Superconducting Medium Speed Synchronous Electrical Generator for 2MW class of Wind Mills

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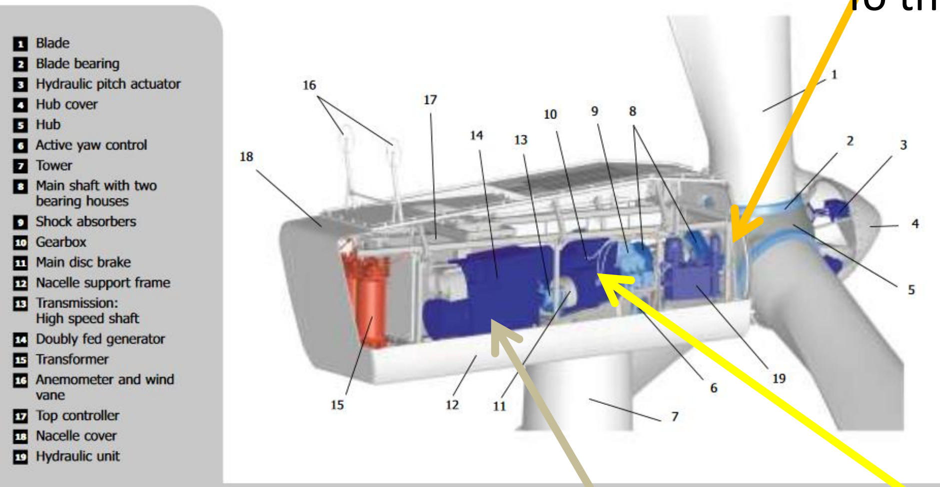
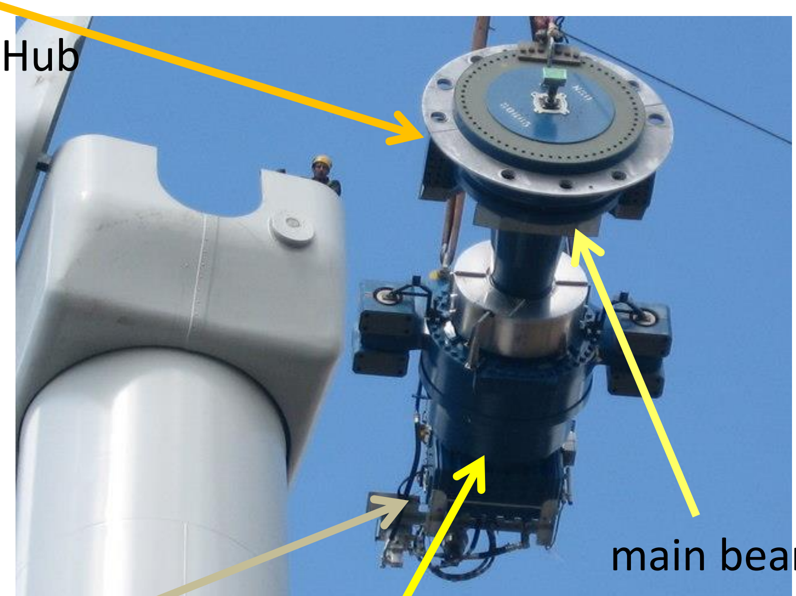
A look into the actual wind generator (2MW)

To the Hub





main bearing

Electric generator 6tn

gearbox 10/15- 1500 rpm

Nacelle weight	72tn
Blades assembly	42 tn,
Tower	220 tn
total	334 tn

Gearbox 20 tn

Does Superconductivity help to improve wind turbines generator?

Critical point	problem	improvement	Superconductor allows
•Torque conversion rate is to high due to the high speed needed for the generator	Complex and heavy gearbox	•Diminishing the speed of the generator •Diminishing the mass of the rotor	Ironless dynamic parts Higher magnetic Field
•High inertia of the rotating system and heavy rotor. High stresses when gusty wind	Very high gear rates. Heavy rotor and high speed leads to high kinetic momentum	•Diminishing the speed of the generator •Diminishing the mass of the rotor • Diminish the gear ratio	Lower rotation speed Lighter rotor Higher magnetic Field Direct coupling
•Losses in copper and iron lead to high working temperatures	Complex systems for cooling and room in the nacelle should be considered	•No iron •Higher field •Less copper	Less heat should be evacuated Less weight, less complexity Less volume. Less power for cooling. Higher efficiency
•Power rating is limited by mass, volume and their impact in the structure	Permanent magnets cannot be used extensively .	• Permanent magnets are not an option for large scale production. To diminish weight and volume need alternative technologies	Very small Rare Earth consumption . Is not a limiting factor for massive production
•Inductance of windings	introduces complexity in the converters	• Changes in the converters for high power	Low inductance and linear Ironless coils

