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Coated Conductors and their Applications for Compact Fusion

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***Abstract*—Next-step US tokamak test facilities and/or compact stellarators configured as fusion pilot plants (FPP) to support fusion commercialization are all recommended options by multiple recent consensus studies. The goal for a FPP is to make 50-100 MW net electricity power plants with either extended long pulses or steady state options. To meet the challenge of operating a pilot plant by 2040, the development of fusion concepts, supporting technology, and pilot plant studies must be performed in parallel. Significant technology maturation efforts are underway by privately funded startups with the goal to demonstrate mature HTS magnet technology. A publicly funded fusion magnet program complements and de-risks the high field HTS fusion magnets presently being targeted by the private sector.**

To de-risk a compact FPP, potential next-step test facilities such as sustained high power density (SHPD) tokamaks and compact stellarators can close system integration and performance gaps for the US to resolve physics and engineering issues. Recent design studies show higher current coated conductors can significantly improve the feasibility of all fusion confinement design options. High current density cables consisting of multiple coated conductors are essential for engineering design of the next step configuration studies to allow space for interior plasma components. These cables have achieved ~10 kA at 4-20 K operation in the conductor testing and over 5 kA/s ramp rate tested on subscale model solenoids targeted directly for fusion test facilities such as SHPD.

The coated conductor options for ohmic heating (OH) magnets will be summarized to demonstrate its capability to achieve 100 A/mm^2 current density desired in a high field OH insert module for compact fusion. Recent studies show that an HTS insert wound with coated conductors or cables meet physics requirements for SHPD plasma startups. Detailed assessment of AC losses during coil current ramping, cooling capability during quench, sizing of the OH and PF coils in the compact radial build and space allocation of structural supports, and expected coil fatigue performance under cyclic loading will be presented to de-couple the OH coil from the inner TF for SHPD. Although the bucked central solenoid (CS) design can be structurally beneficial for stress management in advanced tokamaks, the risk of inner TF legs trapped inside the OH coil is mitigated by the decoupled insert design that is properly

sized and validated by engineering.

***Keywords (Index Terms)*—Compact tokamak, fusion pilot plant, high temperature superconductor, Ohmic Heating coil (OH), sustained high power density (SHPD), Fusion Nuclear Science Facility (FNSF)**

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