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## Understanding and Predicting the Dynamics of Tokamak Discharges during Startup and Rampdown[1]

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Understanding the dynamics of plasma startup and termination is important for present tokamaks and for predictive modeling of future burning plasma devices such as ITER. We report on experiments in the DIII-D tokamak that explore the plasma startup and rampdown phases, and on the benchmarking of transport models. Key issues have been examined such as plasma initiation and burnthrough with limited inductive voltage and achieving flattop and maximum burn within the technical limits of coil systems and their actuators while maintaining the desired $q$ profile. Successful rampdown requires scenarios consistent with technical limits, including controlled H-L transitions, while avoiding vertical instabilities, additional Ohmic transformer flux consumption, and density limit disruptions. The ITER baseline startup and rampdown scenarios have been demonstrated in DIII-D by scaling the dynamic phases by the ratio of the resistive current penetration time between the devices while maintaining the same $I/aB$ and scaled shape within the phase. Discharges were typically initiated with an inductive electric field typical of ITER, 0.3 V/m, most with 2nd harmonic electron cyclotron (EC) assist. A fast framing camera was used during breakdown and burnthrough to study the formation physics. An improved "large aperture" ITER startup scenario was developed and aperture reduction in rampdown was found to be essential to avoid instabilities. Extrapolation of these scenarios to burning plasma devices requires model validation. Current evolution using neoclassical conductivity in the Corsica code agrees with rampup experiments, but prediction of the temperature and internal inductance evolution using the Coppi-Tang model for electron energy transport is not yet accurate enough to allow extrapolation to future devices.

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