Superconductors prefer DC
Losses are very costly

Hybrid architecture:
Copper for AC current
HTS for DC magnetic field

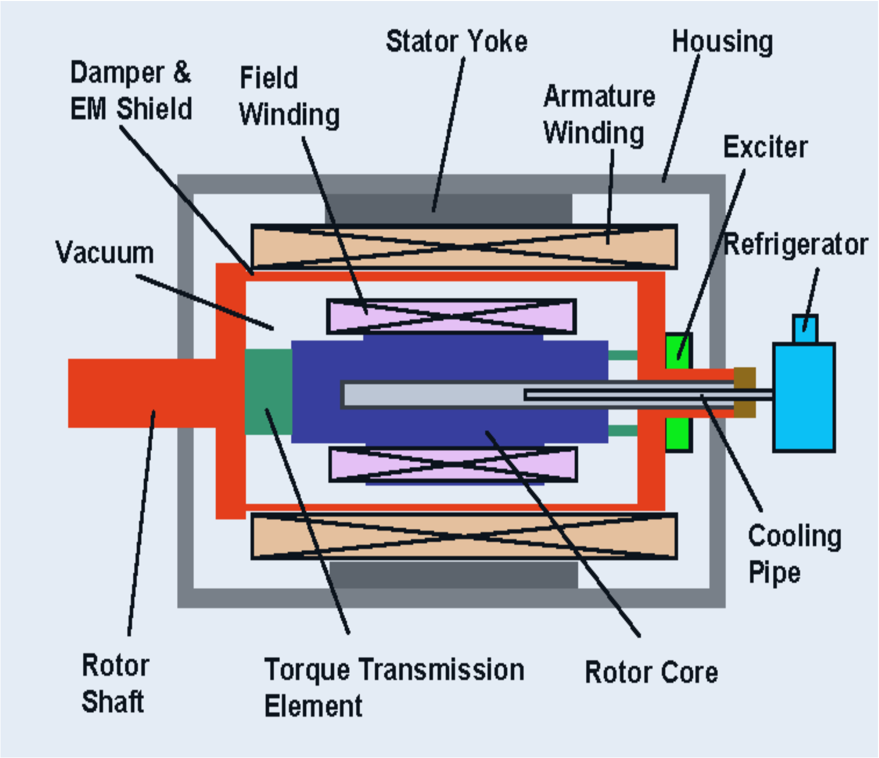
Synchronous Generator

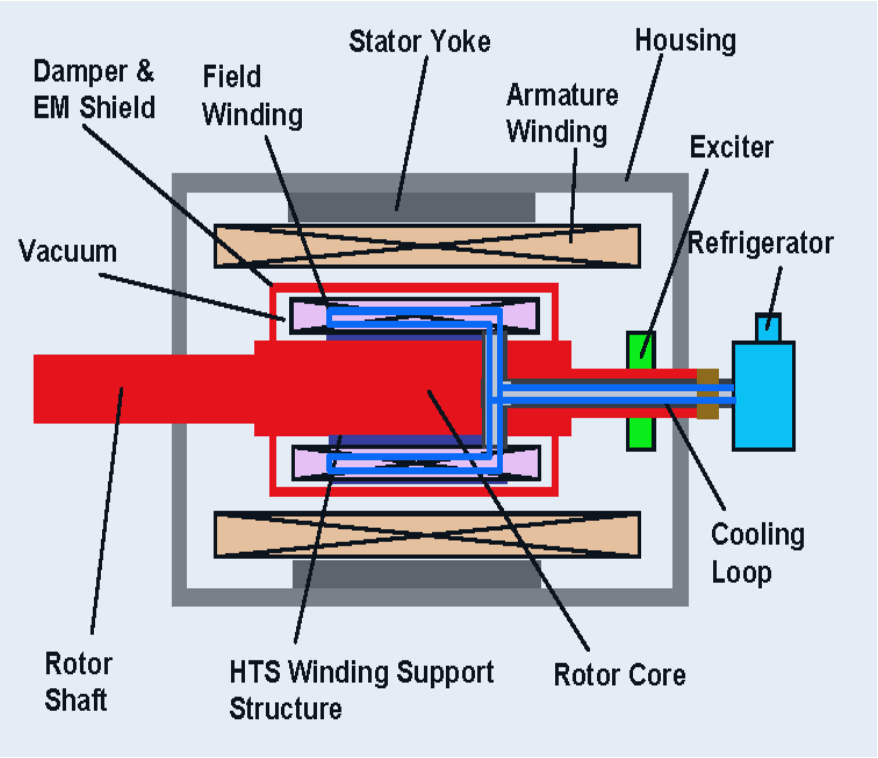
First Phase: definition of the architecture design, building and testing the first prototype	
Start, 2014 September	Initial designs, evaluation of performances, and cost. Definition of the concept for the testing prototype
2015	Decision of the prototype on the basis of scalability, simplicity reliability and possibility of field testing. Retrofitting of a standard 2MW DFIG Trade off, contracts and providers. Materials supply, coils, cryostat, testing bank, building and assembling the HTS stator in the cryostat and testing.
2016 April	Full assembling, installation in the bank, cooling down and no-load testing End of the First Phase.

Our compliments to Furukawa
Super Power
SuperOx
Who provided us with High Quality materials in a record time

Full rotor cooling!

