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Cold start of a 5.5MVA offshore transformer

Bram Cloet(1); Pieter Jan Jordaens(2) ; Jama Nuri(1); Raymond Van Schevensteen(1)

(1) CG Power Systems Belgium; (2) OWI-lab (Sirris)

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Abstract

The state of the art SLIM® wind turbine generator transformers (WTGT) have to operate in wind farms which are often located in remote locations with harsh conditions and very low temperatures. After some days of no wind the transformer can be cooled down to -30ºC or even -40ºC, these conditions need to be tested to ensure the reliability of CG Power System Belgium's WTGT's and the possibility to start in cold conditions. Several tests were conducted in OWI-Lab's large climatic test chamber. OWI-Lab's test facility is the first public test centre in Europe that deals with extreme climatic tests of heavy machinery applications up to more than 150 ton.

Due to the higher viscosity, at low temperatures, of the used cooling liquids, the natural convection cooling of the internal windings may be limited. According to the properties of the cooling liquid that is used inside the WTGT it remains 'liquid' above -45ºC (pour point), but due to the high viscosity the natural convection may be limited and it may be possible that the initial losses generated inside the transformers' windings cannot be evacuated fast enough. To verify this a full load cold start test was conducted at -30ºC. During the cold start test the internal pressure and several temperatures where measured.

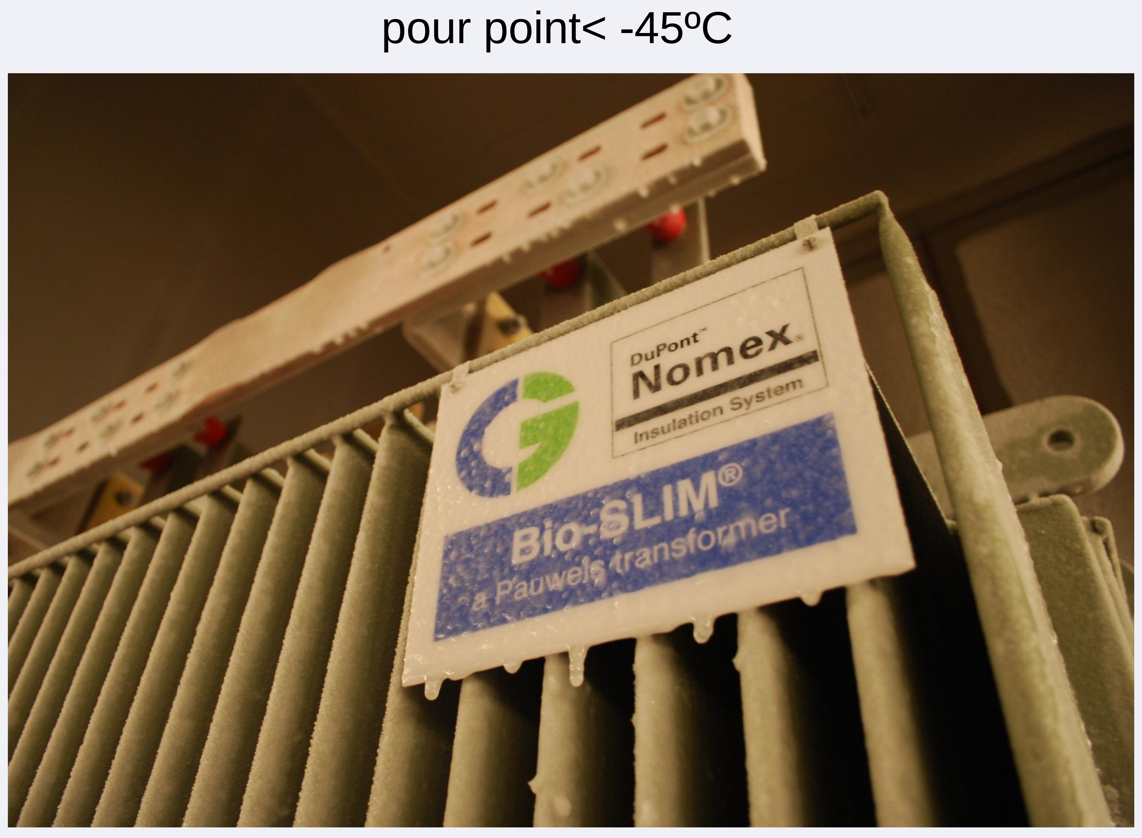
Also a storage test was done at -40ºC to prove that no leaks or other visual issues occurred on the tank and gaskets.

