Low temperature compliance testing of wind turbine applications

pieterjan.jordaens@owi-lab.be

www.owi-lab.be

Winterwind
INTERNATIONAL WIND ENERGY CONFERENCE
FEB 6-8
2017

Laboratory for environmental testing of heavy machinery

Quick Introduction

driving industry by technology

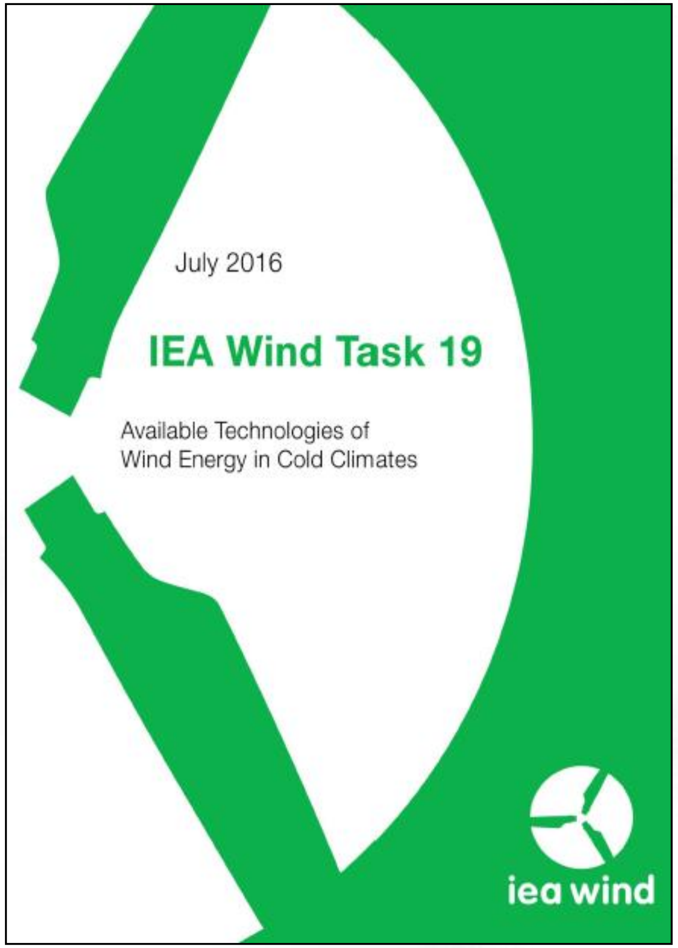
- **Sirris - collective technology centre in Belgium**
  - Supporting companies with implementing technology innovations
  - Multidisciplinary R&D and innovation projects in technology industry
  - Different technology sectors: Automotive, Energy, Aerospace, ICT, …
  - Different key expertise: ICT, Manufacturing, Mechatronics, Materials
  - High-tech test and R&D infrastructure

- **OWI-Lab - RD&I center for wind energy in Belgium**
  - Set-up in 2010 as a new application lab at Sirris to support wind energy R&D
  - Scope: wind energy in general - focus on '**offshore wind**' and '**cold climate**'
  - Range of new and unique test & monitoring infrastructures
  - Partnership with 3 Belgian universities for wind energy research (VUB, KU Leuven, UGent)

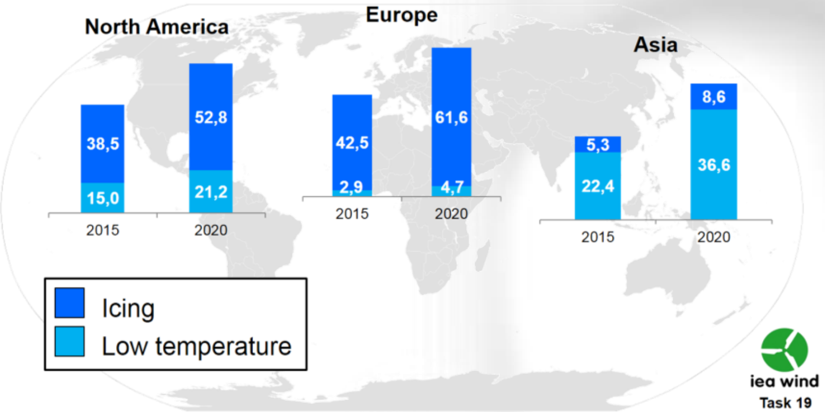
  - Member of EERA JP Cold climate
  - Member of IEA Wind Task19 Wind Energy in Cold Climates

Rationale: Largest "non standard" sectors for wind energy today !