Only rotor coils

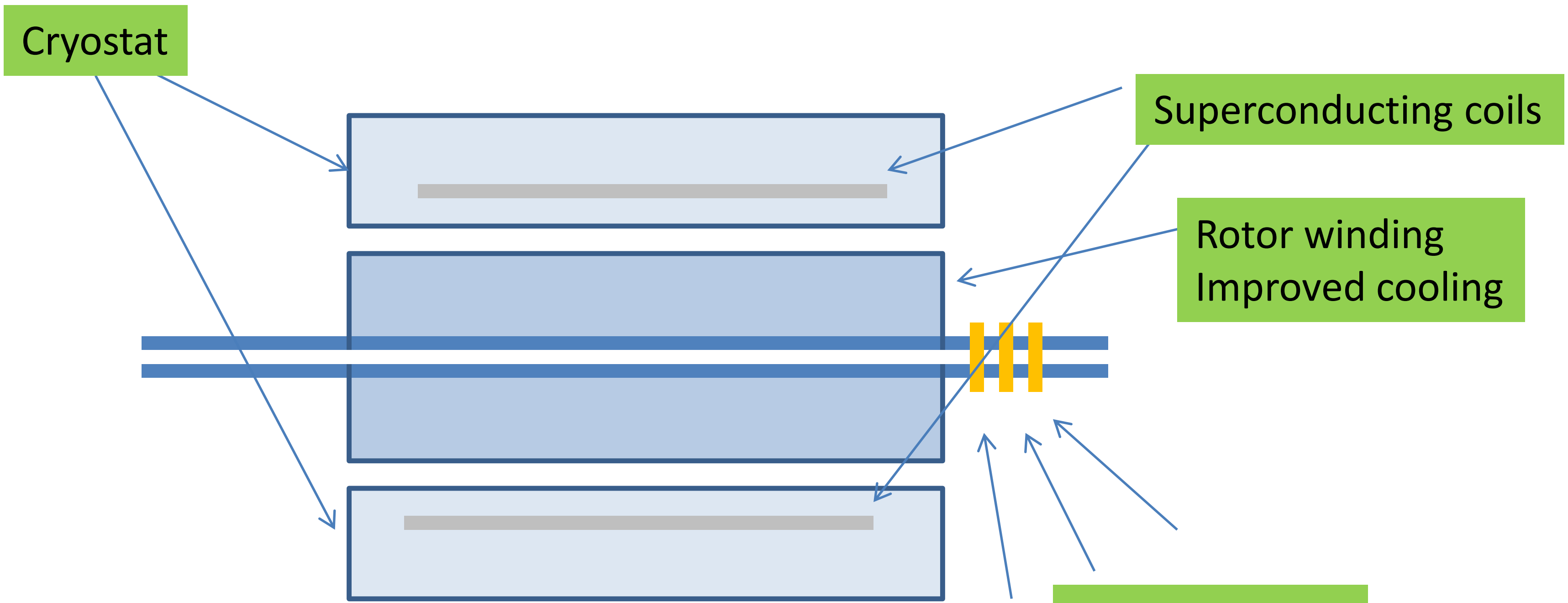




Is typically used in the HTS prototypes

Complex cryogenics: Centrifugal forces, vibrations, Helium at 20 bar rotating pass-through or rotating pumps.

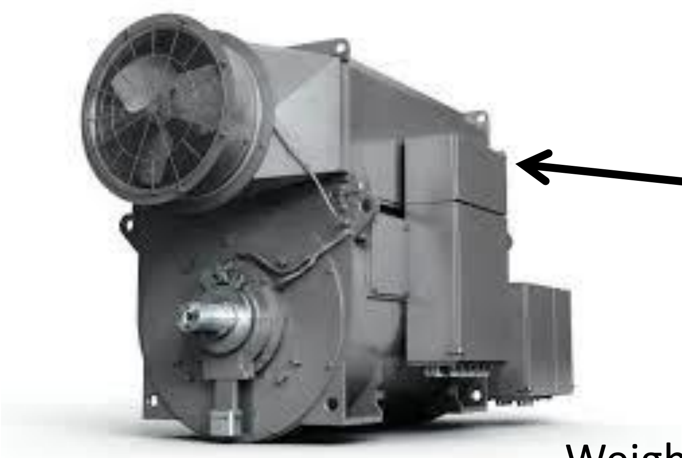
Why not the stator?



Easier for manufacturing
Possibility of hollow shaft for blades maneuver
No rotating seals
Cooling of rotor windings!!

ABB

Cantarey



Siemens

Heat exchanger (copper losses+ iron loses in the stator >40kW)

Feeding of the rotor coils with Sliding contacts

Weight in the range of 6tn

Lightening the generator

6 tm

Taking out the heat exchanger
1 tm less

Smaller and lighter and more reliable, energy savings
Less copper and iron losses and less energy for cooling

Experimental prototype:
reforming a Standard 2MW DFIGenerator
1rst step, only substitution of the estator

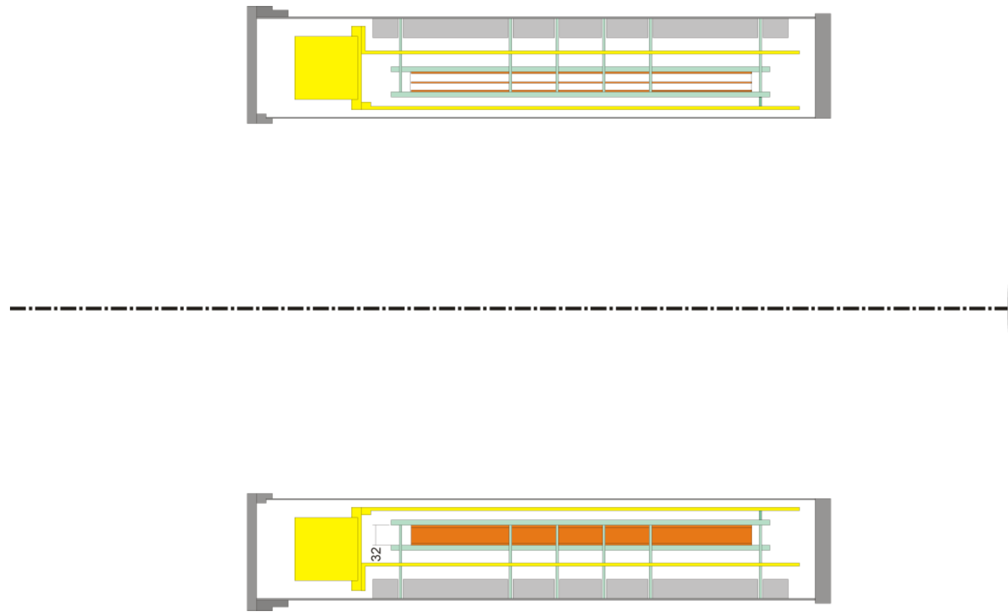
No heat exchanger (1tm less)

