Institute of Technical Physics
Superconducting Magnet Technology
Rotating Machines

1-LP-RM.11

# High-Power-Density Partially Superconducting Machines

## Superconducting-Assisted Propulsion System with Large Airgap for Marine Applications

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## Objective

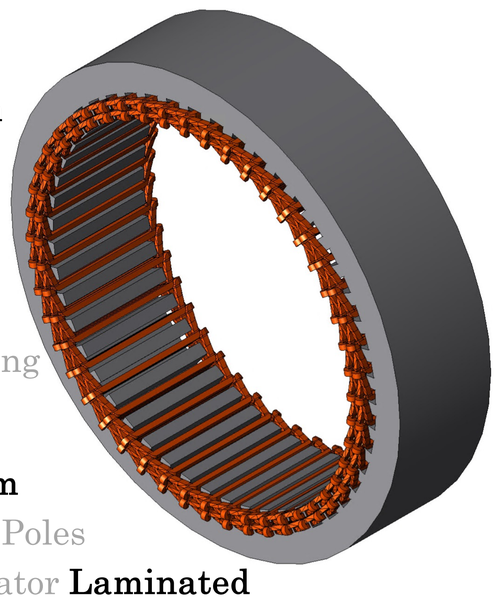
Design a partially superconducting synchronous motor using high-temperature superconductors (HTS), tailored for naval propulsion applications, with the objective of achieving superior power density through the optimization of HTS field windings and overall motor topology, employing second-generation (2G) HTS tapes operating at 30 K.

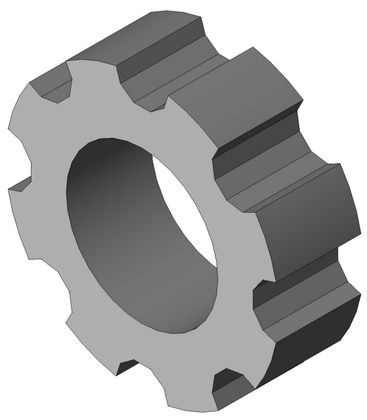
## Methodology

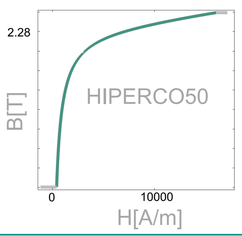
The motor was designed using classical analytical methods, including equivalent circuit and magnetic field calculations, and optimized through multi-objective strategies to enhance power density, efficiency, and thermal performance. Coupled A- and H-formulations within the FEM framework modeled superconducting behavior, enabling adjustments to coil geometry, 2G-HTS tape stacking, and currents to minimize torque ripple, maximize torque output, and ensure cryogenic stability at 30 K while adhering to material constraints.

## Partially HTS Motor

- SOR = 1.20 m
- L = 0.56m
- $g_{air}$ = 40mm
- $Y_s$ = 2
- N. Poles = 8
- 4-layer Winding

