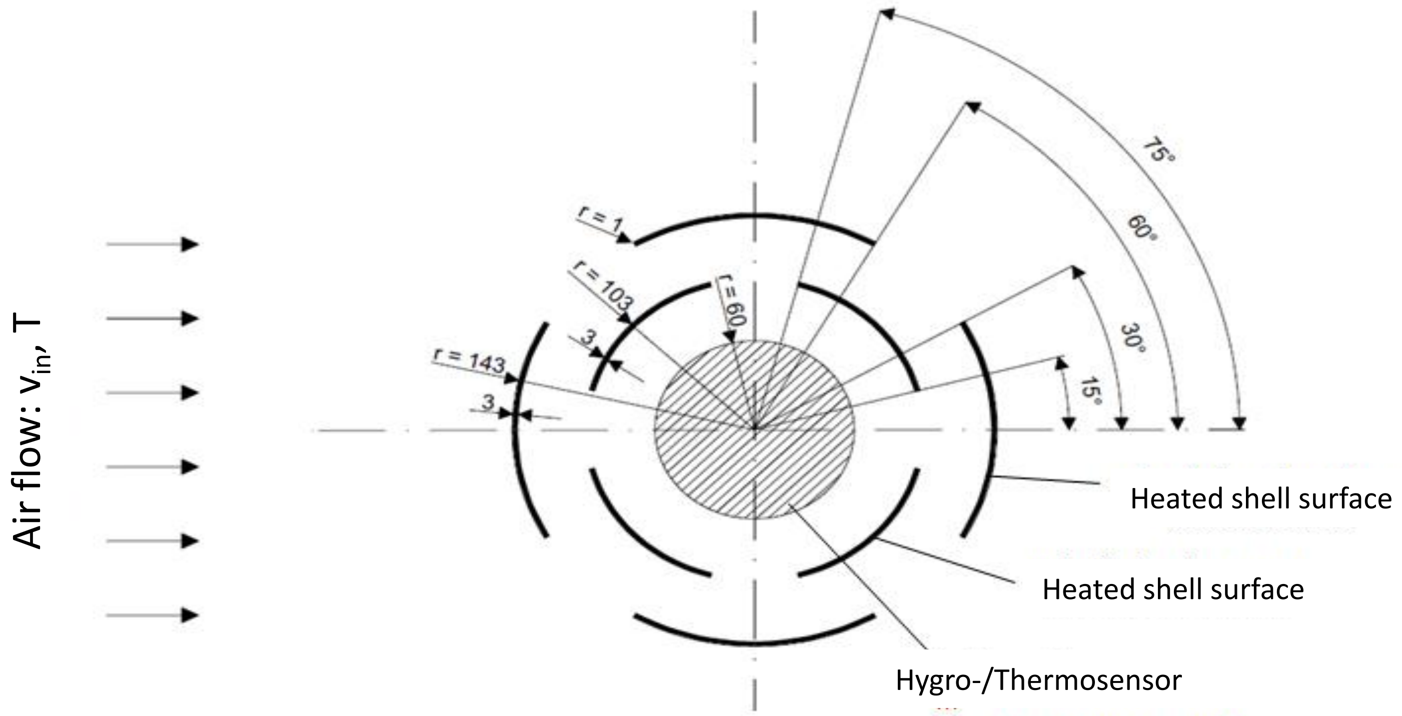
- Ongoing study
- Well equipped
- Grid connection available
- Data transfer critical
- Evaluation of icing events in November 2012 showed good results
- Final evaluation in May 2013

Heated housing for a commercial temp./humidity sensor

Temp.-/humidity sensor at a test rig (red circle), © Lachinger, 2011

- Ice on sensors leads to useless data
- „Labyrinth“ to separate fluid particles and droplets from air
- Heated surfaces to melt ice accretions
- Estimation of heating influences on the measured temperatures necessary

