

# Cryosystem for the EcoSwing Project

## The design and field trial of a 3.6 MW HTS wind power generator

# Nine Partners working towards a common goal



UNIVERSITY OF TWENTE.



- Project web site: [www.ecoswing.eu](http://www.ecoswing.eu)

# Sumitomo Cryogenics Contributors



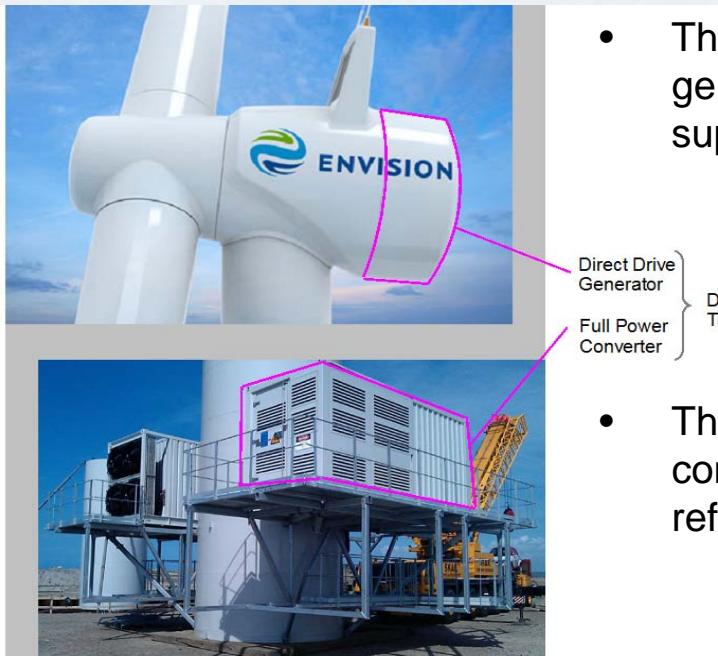
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# Core ambitions



- Design, develop and manufacture a full scale multi-megawatt direct-drive superconducting wind generator
- Install this superconducting drive train on an existing modern wind turbine in Thyborøn, Denmark (3.6 MW, 15 rpm, 128 m rotor)
- Prove that a superconducting drive train is cost-competitive
- **Have the generator running in the field.**

# Platform for technology validation



- The idea is to replace a PM generator with a superconducting generator
- This includes power conversion and refrigeration equipment.

# Ecoswing Design Requirements



- Design according to IEC61400 and IEC60034 series
- 3.600 kW, 2.460 kNm, 690 V, 50 Hz
- Insulation class F
- Max temperature rise class B
- Temperature, external: -20 °C +30 °C
- Altitude: 2000 m
- Humidity <95%, 100% for 10% of life
- Turbine system mechanical load
- Vibrations (Fore-aft, Side-side, Roll, Nod, Yaw)
- Restricted space request for compact design
- Serviceable wear parts
- Service interval minimum 1 year
- Lightning protection IEC61400-24

Same as for conventional generators



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# EcoSwing main design parameters



- 3.6 MW rated
- Diameter: 4 meters
- Direct drive, 15 rpm
- Cold yoke
- 12mm wide ISD GdBaCuO tape (> 20 km of tape)
- 40 double pancakes coils in rotor
- 13 mm air gap
- Air gap shear stress 113 kPa
- Air gap induction 1.6 T

# Unique requirements



- Stability of superconductor supply
- Robust and proven cryogenics (incremental innovation)
- Risk mitigation through testing of sub components.

Unique for superconductive generators



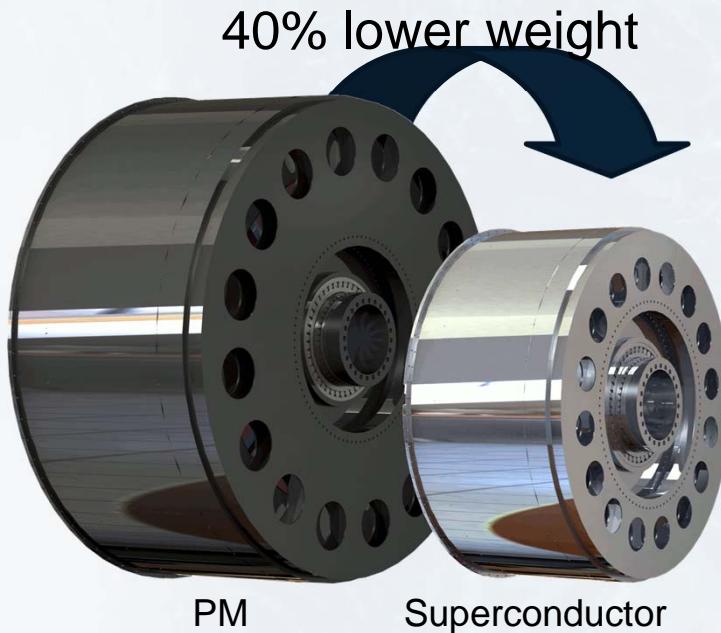
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# Main design goals