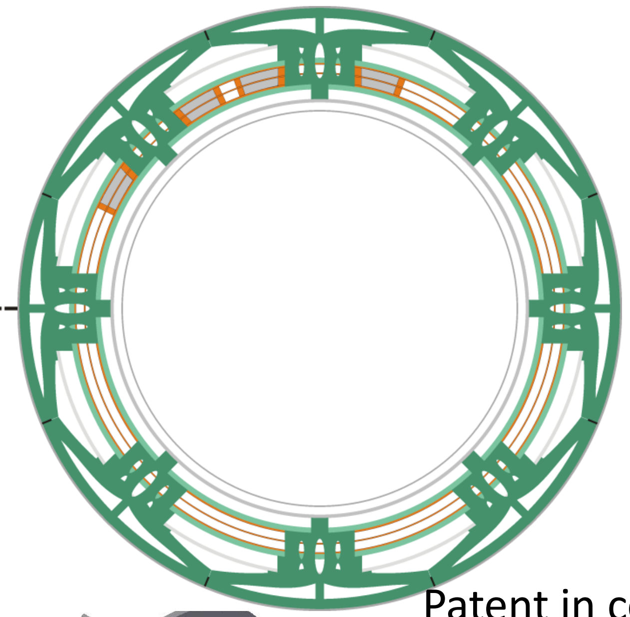
No iron neither copper (1tm less)

From 6tm to 4.3 tm … a first step!