Introduction and test object

First a storage test was done at -40°C on a synthetic ester filled Bio-SLIM® transformer. Secondly a cold start test was done on this Bio-SLIM® transformer to verify that the transformer is well suited to cope with a full load start after the transformer was cooled down to -30ºC. These tests were conducted at the brand new climate chamber of the Sirris OWI-lab located in the port of Antwerp [1].

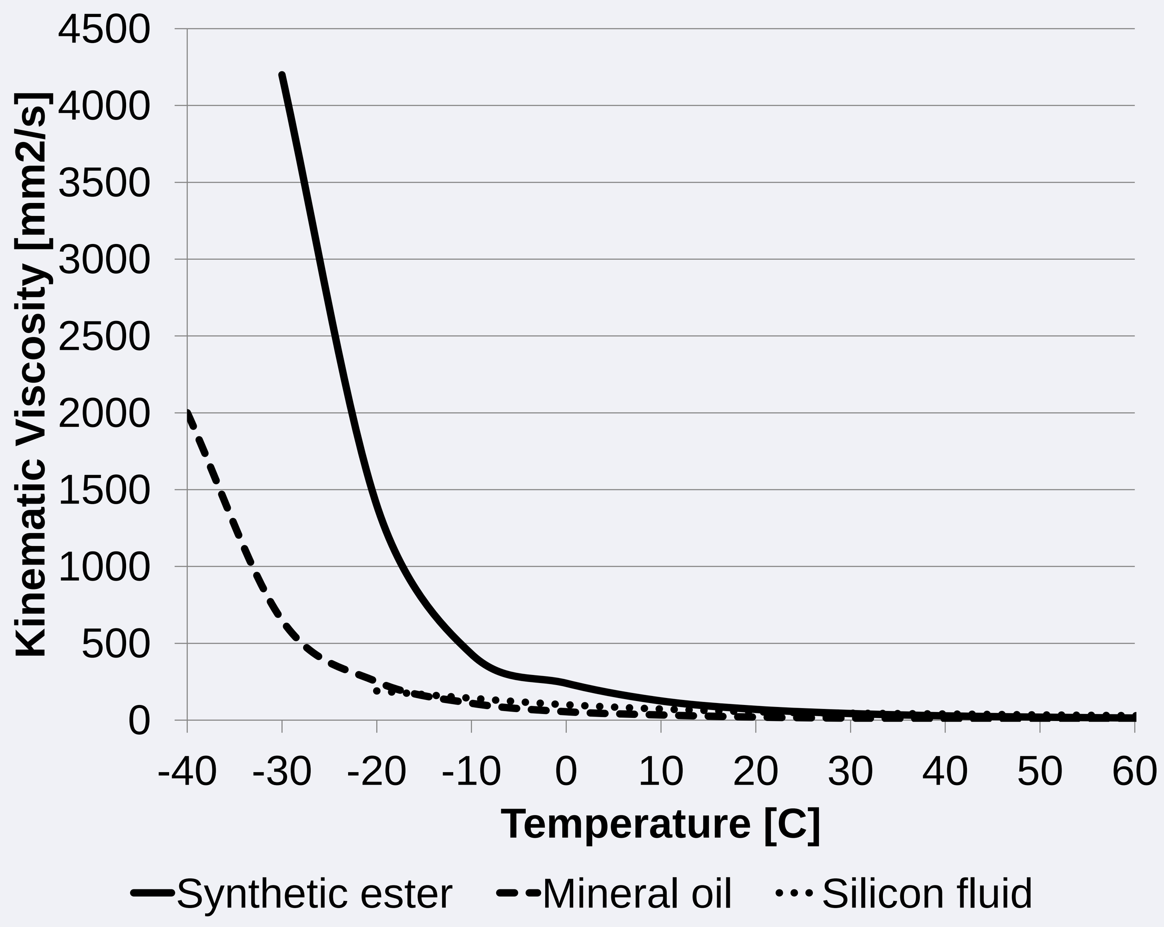
The tests are performed on a synthetic ester filled off-shore WTG Bio-SLIM® transformer with the following properties:

Rated power:	5560kV
High voltage:	33kV
Low voltage:	690V
Short circuit impedance:	12%
Total losses:	50kW
Total mass:	Approx. 11ton
Cooling Liquid:	Synthetic ester (integrally filled) pour point< -45ºC



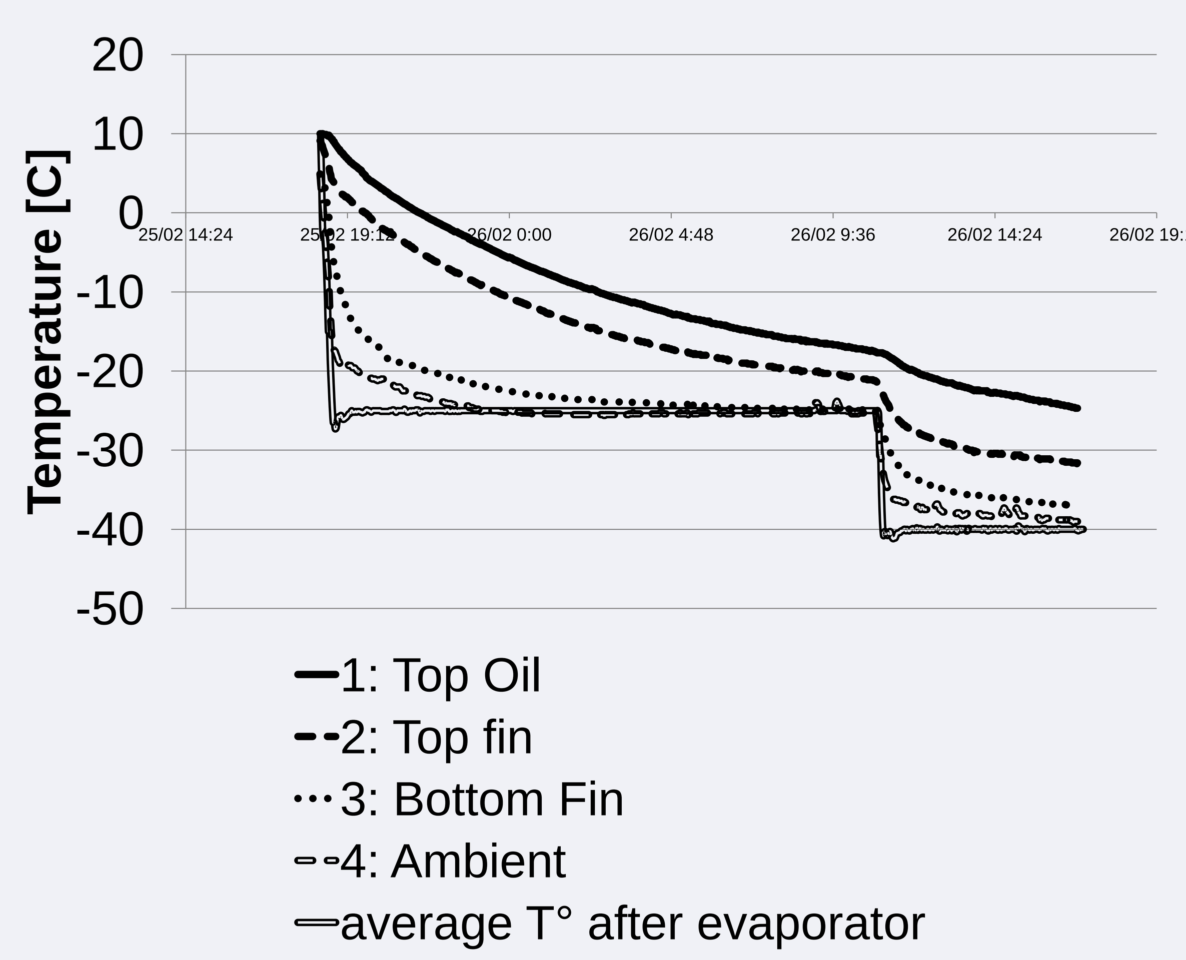
The need for cold start testing

- Cooling performance at low temperatures
  - Higher viscosity limits natural convection
  - Possible cooling issues during cold start