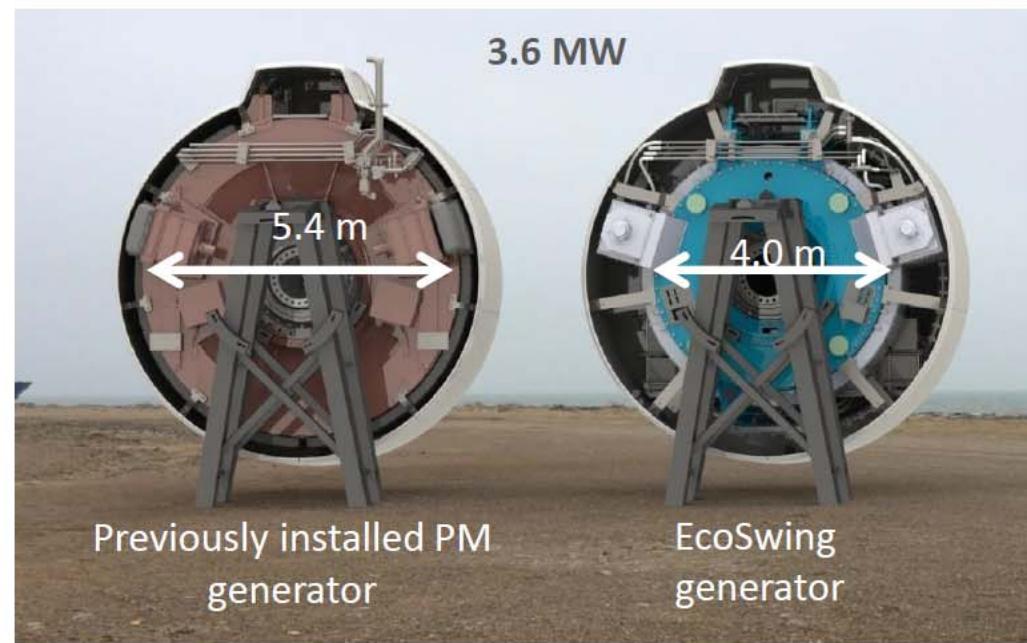


- **All roads capability:** diameter limited to < 4 m
- **Low cost design:** Commercial components for superconductors as much as possible
- **Low weight design:** Optimized for low top head mass
- **Mainstream markets:** 3.6 MW for on-shore and off-shore.

# EcoSwing design



- Decreased diameter from 5.4 m (PM generator) to 4 m
- Built **EcoSwing generator:** **25 % weight reduction** compared to PM generator of same diameter
- Commercial design: **40% weight reduction** compared to PM generator.



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# Cryocooling



SHI Cryogenics Group provides commercial grade cryogenic equipment

- SRDK-500B cryocoolers
- F-70 compressors.

Cooling Capacity (Vertical Orientation)

46W @20K / 85W @30K (50Hz)  
52W @20K / 96W @30K (60Hz)