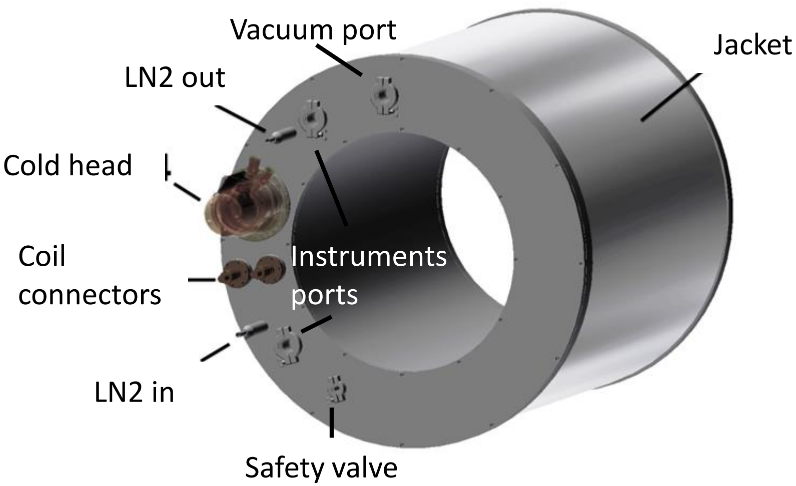
From 1500rpm to 480 rpm

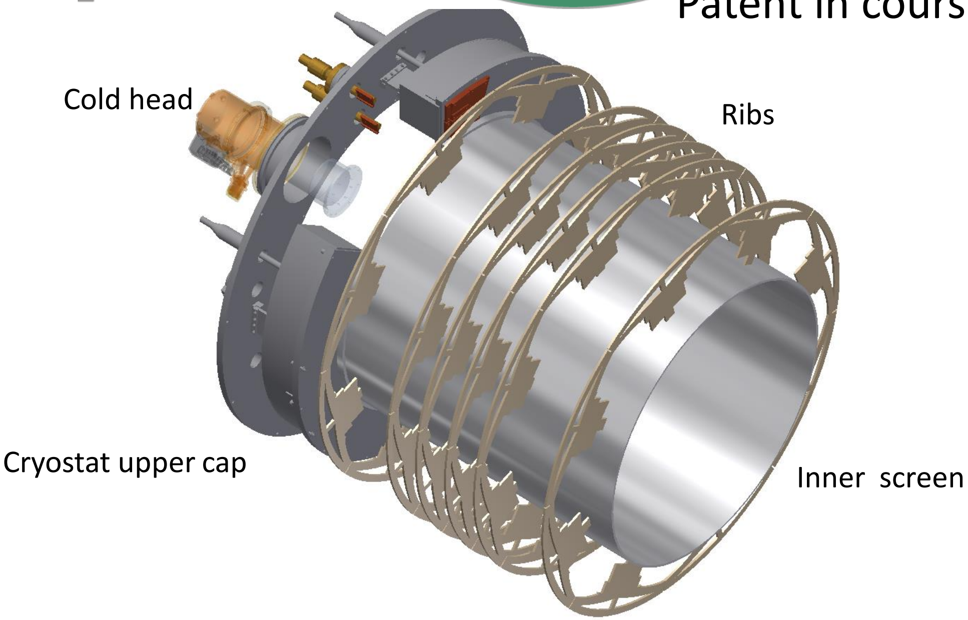
Design : The cryostat





Patent in course





Two cooling levels

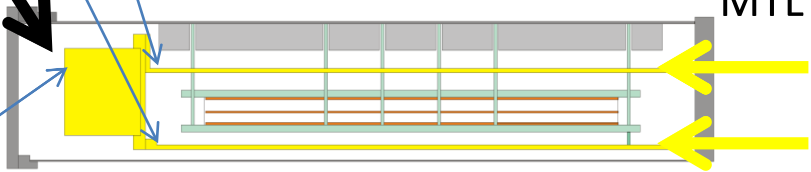
1rst :Thermal Screening and HTS Current leads provided by a LN2 tank/ cryocooler

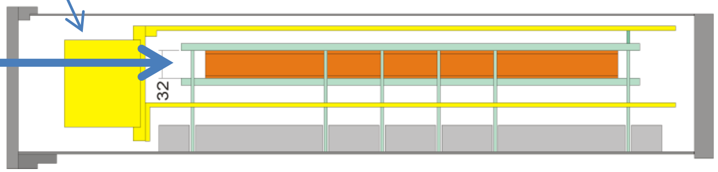
medium temp level (MTL)
allows cooling boostering, &
high efficiency, powerfu, maintenance-less Coolers for MTL

LN2 tank

Screens (Heat radiation and EM radiation)

MTL





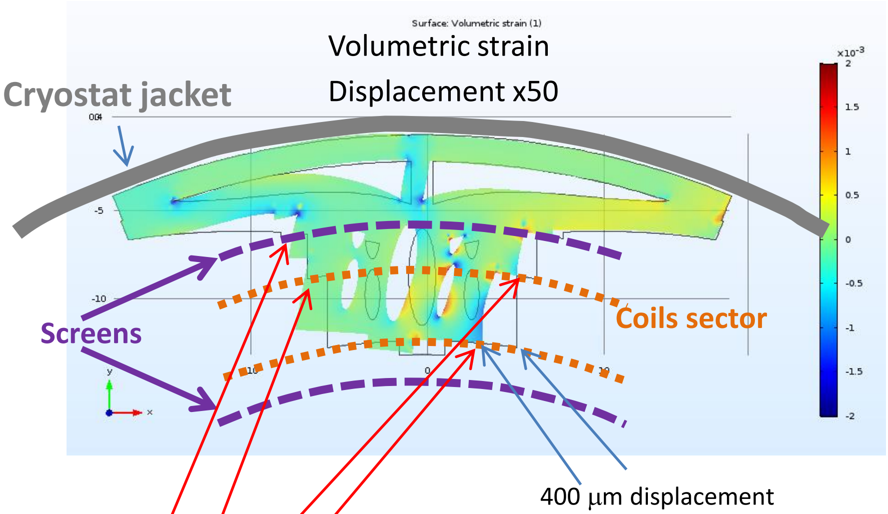
2nd (LTL) :cooling of coils connected by flexible copper coupling to the cryocooler

Patent in course

Torque transmission

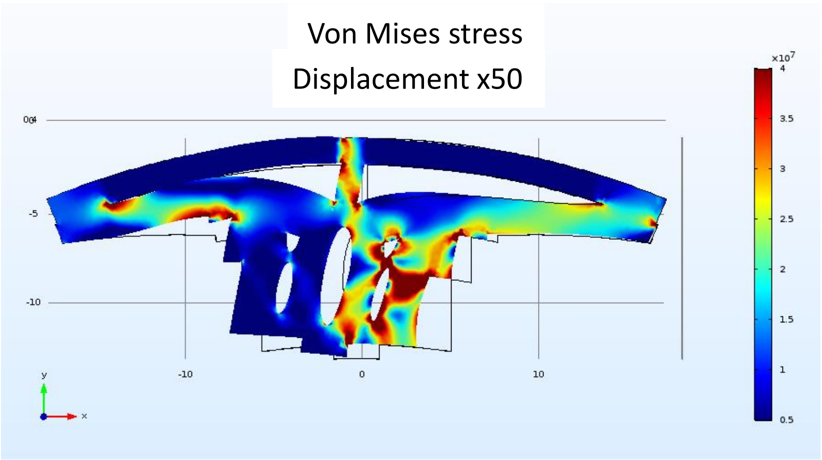
Rated values at 2.5 MW (20% overloaded)

*Torque= 49.7 kN·m
*Force per rib= 1.44 kN
*Pressure in the coil-rib contact= 8.91 MPa
*E@ Room Temp GF10-epoxy= 18 Gpa
* compressive strength =186-448 MPa



