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Model based formation of Advanced Tokamak discharges

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A model has been developed in the transport code ASTRA, which is capable of simulating advanced tokamak discharges, using the density and actuator setup as inputs. The model uses a reduced Gyro-Bohm based core transport, which does include simplified ITG and TEM mode contributions, to achieve a run time of only a few minutes for a full discharge. Edge transport is included via the use of a recently developed scaling law. Also included is the L-H transition, which is triggered based on the heating power at the separatrix. The model does include a set of free parameters, which have been adjusted using a set of reference discharges. These parameters are consistent between discharges, as long as no major scenario changes are done. For a sufficiently different scenario, they would have to be re-evaluated.

With this setup it is possible to quickly test a large amount of possible actuator changes to a reference discharge, allowing for a large part of scenario development to be done through modelling only. This is especially relevant for early heating scenarios, where fully experimental scenario design can cost a lot of discharges. This approach allows for an optimal entry to a desired q-profile early in the discharge, without passing through an unfavorable regime, which is important for present devices due to short pulses but also for a reactor due to its long current diffusion time.

The model was used to design an early-heating discharge at AUG, which was run successfully, showing its viability to be used as a tool for scenario design. In this discharge, co-ECCD was used to achieve a q_{95} of about 5.2. Stable operation for this scenario was possible for values of β_n between 2 and 3, the stability limit was found at $\beta_n \sim 3.2$. Results of this scenario will be shown.
The model was tested in multiple different scenarios at different plasma currents and β_n for both co- and counter-current ECCD operation. A scenario with anomalous flux redistribution (flux pumping) was also investigated.

A counter-ECCD scenario with a higher current than the validation scenario, reaching q_{95} of ~ 4.1 has been investigated. Due to the non-availability of one of the two current drive NBIs at AUG last campaign, this scenario needed to be adapted to run with a different current drive setup than in previous campaigns. Using the model, it was shown that the missing NBI current drive can be substituted by some of the remaining systems and the scenario was successfully run with the changed current drive setup.

An optimizer, built around the RAPTOR fast core transport solver [Sauter, Plasma Phys. Control. Fusion 54 025002] was used to propose changes to the actuators for this scenario to optimize the q-profile. The goal was to improve NTM stability, performance, and reach a stationary elevated q profile early in the discharge. The effect of these changes were checked in ASTRA, before running them on the experiment. Results will be presented.

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