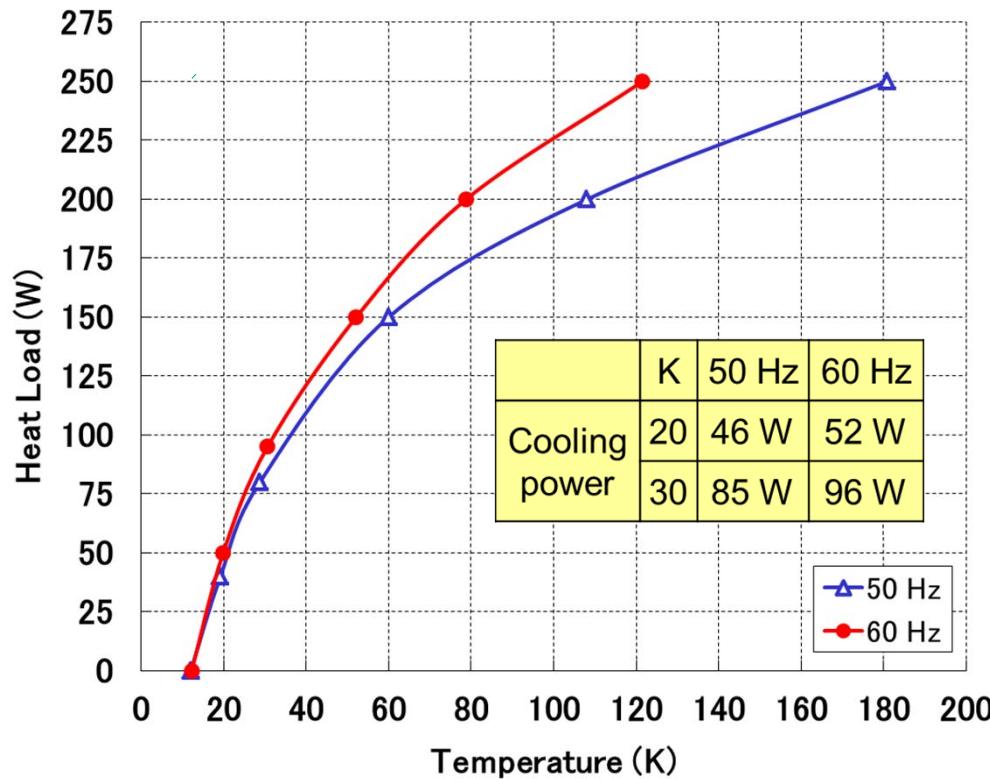
Dimension: H: 570 x W: 180 x L: 325mm

Weight: 25kg

# RDK-500B Cooling Capacity

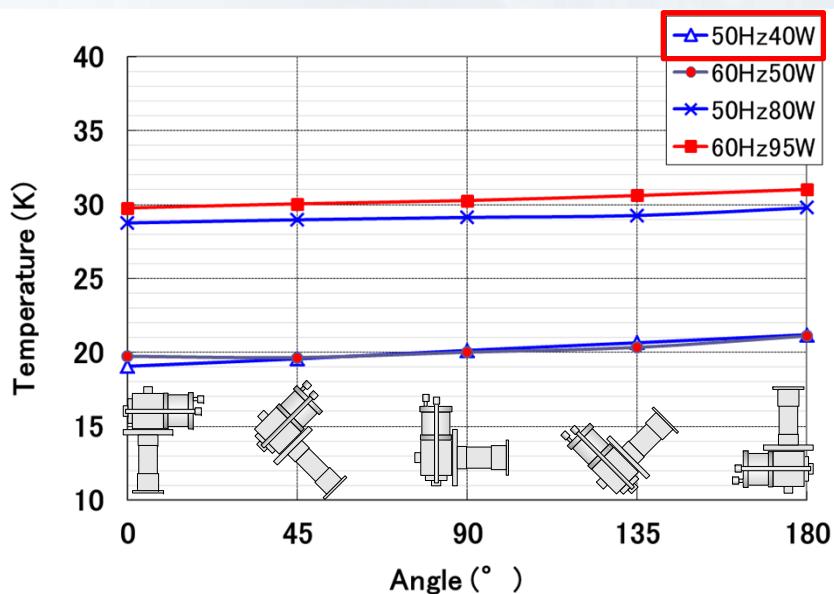


Cooling performance is optimized around 20K region with Bi regenerator material.