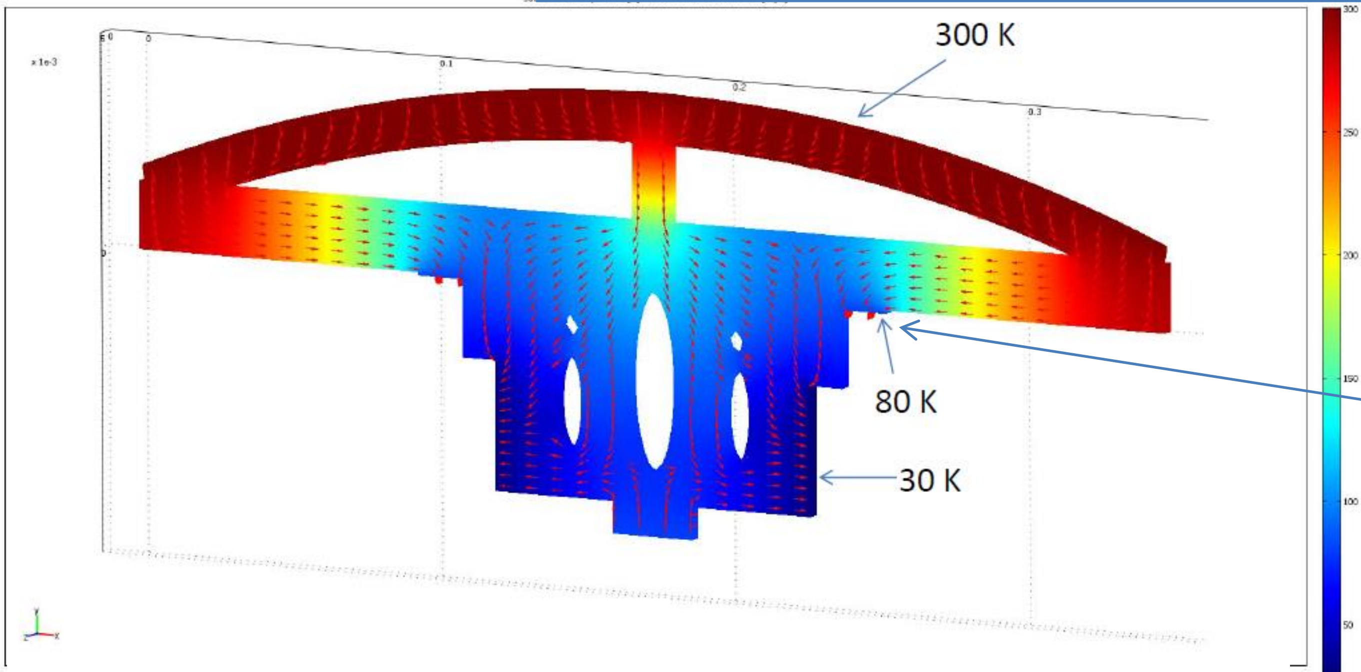
250% of rated values

Critical, need to be fixed to avoid fatigue



Patent in course

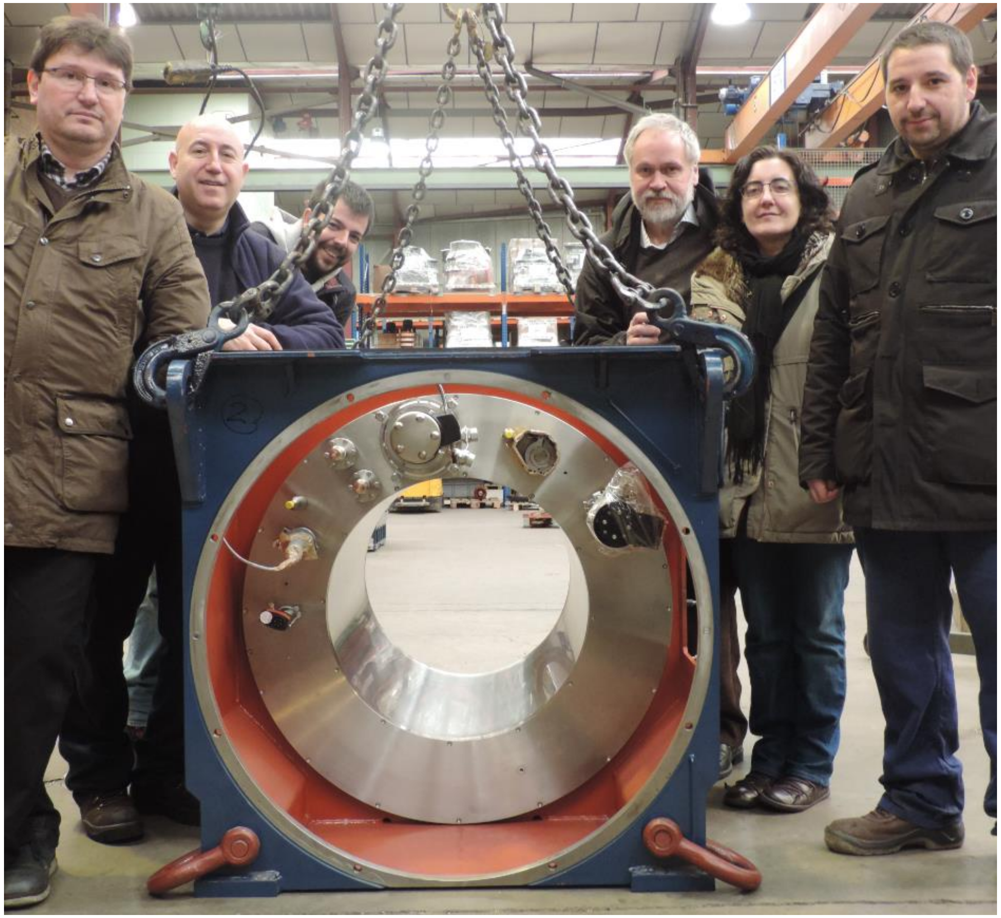
Heat pressure



	Medium level (W) @I=0	Medium level (W) @I=400 A	30K level (W) @I=0 A	30K level (W) @I=400 A
Conduction trough the ribs	11.5	11.5	8.0-14.9	8.0-14.9
Conduction trough current leads	23.0	36.0	0.55	0.55
HTS resistive contacts in 2 Coils	0	0	0	0.016
Radiation	5.8-10	5.8-10	0.1-0.43	0.1-0.43
TOTAL	**40.3-44.5**	**53.3-57.5**	**8.65-15.88**	**8.67-15.90**

