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Extreme cold start-up validation of a wind turbine gearbox by the use of a large climatic test chamber

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Introduction

Wind turbines are installed worldwide, and therefore these systems need to operate in different climatic environmental conditions. They need to operate in the artic cold and/or in the blistering desert heat, and they are supposed to do so for 15-20 years without having major breakdowns. Design engineers need to take such extreme conditions into account in order to have a reliable and efficient product in all conditions. Currently, wind turbines are more frequently installed in so called 'cold climate (CC)' or 'low temperature climate (LTC)' locations where temperatures below -20° C are not that uncommon. Standard turbines are designed to operate in -10° C temperatures, and survive in -20° C conditions. Recent weather data from locations like Inner Mongolia and Canada, indicate that even -45° C and -50° C could occur in the worst case.

As the market for the low temperature turbines is expanding, the IEA task 19 estimates a market potential of 20GW between now and 2017, as such the importance of having reliable and efficient turbines in such locations becomes an interesting topic. Many of these cold climate locations have profitable average wind speeds, free installation space, and the higher air density in cold weather makes this market attractive to investors if the turbine manufacturers can guarantee a high availability, reliability and efficiency.

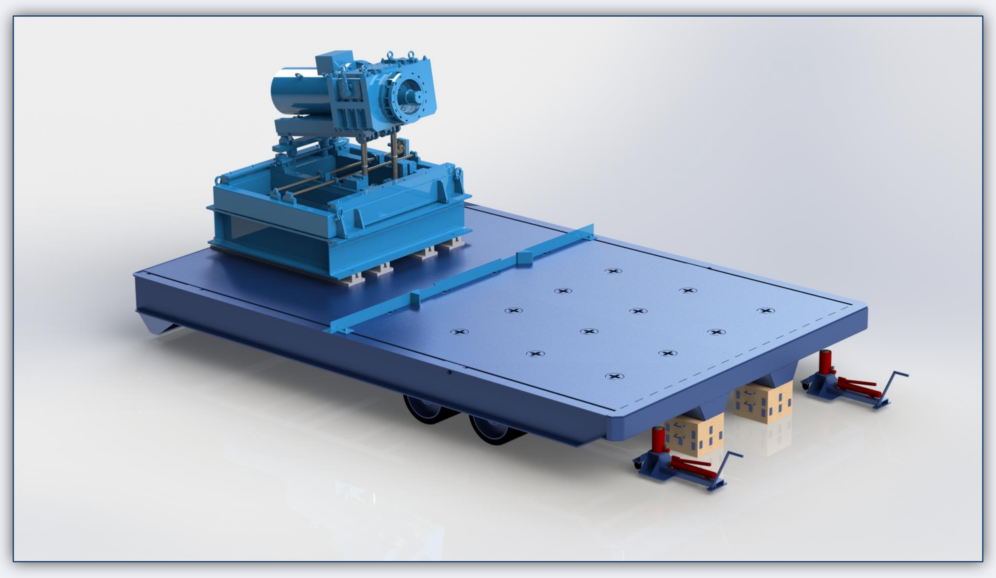
Why cold-start-up testing of a cold climate wind turbine gearbox

Since the early beginning of wind energy, a lot of effort has been made to optimize the wind turbine gearbox designs in order to be adapted for extreme environments. Also in the field of cold climate there is a lot of progress to increase the reliability, availability and efficiency of the full system. A cold start-up event for example is actually rather an exceptional load case. Still, due to the low temperatures, oils and greases become very viscous and stiff which put exceptional load on the gears and oil pumping equipment. Also the power transmissions capacity reduces when oil is cold. Plastics and steels are affected by the low temperatures and become brittle, which could lead to leakage. For these reasons most manufacturers provide CC gearboxes with special lubricants, steel alloys, (additional) reinforced heating, etc…to reduce the risk due to low temperatures.

During normal stop-events (too high or too low wind conditions, emergency stops, icing on blades stops, low temperature stops), the gearbox is not at risk because of these solutions when survival heating is applied. When for example the ambient temperatures goes to -40° C, the turbine will go into survival mode. Most, but not all OEM's, foresee survival heating of the gearbox oil at a certain oil temperature during such stop-event, but this requires parasitic power and leads to less annual power production (AEP) when keeping the oil temperature continuously at 20 or 30 ° C. In the worst case, during a grid failure, heater or sensor failure, power loss for power supply of heating equipment, the gearbox will be cold soaked during low temperatures. Also the thermal management and heating strategy is a topic: continuous heating at 20 to 30° C of the oil will demand lots of power. Therefore, in most cases a cold start-up time (also named time-to-grid time) needs to be taken into account in order to achieve a minimal component and oil temperature before full load production can be applied. In many cases the turbine will first idle (with or without reinforced heaters), and then produce at partial load before working at full load. This cold start-up time needs to be as short as possible as wind is very volatile.