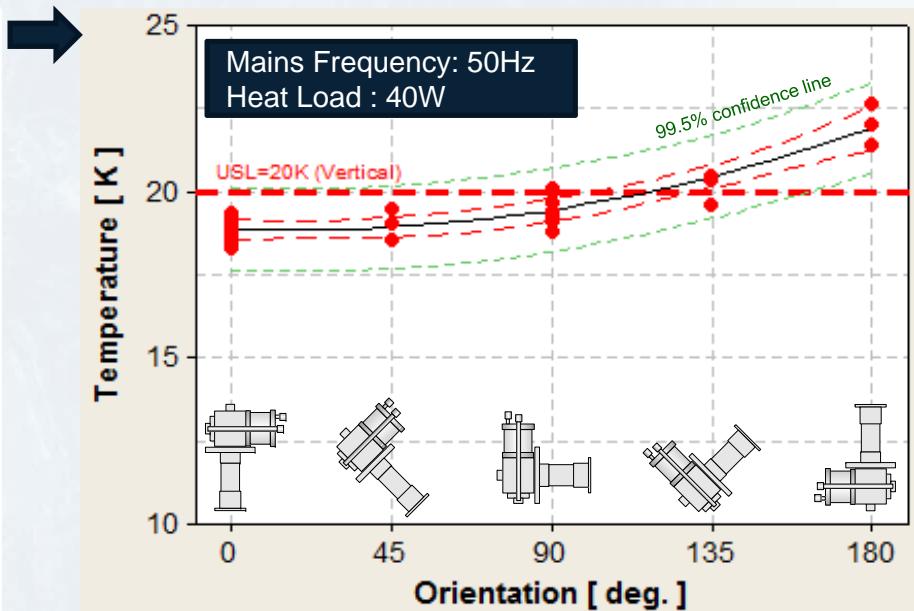


COP: 0.0068 @20K  
0.012 at 30K  
Power consumption:  
7 / 8kw @ 50/60Hz  
Lowest Temp.: 12K  
Cool Down Time: 60min to 20K

# Orientation Dependency



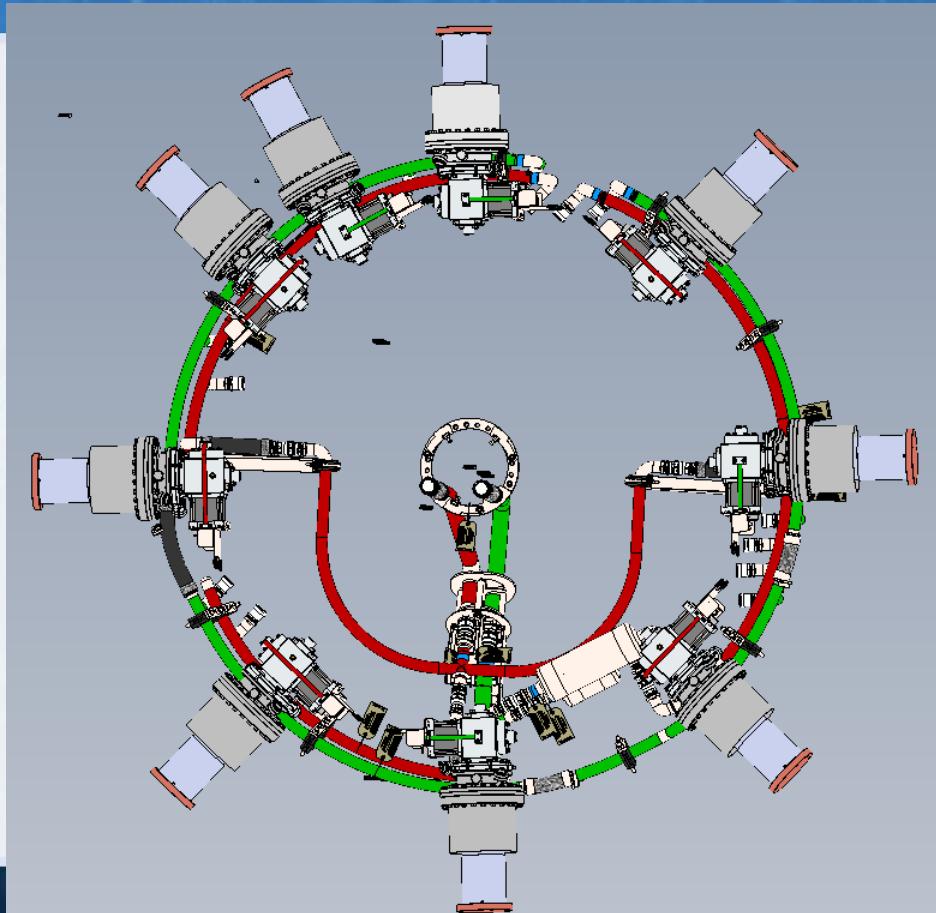
Prototype Data (Y2013)



Production Data (Y2016)