Dedicated solutions and low temperature adaptations are developed to cope with the challenges of cold climates wind farms



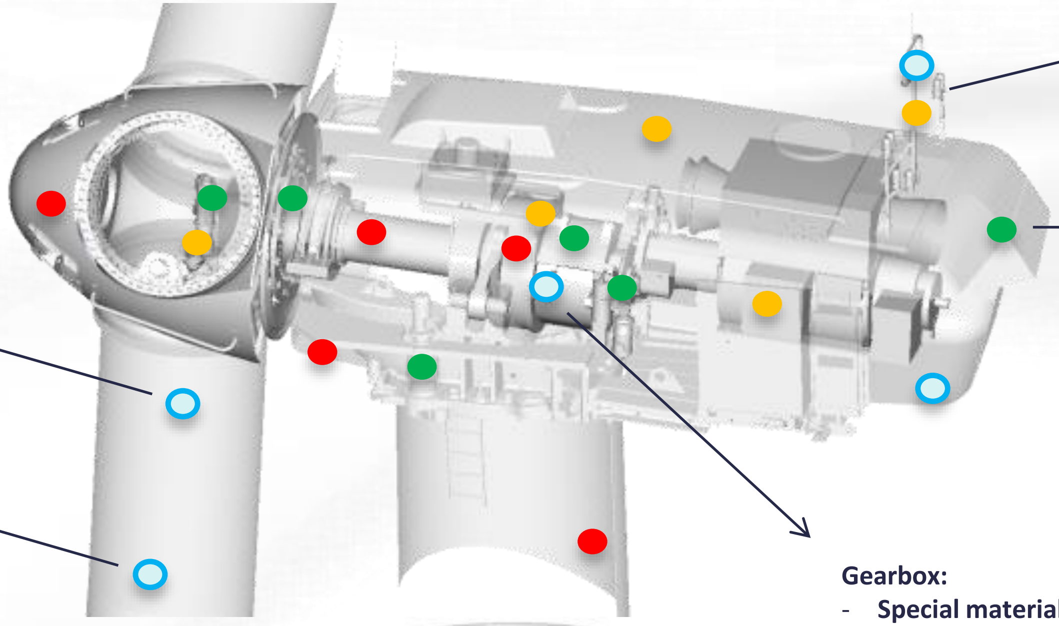
- Overview study of the 'Available technology' made by IEA Wind Task 19
- Study made public recently – July 2016 (see website)
- The study summarizes existing technologies and solutions from weather modelling, to ice detectors,… and turbine manufacturers that deal with wind energy in cold & icing conditions
- Low temperature adaptations & Testing chapter included



http://www.ieawind.org/task_19.html

Recent article 29/07/2016: http://www.windpowermonthly.com/article/1403504/emerging-cold

Overview of most popular measures in “cold climate package”



Ice detection
Heated anemometers

Dedicated low temperature cooling fluids and cooling circuit For gearbox, generator & converter

Ice detection / no-ice detection

Blade de-icing:

- Heating mats in composite
- Hot air system

Gearbox:

- Special materials
- Special lubricants & grease
- Additional (pre-) heating
- Dedicated cold start-up procedures

HEATING: Additional heaters added to switch cabinets and converters, gearboxes, hydraulics, anemometer, slip rings, nacelle space…

