A control-oriented model for breakdown and burn-through in TCV and its application

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The pulsed nature of tokamaks implies the plasma needs to be formed many times, which calls for better understanding and optimization of the tokamak start-up phase. This phase can be divided into different physics regimes: the plasma breakdown, burn-through, and current ramp-up phases. From one pulse to the next, the amount of impurities that contaminate the plasma during burn-through may change significantly. The field of model-based control theory can assist in optimizing plasma start-up, but needs a fast but reliable model to do so. Even though different models [1] and controllers [2, 3] exist, they have not yet been extensively used to improve start-up after breakdown, especially in the presence of changing impurity dynamics. Here, a 0D control-oriented model is derived by combining and reproducing existing models, and extending them with a link to electromagnetics and plasma force balances. This model is able to simulate the entire plasma start-up process, from pre-plasma breakdown evolution of currents and fields to the early plasma current ramp-up phase. Benchmarking the model against TCV interferometry, bolometer, plasma current, and photodiode reconstructions yields sufficient agreement for controller assessment and design. The model is therefore applied to design controllers for all distinct phases of plasma start-up, with the ultimate aim of increasing its reliability and reproducibility. Iterative Learning Control (ILC)[4] has been applied to iteratively update time traces for the various coils to achieve a consistent breakdown location and time. Then, the PF coils are decoupled such that the newly formed plasma current control is separated from its position control. Finally by again applying ILC, it has been shown that, based on simulation results, indeed a controller strategy can be developed that can yield satisfactory performance. These results indicate that, even for changing impurity dynamics from one pulse to the next, reliable plasma start-up can be achieved.

References