# Cold Head Mounting Orientation

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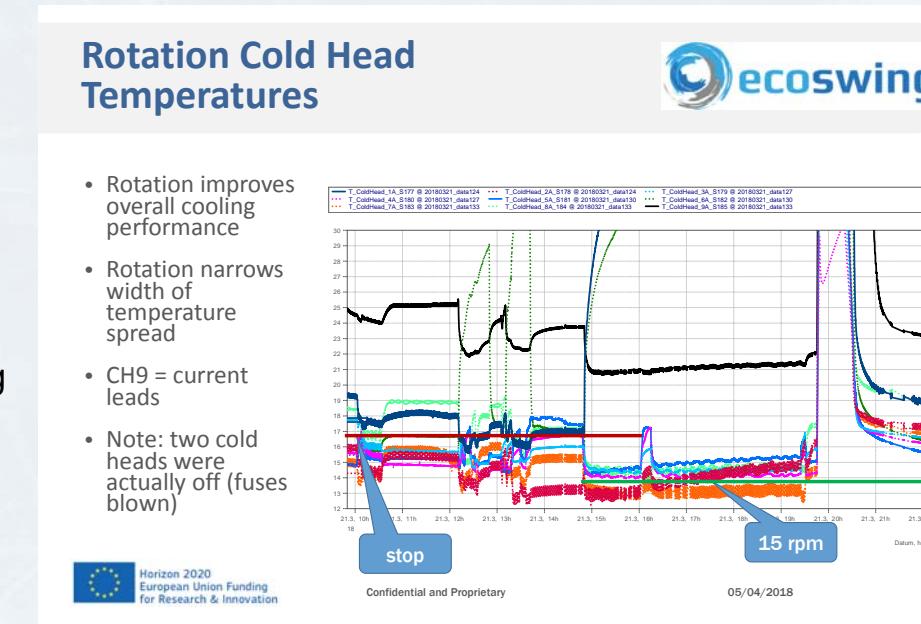


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# Some Detail Findings Cryogenics Performance

- Cold heads perform better than expected during rotation. Probably due to centrifugal force on piston.  
→ Better thermal performance.
- Rotary joint has proven its function using “normal” industrial components  
→ No leakage was detectable during the operation at IWES.
- No bad experience with vibrations on RJA – slipring and HE coupling – no issues.
- World first RJA with standard seals for HTS machines



# Warm rotary gas joint



- Gas is supplied from/to 9 stationary compressors and 9 rotating cold heads through a single warm rotary gas joint.
- Rotary joint has channels for electrical cables to/from electric slipring, positioned behind it on rotation axis
- Two alternate rotary joint designs were tested before installation
- Leak to ambient (gas loss) as well as leak from high to low side were measured.
- The leak rates were from  $\sim 10^{-5}$  to  $10^{-3}$  Pa m<sup>3</sup>/s, depending on condition (rotation speed, overall vs. differential)
- The installed rotary joint has helium loss rate that allows  $\sim 1$  yr operation on 1 standard size refill cylinder.
- Automatic helium refill system was added.