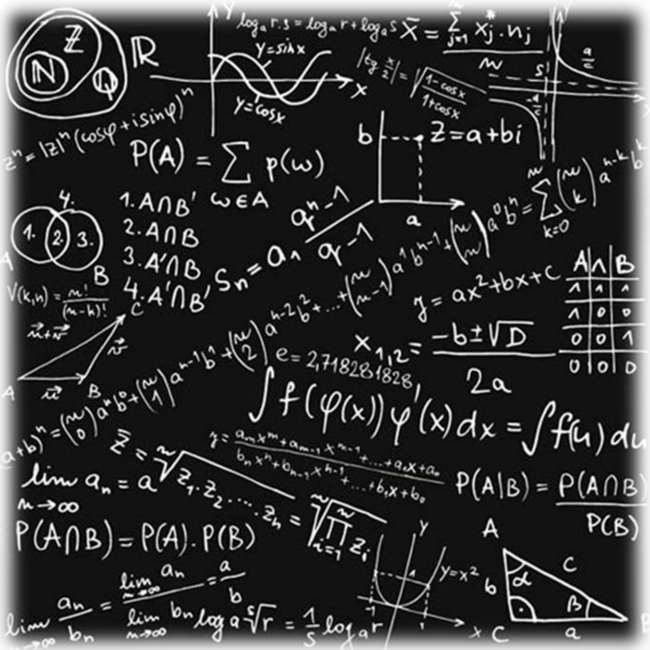
FLUIDS: ‘Low temperature’ oils & greases applied – gearbox, bearings, transformer, cooling, hydraulics,…

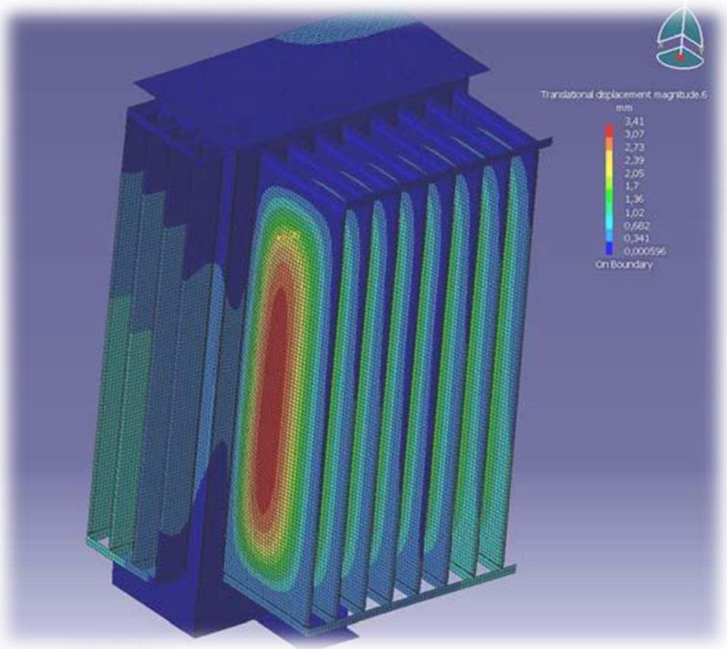
MATERIALS: ‘Low temperature’ materials applied (special steel and cast iron alloys for structures ; elastomers) - gearbox, nacelle frame, hub, main shaft, bearing housing, seals, etc…

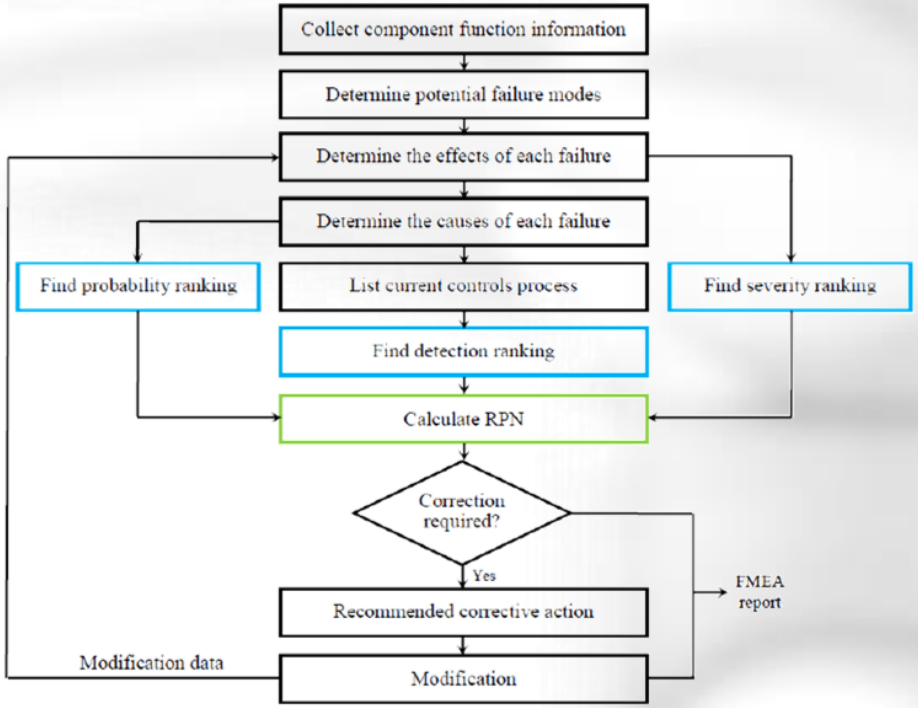
SPECIAL MEASURES: Anti & de-icing solutions, improved nacelle sealing, ice-detection sensors, dedicated cold start-up procedures (cold climate controller), foundation (water ingress)

