Contribution ID: **590** Type: **Poster**

Thu-Af-Po.03-09: Scaling Study of Superconducting Rotors with Spoke Torque Tubes

Thursday 3 July 2025 14:00 (2 hours)

Introduction
A torque tube with a low heat-conduction spoke torque tube was introduced in an earlier study. This study explores the characteristics and design trade-offs of this topology using a combination of analytical models and experimental validation. Results indicate that the spoke-supported topology generally favors small diameters due to its negligible heat leakage. Additionally, a strong positive correlation is observed between specific, specific power and torque, and cryocooler lifting power.

Modeling of Rotor Electrical Properties
The electrical modeling links the machine's active region temperature to its torque production. Torque (τ) is expressed as a function of temperature (T) with the machine's power subsequently derived.
$\tau_{max} = 2A_{peak}B_{peak}R_{ag}^2 LHere,A_{peak}$ represents the electric loading, defined by the armature stator design, while on the rotor side, $B_{peak} \propto J_f$. R_{ag} is the air-gap radius, and L is the active length. The baseline machine coil design yields the relationship: J$_r = 170B_{coil} Inthisstudy, SuperPower2GHTStapewasselected, withitsconductorca$
$90.5e^{-0.057T} **Modelingofrotormechanicalandthermalproperties** Themechanicalmodelingdeterminestherotor' sgeometr$

1. The HTS holder are designed for coil's compressive and shear stress, 2. The Dewar is designed to resist buckling by ambient pressure and torsion, 3. The shaft is sized for the torque generated.

Thermal modeling constructs the full heat transfer path, incorporating:

1. The temperature delta across HTS coils and their support structure, 2. Conductive cooling paths between the cryocooler and HTS coil, 3. Conductive leakage through the spoke torque tube, and 4. Radiation heat leakage that includes the realistic performance of multi-layer insulation

Study Results The electrical and mechanical models are combined to relate machine dimensions to performance. The model iteratively computes the steady-state HTS temperature and the resulting torque generation. The machine diameter is varied while the machine's aspect ratio (diameter to active length) and rotor tip speed are held constant. Scaling the motor from the baseline design reveals the following trends:

1. Small Diameter Preference: The topology favors a smaller diameter due to negligible thermal conduction through the spoke torque tube and the dominance of radiation heat leakage. Reducing the diameter decreases radiation heat transfer proportionally with surface area, while the spoke length decreases proportionally with the diameter. Specific power and torque are maximized at the minimum diameter in the study. **2. Torque and Power Trade-Offs:** Torque and power reach their maximum near, but not at, the minimum rotor diameter. This results from the R_{ag^2} term in the expression for τ_{max}. Slightly increasing the diameter trades field coil current density for radius, improving performance. When cryocooler technology is simulated with improved performance curves, torque, and power scale proportionally with cryocooler lift capacity. In the full paper, each of the diagrams will be displayed, and their implications will be discussed in detail.

3.Significant Impact of Cryocooler Technology Improvements: When improved cryocooler performance curves are simulated, torque and power scale nearly proportionally with cryocooler lift capacity.

In the full paper, detailed diagrams will be provided, and their implications discussed in depth. This study highlights the intricate balance between mechanical, electrical, and thermal design in HTS synchronous machines, emphasizing the impact of scaling and the interdependence of key parameters.

Authors: Dr XIAO, Jianqiao (Hinetics Inc); Dr HARAN, Kiruba (University of Illinois Urbana Champaign)

Presenter: Dr XIAO, Jianqiao (Hinetics Inc)

Session Classification: Thu-Af-Po.03 - Rotating Machinery III