# Helium Rotary Joint Assembly



09.01.2018

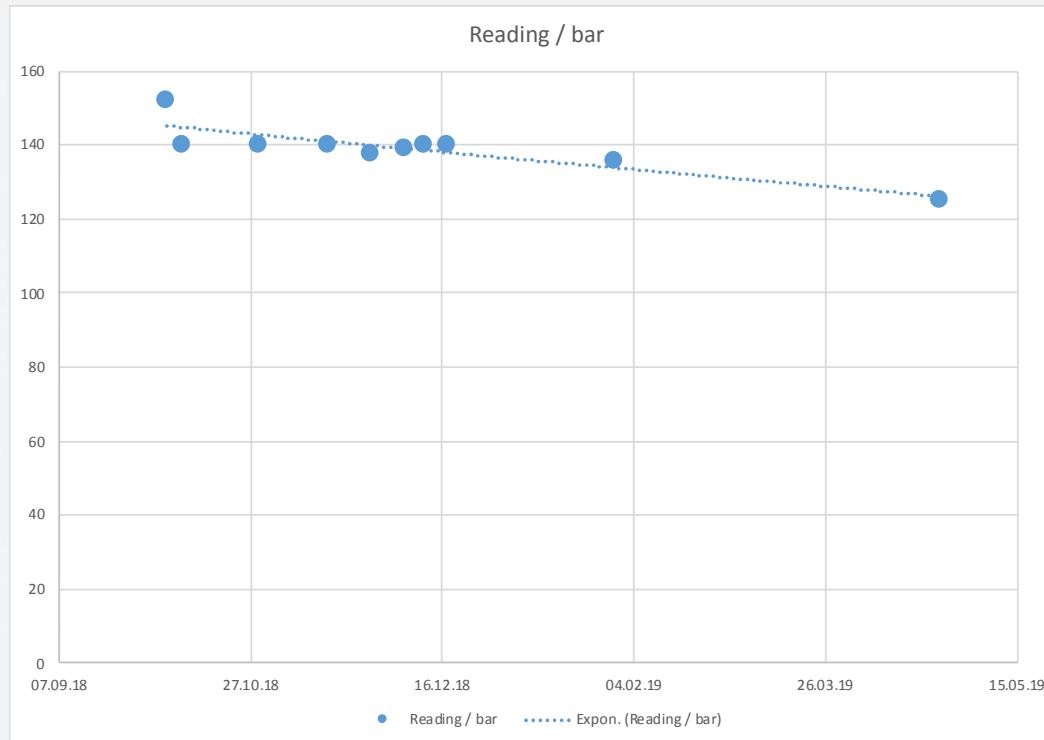


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## Excitation Stage 2 – Summary He Refill runs stable at low leak rate



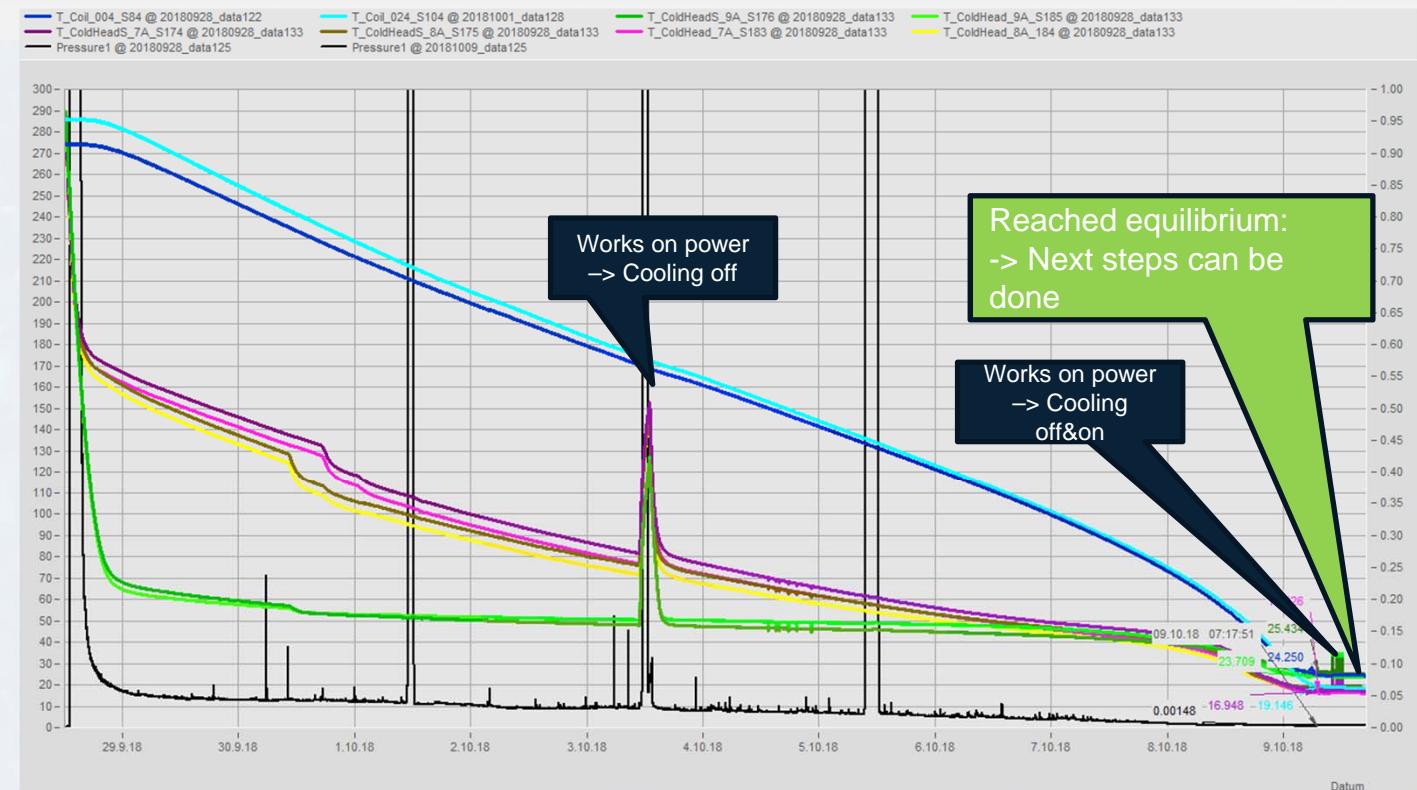
Average leak rate  
0.008 Pa m<sup>3</sup>/s

# Cooldown 28.09. to 09.10.2018



Turbo pump was switched off on 08.10.2018 and valve closed.