Before and after

Copper iron stator



Superconducting stator

Winding challenges

Gap is an issue: cylindrical coils have been built: gap= 4cm

Non isolated coils:

Proprietary winding system (Patent in course)

High stability in front of quench

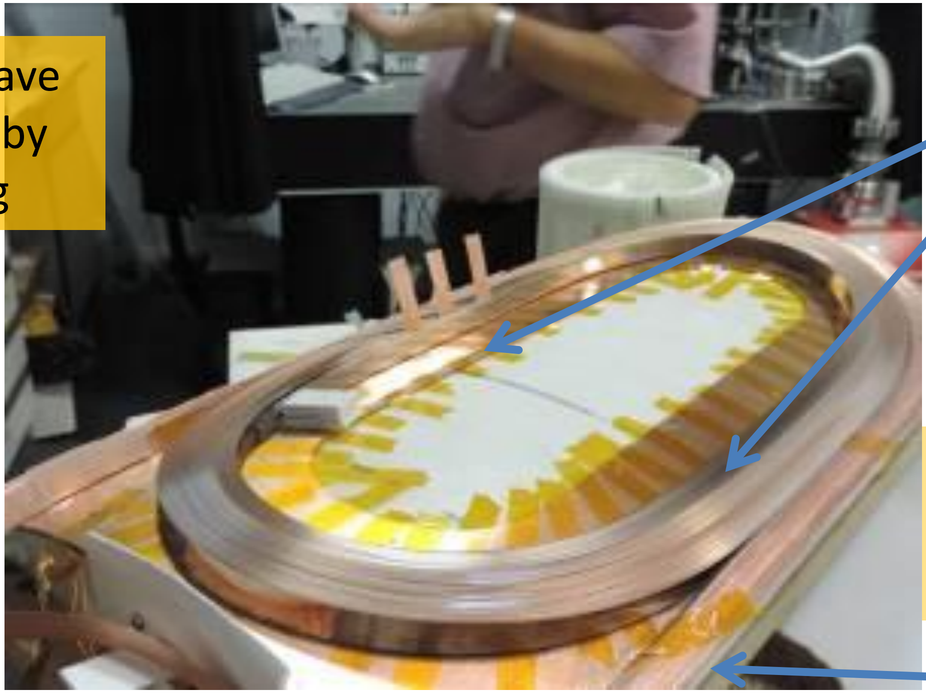
High electromagnetic protection against transients from the rotor field

High effective critical current

Low pass filtering with time constant in the range from seconds to minutes

Automatic stress controlled feeding of tape system has been developed

Tape Junctions have been performed by standard splicing



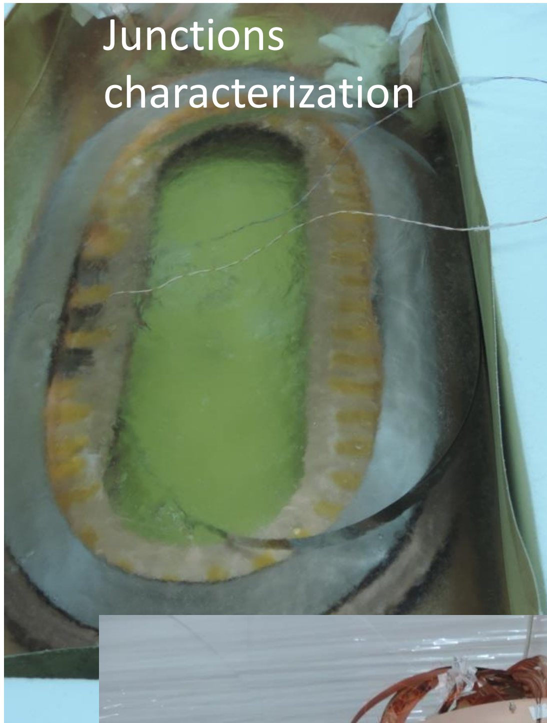
Improved contention of the coil is added in a second step