iea wind Task 19

Purpose of prototype testing in the climate chamber







FMEA Process – Pillay and Wang 2003

Design validation

Checking if simulation models are valid (model validation)

Risk mitigation

Certification

Deliver reliable machinery + shorten the time-to-market

Driver 1 and reasoning for 'testing' within the wind power business

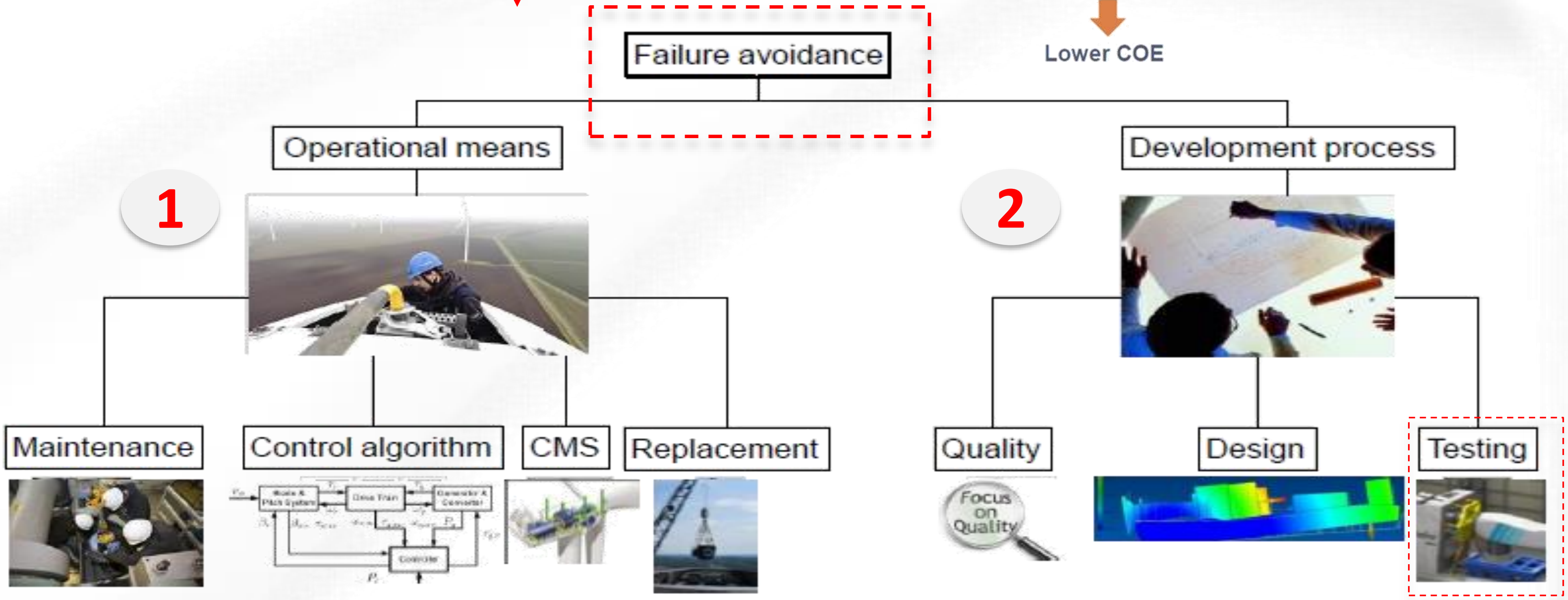
$$COE = \frac{CAPEX + OPEX}{AEP}$$

Higher reliability and better maintenance

Lower downtime

Lower OPEX and higher AEP

Lower COE

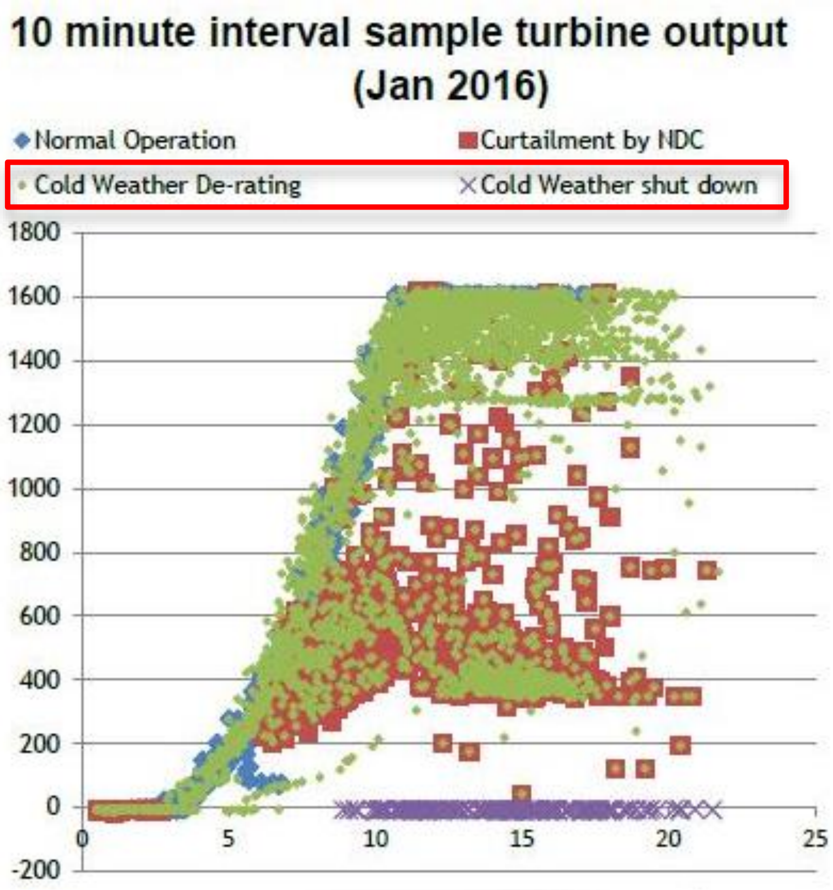


Essential part in the product development cycle

Attention point: wind turbine need to be fitted for the job to work in challenging environments:
Cold Climate, Hot Climate, Tropical Climate, Offshore

Source: Fraunhofer IWES

Insights in field performance in low temperatures → driver 2 = increase production during good cold wind conditions (maximum energy yield)



