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M3Or3B-01: A low AC loss, fast ramp HTS solenoid prototype for compact fusion energy system

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We aim to build and test a Bi-2212 insert prototype coil designed by Princeton Plasma Physics Laboratory (PPPL) for the feasibility study of next step compact device such as compact stellarator or spherical tokamak (ST) ohmic heating central solenoid in a fusion pilot plant (FPP) beyond the present National Spherical Torus eXperiment Upgrade (NSTX-U). Low AC loss is critical for fast ramping of pulsed machine operations. The Rutherford cable is one potential promising configuration for testing such a prototype coil for fusion tokamak applications.

As part of FES-HEP collaboration, LBNL has an unique cabling capability to fabricate round wire of 2212 into a 17 strand Rutherford configuration. In particular, the model coil is expected to be tested at PPPL in a self-field and in the background field up to 3 T and 10 T/s pulsed test facility for fast ramp testing. The basic parameters for a 5T model coil assumes a Bi-2212 spool with performances such as Ic (5T, 4.2K) = 323 A after 50 bar over-pressure heat treatment (OPHT).

The US Magnet Development Program supplied a non-desirable 10 kg Bi-2212 wire (billet drawn to 0.8 mm diameter and would be about 2 km long). Such a 2212 wire can make about 100 meters of Rutherford cable of 17 strands. As the first step, LBNL completed the fabrication of a 17-strand Bi-2212 Rutherford cable in December 2024 so the model coil can be fabricated for testing in 2025. Two design options for the model coil HTS solenoid will be presented based on the 17 strand Rutherford cable. The Rutherford cable has a 7.8 mm width and 1.44 mm thickness and a cable engineering current density of >390 A/mm2 for the model coil operating at 4393 A (assume 80% of Jc at 4.2K, 5T).

The 17 strand Rutherford cable will be tested first in a fast ramp pulsed test facility (up to 3 T, 10 T/s) at PPPL to evaluate AC loss characteristics. AC losses measurement is planned either via voltage current or calorimetry measurement. Possible quench tests and a targeted mechanical loading testing can be performed to validate the cable operation repeatability.

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