NONLINEAR BURN CONTROL IN TOKAMAKS USING IN-VESSEL COILS[1]

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Control of the plasma density and temperature to produce a certain amount of fusion power, known as burn control, is one of the key issues that need to be solved for the success of tokamak fusion reactors such as ITER. In order to reach a high fusion power to auxiliary power ratio, tokamaks must operate near temperature and density stability limits. Therefore, active control to maintain a desired burn condition and avoid instabilities is absolutely necessary. Previous work makes use of mainly three different types of actuation: modulation of the auxiliary power, modulation of the fueling rate, and controlled injection of impurities. However, recent experiments showed the feasibility of modifying the plasma energy by using the in-vessel coils as actuators. Inspired by such experiments, a new burn control scheme is proposed in this work to exploit the in-vessel-coil system in combination with auxiliary power and fueling rate modulation. The in-vessel coils generate non-axisymmetric magnetic fields that modify the confinement of the plasma, which influences the plasma energy dynamics. By using the in-vessel coils, energy losses can be enhanced when needed and thermal excursions can be prevented. Moreover, actuation of the in-vessel coils may prevent the injection of impurities and its associated drawbacks. A control-oriented model has been developed to account for the influence of the in-vessel-coil currents on the plasma burn. While much previous work uses linearization techniques, a model-based nonlinear burn controller is proposed in this work. This nonlinear control approach is applicable to a larger range of operating conditions and is stable against a larger set of perturbations when compared with linear control approaches. The effectiveness of the controller is demonstrated via nonlinear simulation studies for different plasma scenarios.

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