Source: Azure international / Clean Energy – Winterwind 2016

Location wind farm: Mongolia (cold climate)

- Dry air conditions at this location in Mongolia – almost no influence of icing on power curve, only effect of the low temperatures
- Power loss due to:
  - **Cold weather shut-downs**:

    The control system will shut the turbine down when the average temperature measured in the nacelle drops below -30°C.
  - **Cold weather de-rating**:

    When T< -15°C and >-30°C the turbine will be operating below the optimal power curve. Reasons include oil heating and limiting stress forces

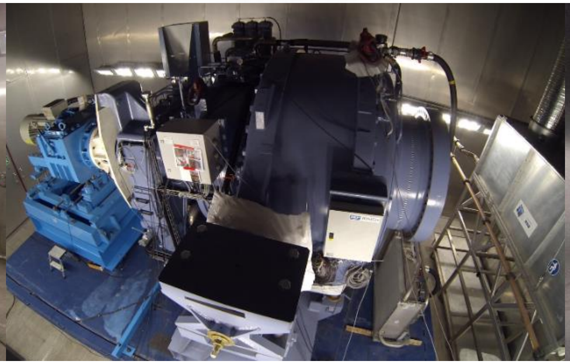
Unique test infrastructure – large climate chamber

- **Public large climatic test chamber for wind turbine applications** (+60°C to -60°C / Humidity / IR-Solar load)
- **Focus: climatic validation tests of wind turbine equipment (cold, hot-tropical and offshore climates)**

