Physics-based Control-oriented Modeling of the Safety Factor Profile Dynamics in High Performance Tokamak Plasmas

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***Abstract*— The tokamak is a device that utilizes magnetic fields to confine a reactant gas to generate energy from nuclear fusion reactions. The next step towards the realization of a tokamak power plant is the ITER project, and extensive research has been conducted to find high performance operating scenarios characterized by a high fusion gain and plasma stability. A key property related to both the stability and performance of the plasma is the safety factor profile (q-profile). In this work, a general control-oriented physics-based modeling approach is developed, with emphasis on high performance scenarios, to convert the first-principles physics model that describes the q-profile evolution in the tokamak into a form suitable for control design, with the goal of developing closed-loop controllers to drive the q-profile to a desired target evolution. The DINA-CH&CRONOS and PTRANSP advanced tokamak simulation codes are used to tailor the first-principles-driven (FPD) model to the ITER and DIII-D tokamak geometries, respectively. The model's prediction capabilities are illustrated by comparing the prediction to simulated data from DINA-CH&CRONOS for ITER and to experimental data for DIII-D.**