A Coaxial Helicity Injection System for Non-Solenoidal Startup Studies on the PEGASUS-III Experiment

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Initiating current without using magnetic induction from a central solenoid is a critical scientific and technical challenge facing the spherical tokamak. One such technique that has shown promise on several devices, including NSTX, is coaxial helicity injection (CHI). In CHI startup, biased coaxial electrodes drive current along vacuum field lines, providing poloidal current. When the Lorentz force on this current exceeds field line tension, a magnetic bubble blows into the vacuum vessel, reconnects, and forms a high-current diverted tokamak. This plasma can be caught by another current drive method (transient CHI), or injector current can be continuously driven between the electrodes, driving fluctuations that sustain the plasma through dynamo action (sustained CHI). Major outstanding issues for CHI include: eliminating the need for a vacuum vessel break; mitigating plasma material interaction (PMI) and minimizing impurity injection; the scaling of I_p with injector and/or flux footprint shape and separation; the degree of axisymmetry required to achieve high I_p; and understanding of the reconnection and dynamo mechanisms. Thus, a first of its kind CHI system capable of both sustained and transient CHI is being installed on PEGASUS-III. It utilizes two coaxial, segmented, floating electrodes located entirely within the vacuum vessel in the upper divertor region. The design enables I_p scaling studies as the electrode shape, coupled with a new 480/288/244 kA-turn divertor coil triplet, allows for variation of the flux footprint shape and location simply through manipulation of coil currents. Together, they are projected to allow over 60 mWb connected flux and $I_p >$ 300 kA. The segmented electrodes facilitate simple changes to shape, position, and plasma facing material. This flexibility may be critical for mitigating PMI or impurity sourcing from the electrodes. Injector current will be supplied by a 4.13 kJ, 2.1 kV, 22 kA transient capacitor bank or a feedback-controlled 2 MJ, 2.7 kV, 16 kA CMLI sustainment system. Additionally, the improved PEGASUS-III diagnostic set will enable greater understanding of the flux conversion efficiency and dynamo current drive scalings that ultimately define the peak I_p achievable with CHI.

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