- Before:  
 $2.8 \times 10^{-7}$  mbar
- After 12 h:  
 $1.97 \times 10^{-7}$  mbar
- Selfsustaining

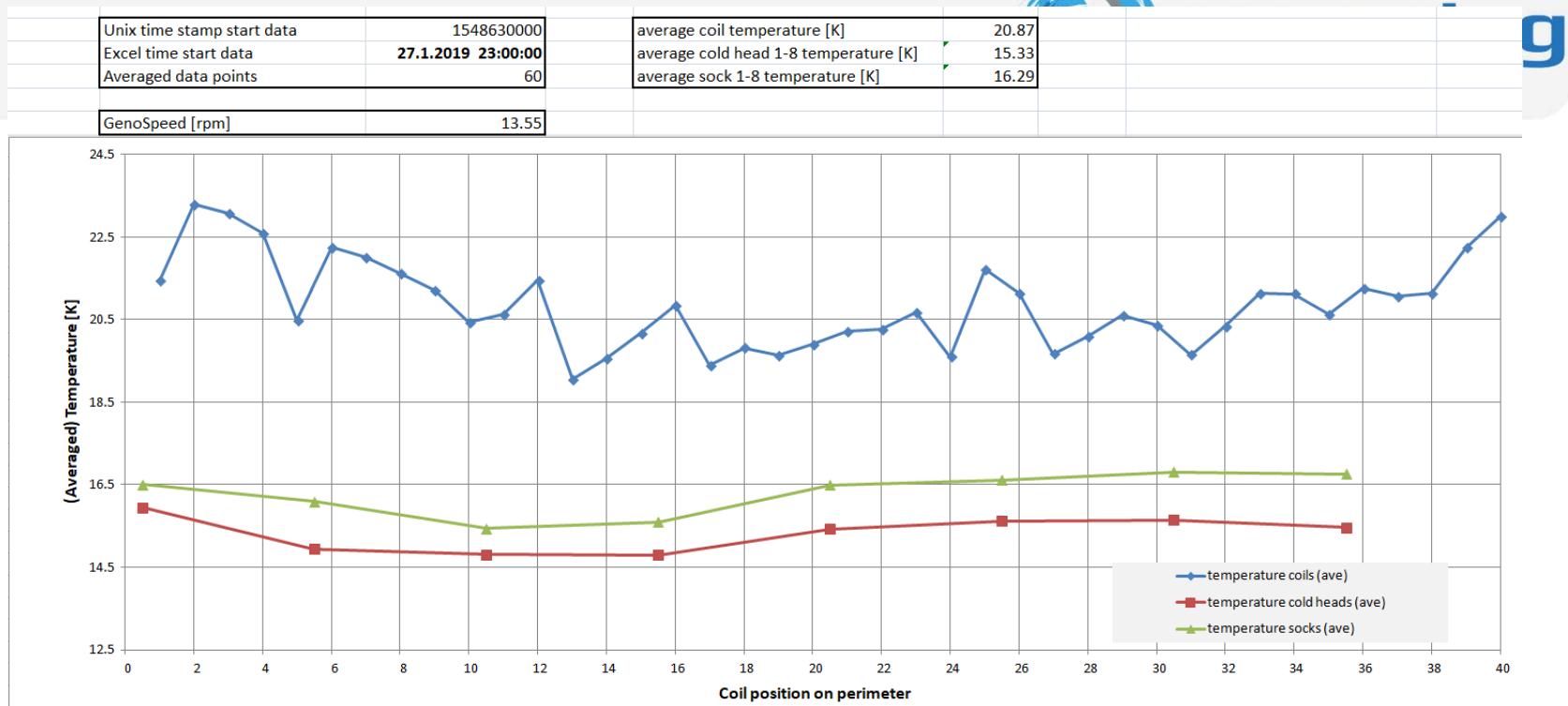


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# $\Delta T$ cold head-sock-coils