XANT

Full size small & mid-range wind turbine nacelle (or assembly) tests

Power electronics tests
Pitch & Yaw cold starts
Hydraulic brake tests
Generator tests



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Functional component testing with or without wind turbine auxiliaries (forced cooling, pumps, heating, expansion tank, lubrication unit,…)

Electrical, mechanical and hydraulic components as
gearboxes, transformers, switch gears, power electronics, anti & de-icing systems,…

R&D tests on the behavior of fluids, oils and hydraulics in a full functional set-up

Icing tests in the climate chamber

Recommended practice & Lab Testing experiences

DNV·GL

RECOMMENDED PRACTICE

DNVGL-RP-0363 Edition April 2016

Extreme temperature conditions for wind turbines

The electronic pdf version of this document found through http://www.dnvgl.com is the officially binding version.
The documents are available free of charge in PDF format.

DNV GL AS

8.2.2 Start up procedure of wind turbine after long stand still during grid failure

A complete start up procedure concerning heating up or cooling down to operational temperature range should be given for the complete wind turbine after grid failure. The procedure should contain the measures for heating/cooling without grid power where necessary (e.g. for heating up the generator or main power transformer before switching on). The electrical installations (transformer, generator, converter and control cabinets etc.) are to be included in the procedure.

4.4 Braking systems

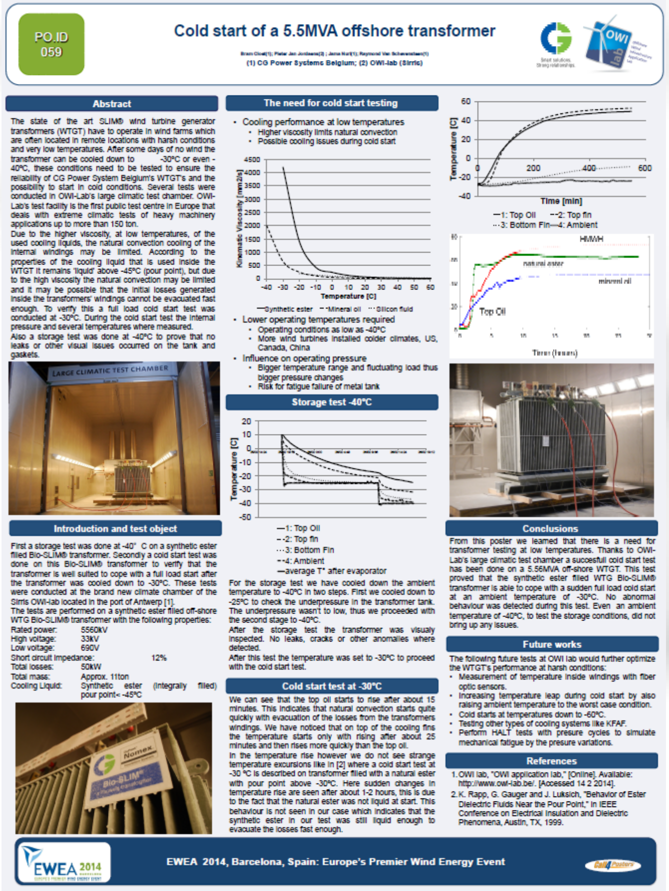
It is to be shown that the braking systems (including their possibly existing energy storage) remain functional in the temperature range between $\theta_{min,operation}$ and $\theta_{max,operation}$.

A test of the pitch system for extreme low temperature conditions may be required (see [7.4.3]) and the respective requirements in the following should be taken into account:

The test shall ensure and show that the pitch system is capable to run all blades into feathered position in an appropriate time under assumption of appropriate loading. This test is required whenever a braking system is designed as pitch system.

Liquid filled wind turbine transformers

- **Risks during low temperatures:**
  - Under load – no risk due to transformer losses
  - Stand-still in low temperature > 24h
    - Risk of tank underpressure and related air suction due to shrinking of the transformer oil
    - Risk of overpressure during cold start-up and warm-up in general as air can not evacuate fast enough
    - Risk of accelerated temperature rise in windings as natural cooling convection is limited at low temperature (stiff fluids)
    - Failure of auxiliaries and leakage (pumps, cooling circuits, radiators, tripping sensors, seals, etc.)