In the prototype phase, the CC adaptations and operational limits of the design need to be tested and verified. Test data is also needed for optimization projects, for example to minimize the start-up times of the turbine through fast and controlled warm-up process and efficient thermal management. Physical design verification becomes important in this manner as simulating the effects described above are very complex and time consuming. Also, when models are used, they need to be verified through physical tests.

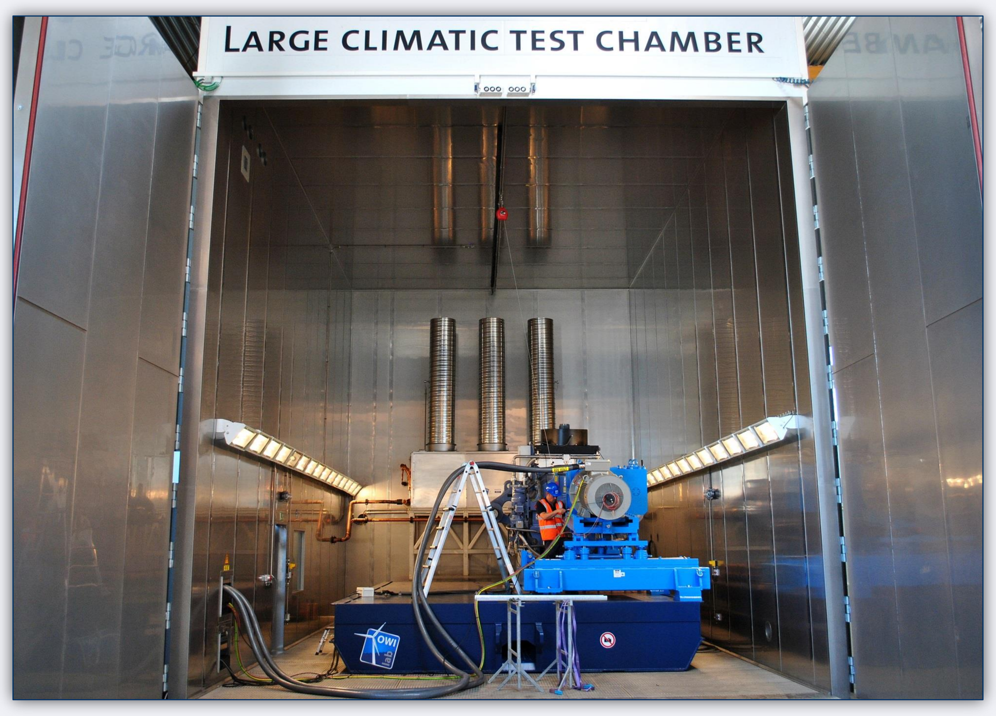
Test approach of a 2.XMW gearbox test at -40°C in the large climatic test chamber



As not many public climate chambers can cope with heavy machinery, OWI-Lab invested in a large climatic test chamber to test and verify different wind turbine components. Requirement for the design of the full test bench was to have a flexible multi-purpose climate chamber. In order to cope with the cold start-up test of a gearbox, also a no-load test bench was needed. This dedicated 315kW test bench was developed in partnership with ZF Wind Power Antwerp NV.

Test method:

The full set-up was placed under a tilting angle of 5° on an adjustable test bench to simulate the wind turbine mounting. Next, the full gearbox system (gearbox + oil lubrication unit) was cold soaked to -40° C. After cooling down for a full day, different start-up procedures have been performed with and without oil heaters ; idling was simulated at a certain temperature by the use of a 315kW motor inside the climatic test chamber.



Test results:

- Different cold start-up procedures were successfully simulated and verified in the climatic test chamber .
  To define the operational power and torque limitations of the turbine, and to have limit values for the turbine controller, different parameters in the gearbox and the lubrication unit have been measured:
  - Break-away-torque at -40° C was measured for cut-in speed at low temperature
  - Gearbox oil sump temperatures and pressures
  - Bearing temperatures
  - The time-to-grid time was determined after cold soak to -40° C with and without oil heating
  - Warming up time to partial load production was determined
  - Time to full load production was determined
- The full system was checked for any leakages due to thermal effects

New test infrastructure and future R&D works

In order to further investigate the behavior of extreme thermal effects on the gearbox and it's auxiliaries, OWI-Lab invested in a research gearbox to test and validate new cold climate lubrications and greases, and look into certain R&D topics which could further increase the reliability, and efficiency of the system. OWI-Lab will also strive to answer the below research questions in partnership with industrial companies, universities and R&D centers which are interested in this manner:

- What are the long term effects of thermal load on pump windings and seals?
- Can new lubricants lead to more efficient and reliable operations?
- What is the best thermal management and heating strategy in different temperatures to have a faster warming-up time?