- Lower operating temperatures required
  - Operating conditions as low as -40ºC
  - More wind turbines installed colder climates, US, Canada, China
- Influence on operating pressure
  - Bigger temperature range and fluctuating load thus bigger pressure changes
  - Risk for fatigue failure of metal tank

Storage test -40ºC



For the storage test we have cooled down the ambient temperature to -40ºC in two steps. First we cooled down to -25ºC to check the underpressure in the transformer tank. The underpressure wasn't to low, thus we proceeded with the second stage to -40ºC.

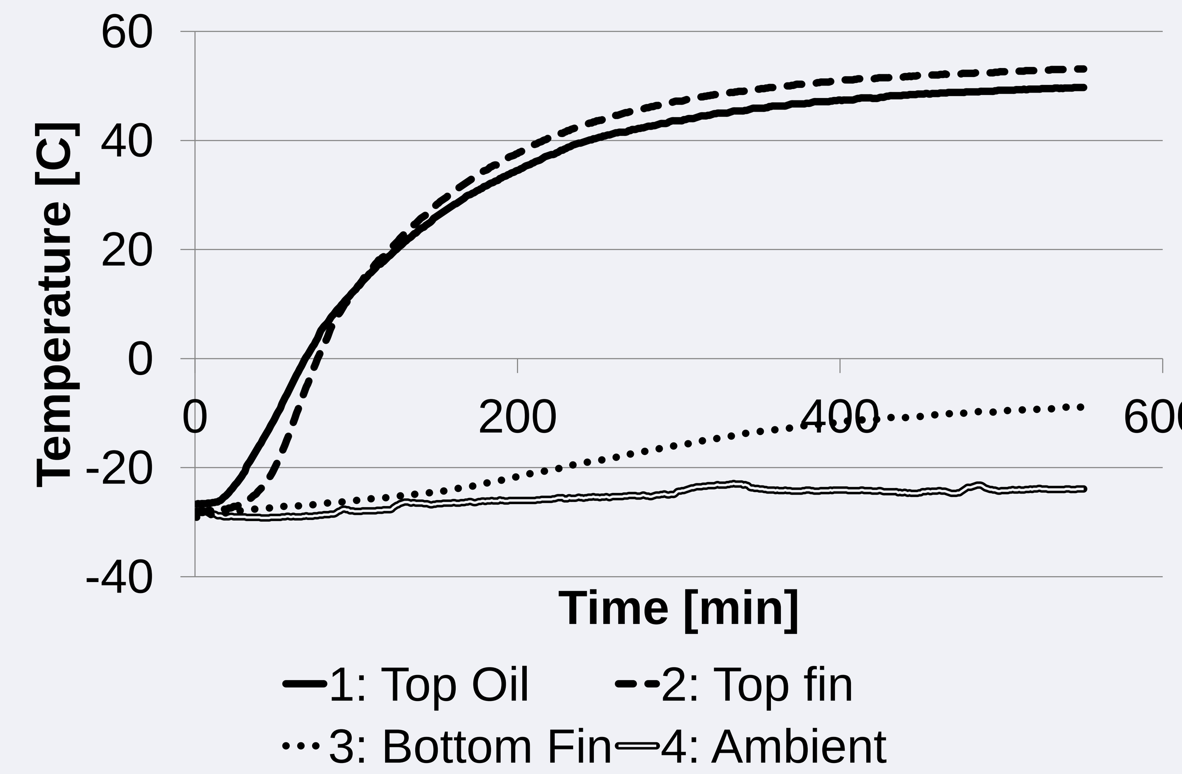
After the storage test the transformer was visualy inspected. No leaks, cracks or other anomalies where detected.

