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[Invited] An AC Homopolar HTS Generator for Flywheel Energy Storage

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High speed, compact, lightweight and highly efficient motors and generators are needed for applications in power and transport systems. Here we discuss one application in an energy storage system for subway station regenerative braking energy storage. In this application high rotational speed (> 25,000 RPM) and rapid two-way high power transfer (> 500 kW) within a small footprint are key performance requirements
An AC Homopolar synchronous machine is an ideal choice for such applications. These machines employ a conventional high speed AC armature winding but utilise a stationary DC excitation winding on the stator that simplifies a design for high rotational speed. The rotor is also simplified to a ferromagnetic solid rotor, with the speed only constrained by the mechanical stress limit of the rotor material. Homopolar machines have been demonstrated that can deliver electrical frequencies in multiple kHz and rotational speeds past 60,000 RPM, but delivering power levels past 10's of kW has been challenging at high electrical frequencies due to significant cooling losses for the DC field coils. Modern HTS materials are ideal candidates to provide low-volume, high JE, high field DC coils to meet this challenge; replacing the DC field excitation coil with a suitable superconducting coil will lead to MegaWatt class machines.
We describe the design of a homopolar machine with a high temperature superconducting DC excitation coil, an integrated novel brushless flux pump exciter, and analyse the performance for application as a flywheel energy storage unit. The brushless exciter fundamentally reduces the thermal load upon the cryogenic system by removing the need for thermally inefficient normal-conducting current leads and the impact on cryogenic overhead is discussed.

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