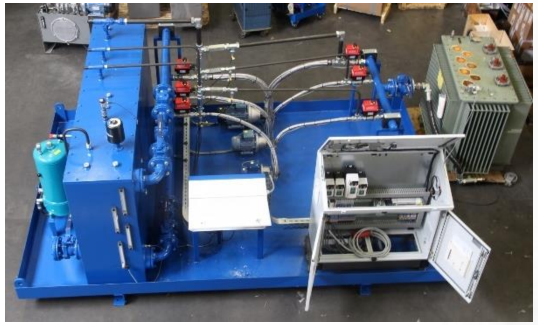
Poster and Paper available
EWEA 2014: Cold start of a 5.5MVA offshore transformer

Smart solutions.
Strong relationships.

Liquid filled wind turbine transformers

- **Lessons learned during climate chamber tests:**
  - Design of the transformer tank flexibility should take low temperature cool down and start-up into account (under- and overpressure)
  - Usage of correct type of pressure control in tank (hermetically sealed, gas cushion, breather, expansion tank)
  - The importance of seals (eliminate air suction / leakage)
  - Usage of the right auxiliaries that can work in cold climate

- **Continuous optimization and R&D effort:**
  - New fatigue tank test bench – topic under & overpressure and effect on lifetime of transformer tank
  - Field monitoring campaign of instrumented WTG transformer in cold climate (North - USA)



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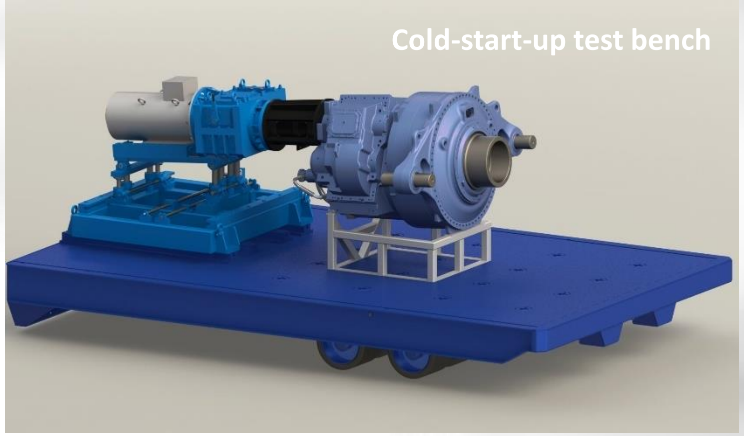
Wind turbine gearboxes – cold start-up tests

- **Risks during low temperatures:**
  - Ensure sufficient lubrication of gears and bearings during cold start-up procedure (CSP) as the oil is stiff.
  - Cold-start-up time must be within a certain allowable time limit (based on customer requirements)
  - Failure of auxiliaries and leakage (pumps, cooling circuits, filters, sensors, seals, etc.) → ensure survival limit of -40°C of all parts, even during a grid-disconnection.
  - Ensure sufficient oil flow in pumps to mitigate risk of cavitation
  - Heaters needed for pre-heating, but surface temperature of heaters should be low enough in order not to burn gearbox oil.



Wind turbine gearboxes – cold start-up tests

- **General procedure (OEM / Supplier dependent):**

Lubrication oil is heated up in separate oil tank and the gearbox oil sump from -40°C to +10°C. Friction losses from gearbox are than used to heat-up the oil quicker, next rotor speed is increased in a pre-determined procedure until partial load and full load can be applied.

- **Lessons learned during climate chamber tests:**
  - Generic lessons linked to the associated risks – example oil pumps, cavitation, seals,…
  - Climate chamber test = Standard test in validation trajectory (Cf. Automotive or off-highway vehicle tests)
  - Average cold-start-up time for gearbox: 5h – with wind

- **Continuous optimization and R&D:**
  - Testing of new lubrication oils and their performance during cold-start

Contact person & more information

pieterjan.jordaens@owi-lab.be

be.linkedin.com/in/pieterjanjordaens/en

@OWI_lab

Knowledge sharing – LinkedIn Group:
Offshore Wind Infrastructure
Application Lab (OWI-Lab)

www.owi-lab.be