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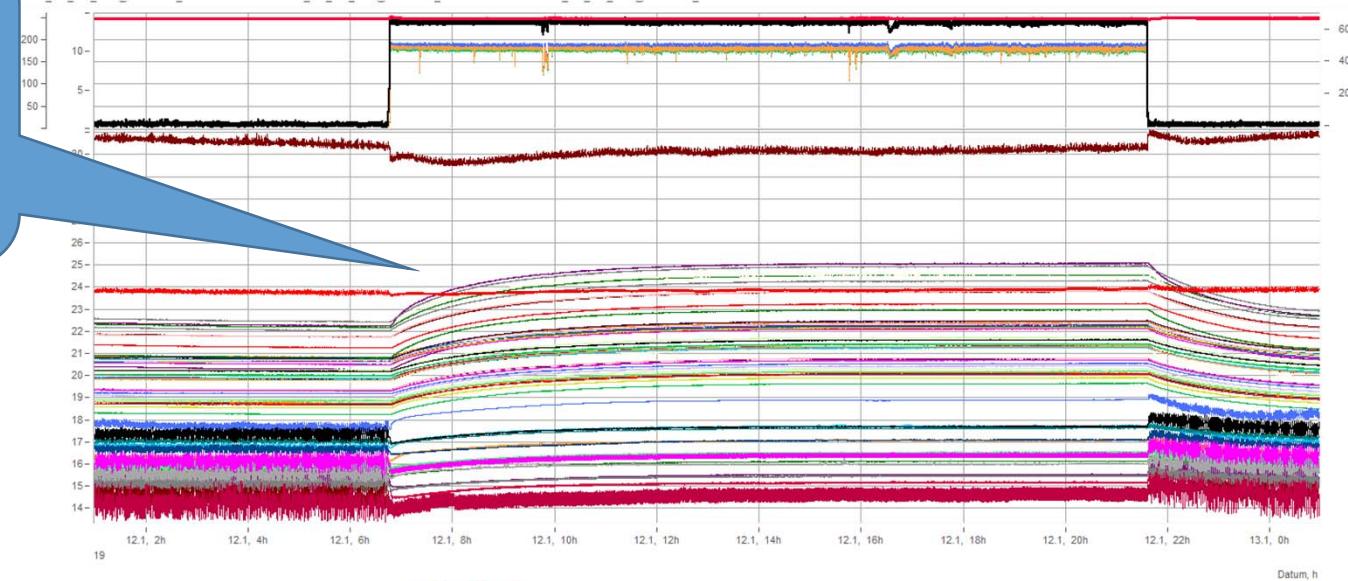
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# Power Production 12.1.2019

## First attended long period



- 2 MW
- HTS rotor thermally stable



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# Summary and conclusions:



EcoSwing ended on schedule.

On one hand the Consortium are quite sad to finish this inspiring project, on the other hand proud to announce a number of ground-breaking successes:

- EcoSwing generator and power converter reached target range +3 MW
- More than 650 h of grid operation producing power
- Automated unattended operation enabled
- More than 7 months of stable and reliable cryogenic system operation
- Superconducting rotor coils showed great performance and reliability

# Acknowledgements to the Team



Alexis Riviere	Hans Kyling	Michael Reckhard
Anders Rebsdorf	Hendrik Pütz	Mogens Christensen
Anne Bergen	Hermann Boy	Nathalie Renard
Ans Veenstra	Jan Wiezoreck	Patrick Brutsaert
Aurélie Fasquelle	Jean-Luc Lepers	Peterson Legerme
Aymen Ammar	Jean-Philippe Francke	Roland Stark
Bastian Schwering	Jens Krause	Sander Wessel
Benoît Dupont	Jesper H.S. Hansen	Sofiane Bendali
Bob Deobil	Jürgen Kellers	Stephane Eisen
Carsten Bührer	Kazu Rajju	Thomas Hisch
Cédric Dupont	Kimon Argyriadis	Thomas Skak Lassen
Christian Broer	Konstantin Yagotyntsev	Thorsten Block
Christian Koppe	Marc Dhallé	Torben Jersch
Christian Kruse	Marcel ter Brake	Trevor Miller
Christian Mehler	Markus Bauer	Werner Prusseit
Daniel Laloy	Martin Keller	Xiaowei Song
David Laurent	Martin Pilas	Yoichiro Ikeya
Frederick Deneubourg	Matthias-Klaus Schwarz	Yves Debleser

