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Analysis of Electron Cyclotron Wave Assisted Plasma Start-up in SST-1

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In superconducting tokamaks, electric field generated by the central solenoid (CS) for plasma start-up is generally less than that for non-superconducting tokamaks due to the requirement of a robust vacuum vessel and cryostat without insulating break. Moreover, with the CS made of NbTi conductor, there is limitation to maximum dI/dt in the coil to avoid stress limits, resulting in limited loop voltage. To ensure reliable start-up, electron cyclotron wave (ECW) assisted pre-ionization has been applied in several superconducting tokamaks. We initiated the study of start-up in SST-1 with a 0D model and show that ~100 kW of ECW power must be absorbed for start-up for an initial hydrogen atom density NH (t=0) ~4x1018 m-3, an error field Berr=1 mT, carbon and oxygen impurity fractions nC/ne=nO/ne=0.5%, and an EC beam radius of ~5 cm. These findings agree well with the temporal evolution of discharges. However, the 0D model is not sufficient for investigating the physical processes as it lacks radial variation of electron density and temperature, transport, and localization of the ECW power. In this paper a one-dimensional (1D) model that includes radial transport to study ECW assisted start-up is reported. The 1D model comprises of five equations, viz. energy and particle transport for electrons and hydrogen ions and a toroidal current equation. Electrons are assumed to be heated by ECW and Ohmic power and lose energy via several processes. Ions are heated only by the equipartition energy transferred from electrons and lose energy by charge exchange between hydrogen atoms and ions. We consider cylindrical symmetry, on-axis ECW power absorption and the Bohm diffusion. Reaction rate coefficients are calculated using the Average Ion Model. The present study indicates that with increasing initial hydrogen atom density, greater ECW power is required for start-up. This result is attributed to the power loss from ionization and equipartition. The required ECW power thus depends weakly on direct power loss caused by Berr and radiation loss by impurities. These results imply that controlling the initial hydrogen atom density, suppressing Berr, and reducing the impurity density are all useful for reliable start-up. Comprehensive analysis of start-up and the physical processes those dominate the radial distribution of parameters, as the discharge evolves, will be reported.

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