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Design of Superconducting Synchronous Machines for Low Speed Applications

Abstract:

Synchronous electric machines with superconducting field windings have been around for a long time but have not gone beyond prototypes and very limited demonstrations. However, magnetic resonance imaging (MRI) systems use superconducting magnets that are made in significant volumes each year and run with high reliability.

This lecture provides a brief review of the technology advances that move superconducting machines toward commercialization and then discusses how one would go about designing a superconducting machine. Review of electric machine fundamentals will be provided to assist those new to the subject.

The notional design of a superconducting synchronous motor rated for 36.5MW of shaft power at 120rpm that would be compatible with a 6kV DC bus is presented as an illustrative example. Such a machine could serve as a propulsion motor for a large ship. The machine is based on low temperature superconducting field coils and an armature with reduced steel. The large magnetic fields produced by the field coils result in an air gap magnetic field greater than 2T.

Mechanical considerations are also discussed, including the electromagnetic forces that are central to understanding the signatures of the machine.

Drivetrain Design for Wind Turbines

Abstract:

Wind turbines represent the second largest source of renewable power (though solar is gaining). Wind energy started with land-based turbines. In recent years offshore wind turbines are being deployed to capture the steady winds and relieved height constraints.

This lecture starts with a discussion of energy accounting for wind turbines by considering the levelized cost of energy (LCOE). The drivetrains of onshore and offshore are then motivated by considering the dominant factors in LCOE. The lecture then transitions to a discussion of permanent magnet generators (PMGs) used to support the direct-drivetrains used in offshore wind turbines. The converters through which the generator power is processed to the grid are discussed, including a discussion of space vector modulation for multi-level converters. The lecture concludes with a discussion of how the PMG is controlled through the converter.

The Physical Limitations of Electric Machines

Abstract:

Motivated by a deceptively simple equation for the power conversion by an electric machine, we will develop from first principles a deeper understanding of what ultimately limits electric machine performance. Beginning with a description of the electromechanical energy coupling within a generic electric machine, we move toward an understanding of the conditions for average power conversion by that electric machine. This naturally leads into a discussion of the differences between various types of synchronous and asynchronous AC electric machines. The lecture will highlight the competing tradeoffs between electric, magnetic, mechanical, and thermal performance that must be balanced to achieve a viable and practical design. Application examples will be drawn from high-speed applications typical of aviation to low-speed applications typical of renewable energy.