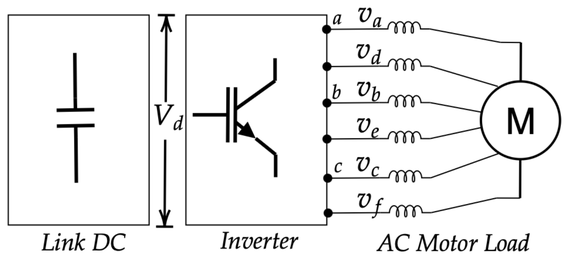




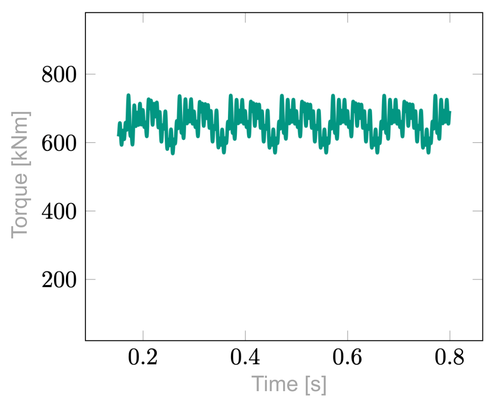


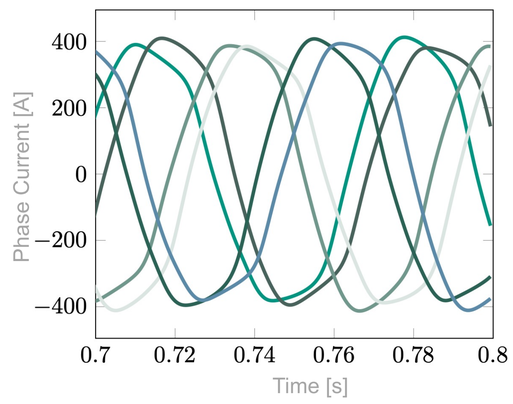

- ROR = 0.90 m
- Non-Salient Poles
- Rotor and Stator Laminated

## Main Data

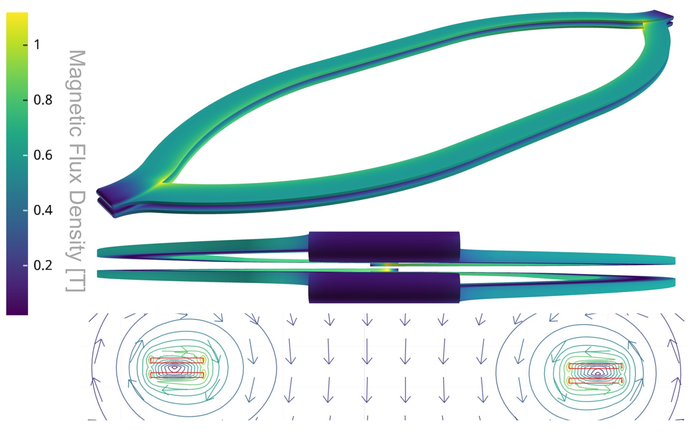


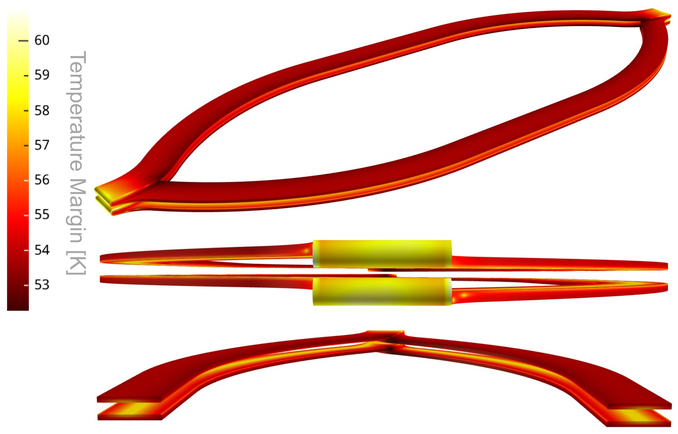

- m = 6-phases
- $V_{ph}$ = 3600V
- $I_{ph}$ = 280A
- $J_1$ = 15E6A/m²
- $P_{out}$ = 15MW
- T = 665kNm
- $v_s$ = 225rpm
- freq. = 15Hz



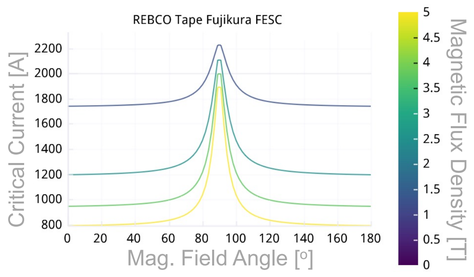



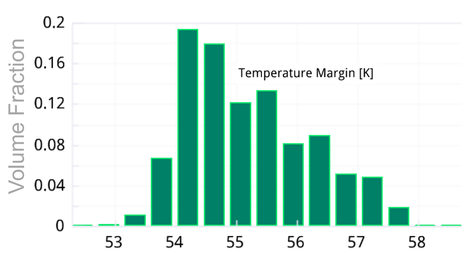

## DUDA HTS Field Winding @30K



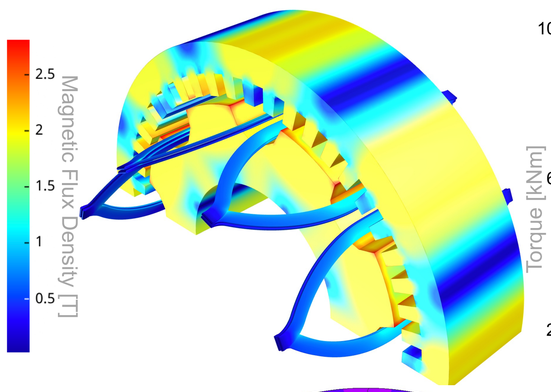



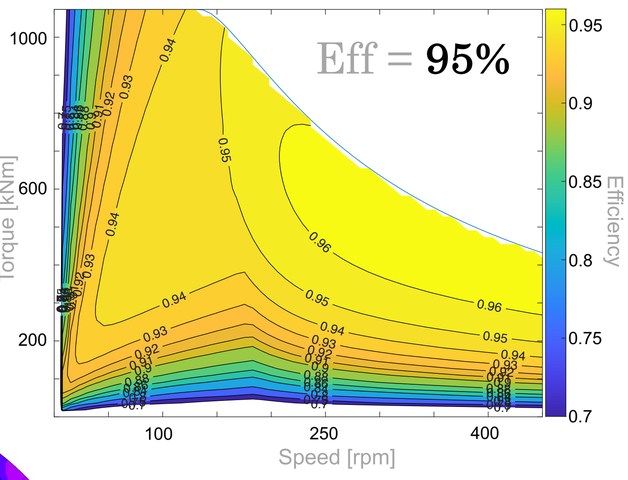

- $N_t$ = 150
- $N_{cS}$ = 2
- $w_t$ = 6mm
- $L_t$ = 4.8km
- $I_{app}$ = 290A
- $J_{hts}$ = 2.4E10A/m²

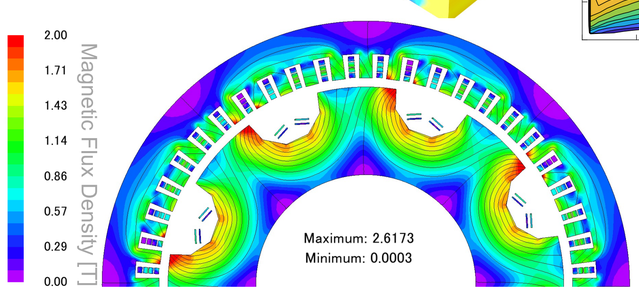



## Static and Transient Results




- VPD = 9.3 MW/m³
- $T_{sp}$ = 90 Nm/kg

## Conclusions

| | | |
|---|---|---|
| 225 rpm | Low Speed | Suitable characteristics for ships |
| 15 MW | High Output Power | Operating temperatures of 30K |
| 665 kNm | Torque “Pushing” Boundaries | DUDA coils better cooling capacity |
| 9.3 MW/m³ | Good Volumetric Power Density | Efficiency up to 95% with large airgaps |

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