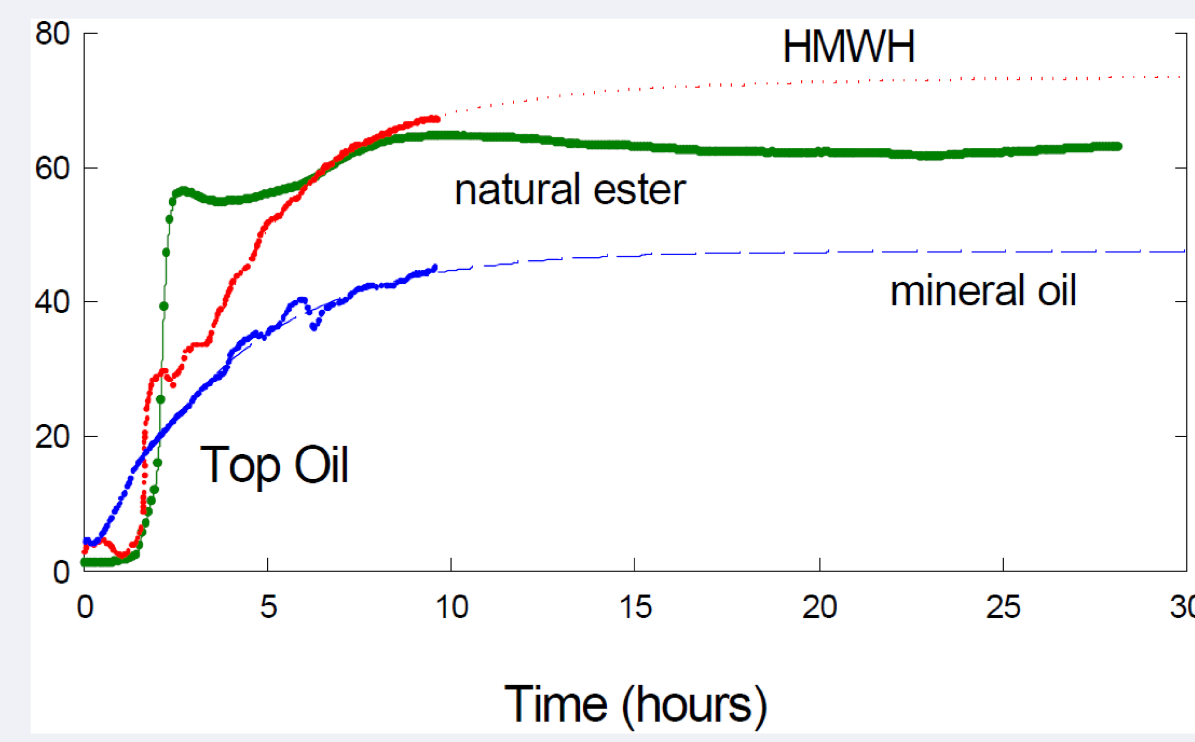
After this test the temperature was set to -30ºC to proceed with the cold start test.