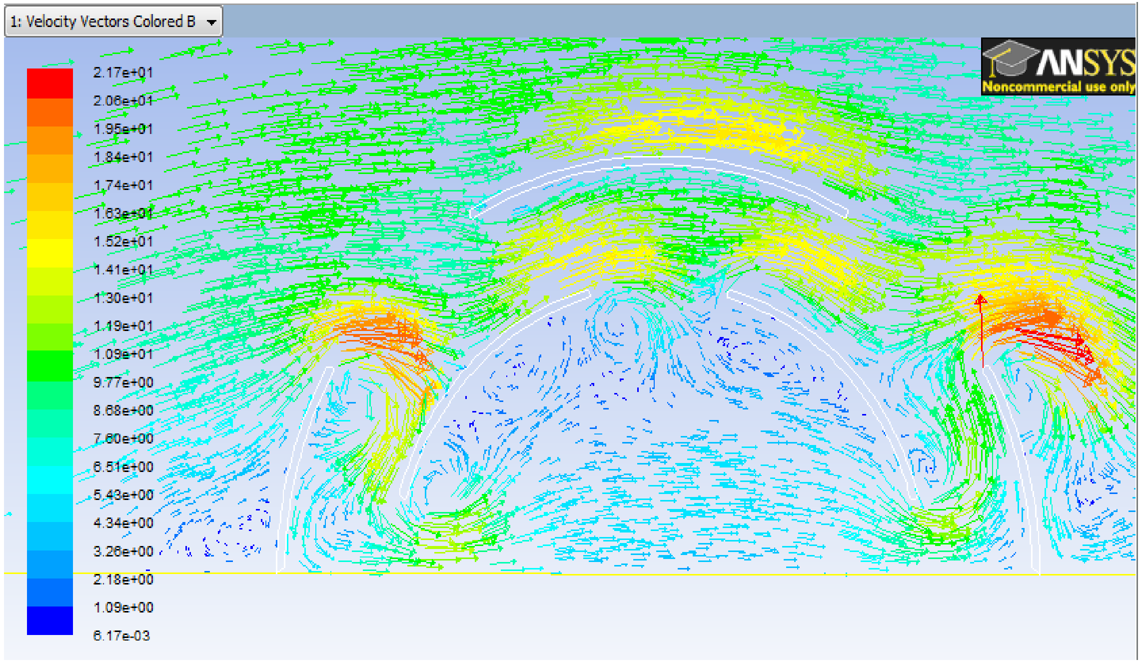
Housing design



CFD simulations

- Highly turbulent flow

- Separation of droplets from flow at swirls and eddies



Velocity vectors for v_{in} = 5 m/s

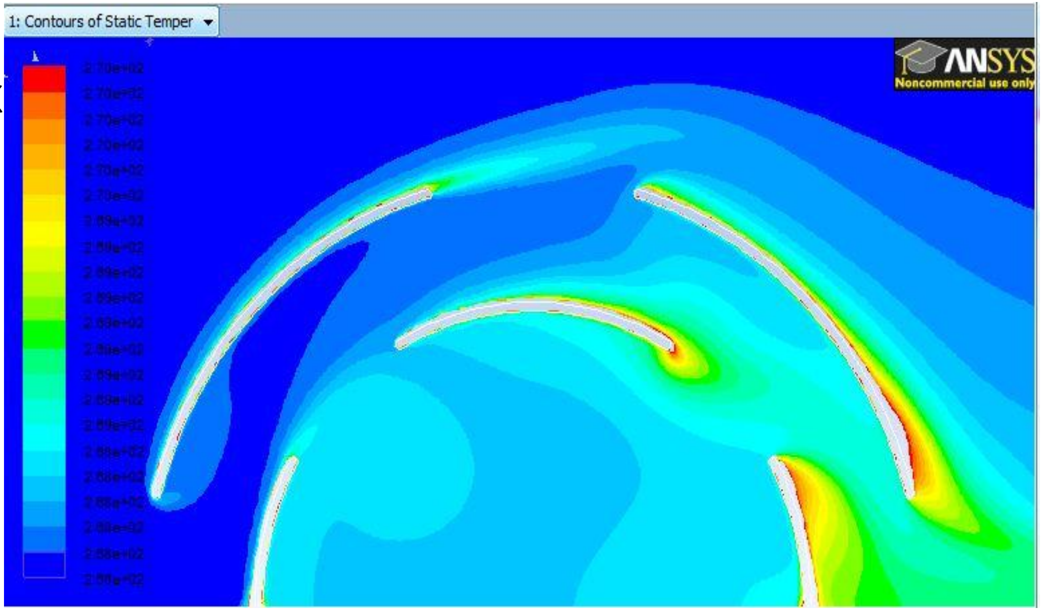
CFD-Simulationen

- Heated surfaces lead to a small scale influence on fluid temperature

- Influence must be predictable to correct the measured temperatures

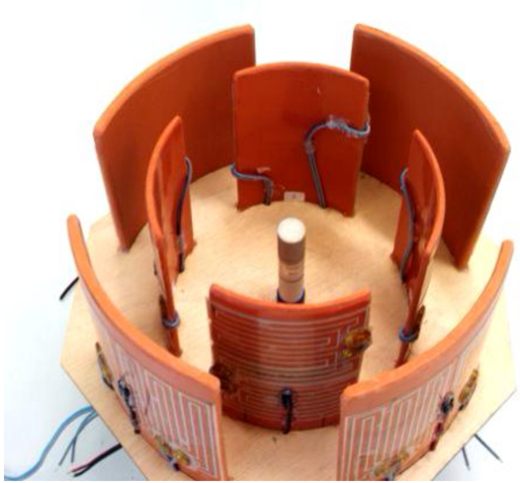
270 K

268 K



Temperature scales for v_{in} = 10 m/s andT_{in} = 268 K,
1 colour scale is equivalent to ΔT = 0,1 K

Prototype und test



Results:

- Ice amount on the surface is reduced due to heating
- Small scale temperature deviation (as simulated)
- Further tests with different ambient conditions necessary

Outlook

- Further test sites for T-crh-Algorithm and heated sensor housing necessary
- Sites next to erected wind turbines preferred
- Development of an automated picture evaluation method

- Further development of the heated sensor housing