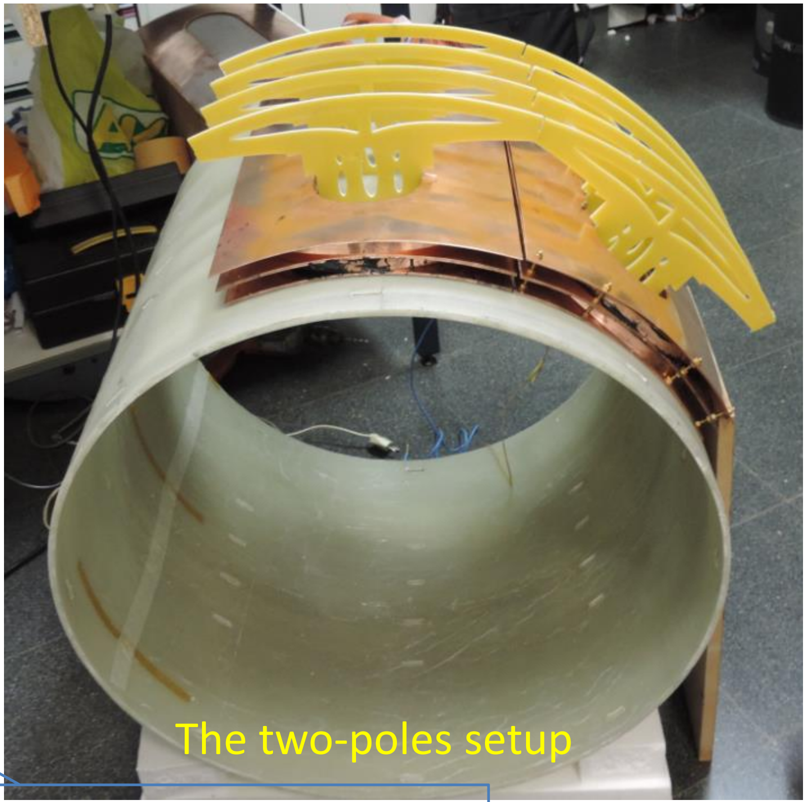
Copper heat sink connected to the cryocooler

Windings

Budget allows only two options: 1 Pole of 2T
2 Poles of 1T

We decided 2Poles. Upgrade to 8 x2T coils in a second step





Magnetic field and thermal sensors

Assembling the superconducting insert in the cryostat

In the testing site

No load Testing

*Vacuum: well

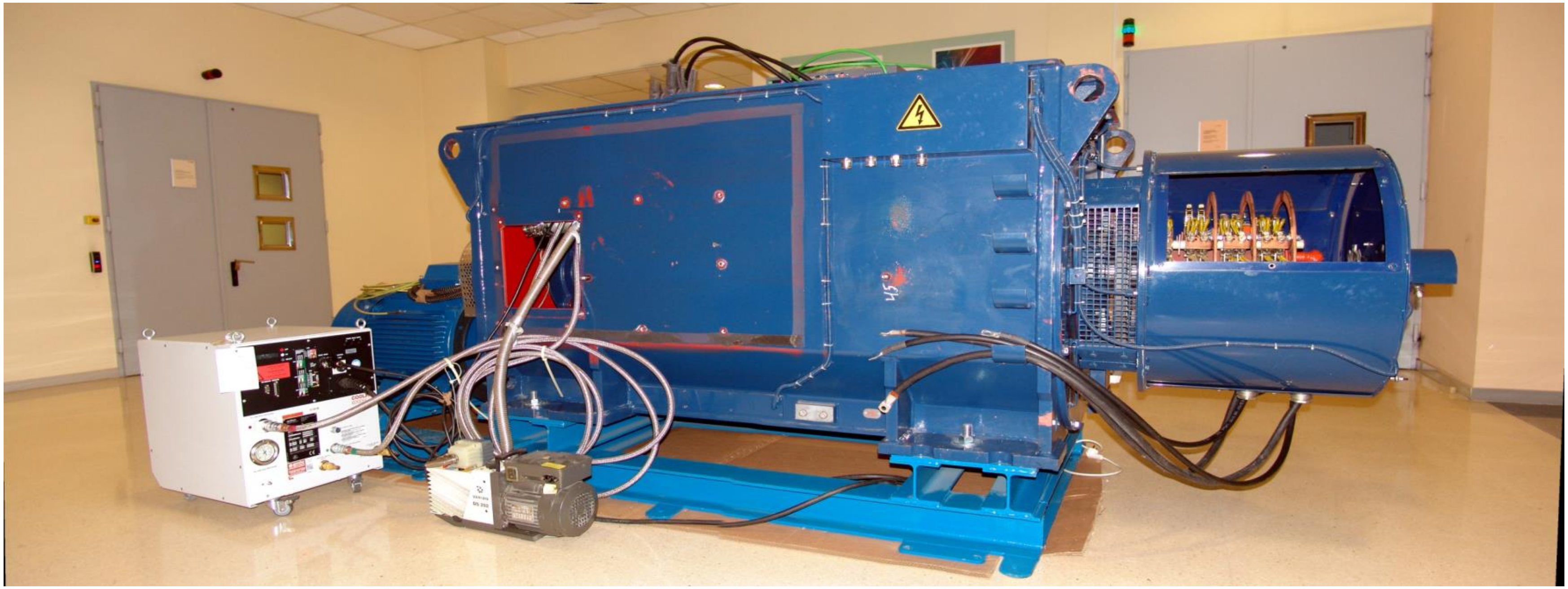
*Cooling: less than 30 h to achieve record 23K in the coils, 30-40K is the rated operating temp

*Manufacturing problem in the MTL of the current lead, current limited to 120A (problem identified and solution defined)

*Line Voltage in the expected level at 480 rpm, strictly proportional to speed and excitation current very low harmonic distortion in in the line voltage

*Sensing and electronics operates well, low noise in the sensors (good screening).

The generator



The generator with its ancillary equipment

Waiting for the second phase: cryogenics with MTL cryocooler and ironless rotor

Third phase: new set of 8x 2T coils and HTS rotor 3-4 MW machine?

Visits are welcome!