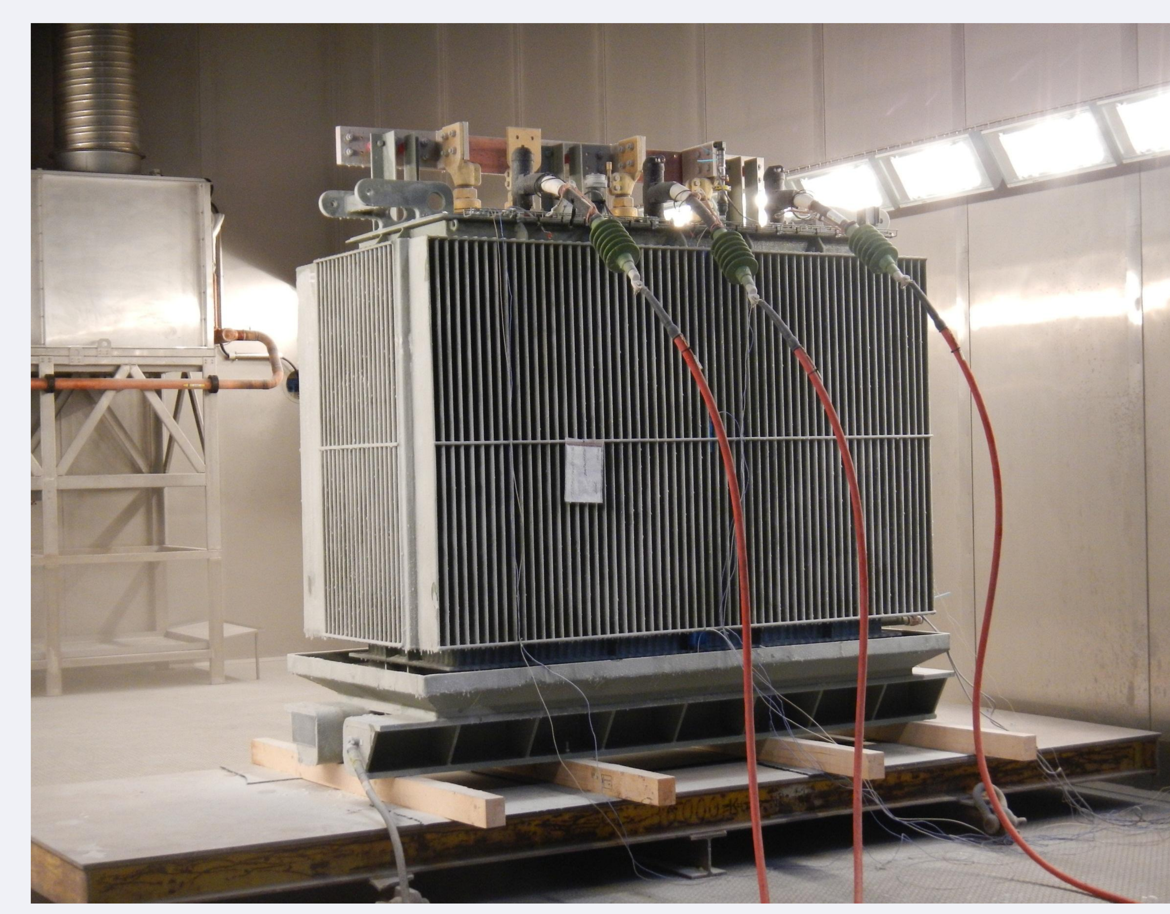
Cold start test at -30ºC

We can see that the top oil starts to rise after about 15 minutes. This indicates that natural convection starts quite quickly with evacuation of the losses from the transformers windings. We have noticed that on top of the cooling fins the temperature starts only with rising after about 25 minutes and then rises more quickly than the top oil.

In the temperature rise however we do not see strange temperature excursions like in [2] where a cold start test at -30 ºC is described on transformer filled with a natural ester with pour point above -30ºC. Here sudden changes in temperature rise are seen after about 1-2 hours, this is due to the fact that the natural ester was not liquid at start. This behaviour is not seen in our case which indicates that the synthetic ester in our test was still liquid enough to evacuate the losses fast enough.







Conclusions

From this poster we learned that there is a need for transformer testing at low temperatures. Thanks to OWI-Lab's large climatic test chamber a succesfull cold start test has been done on a 5.56MVA off-shore WTGT. This test proved that the synthetic ester filled WTG Bio-SLIM® transformer is able to cope with a sudden full load cold start at an ambient temperature of -30ºC. No abnormal behaviour was detected during this test. Even an ambient temperature of -40ºC, to test the storage conditions, did not bring up any issues.

Future works

The following future tests at OWI lab would further optimize the WTGT's performance at harsh conditions:

- Measurement of temperature inside windings with fiber optic sensors.
- Increasing temperature leap during cold start by also raising ambient temperature to the worst case condition.
- Cold starts at temperatures down to -60ºC.
- Testing other types of cooling systems like KFAF.
- Perform HALT tests with presure cycles to simulate mechanical fatigue by the presure variations.

References

1. OWI lab, "OWI application lab," [Online]. Available: http://www.owi-lab.be/. [Accessed 14 2 2014].
2. K. Rapp, G. Gauger and J. Luksich, "Behavior of Ester Dielectric Fluids Near the Pour Point," in IEEE Conference on Electrical Insulation and Dielectric Phenomena, Austin, TX, 1999.

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