Reduced transport models for a tokamak flight simulator

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Abstract

A tokamak flight simulator is a tool to predict the plasma behavior of a scheduled discharge, such that either actuator trajectories or plasma parameters satisfy the experimental goals, and to reduce probability of plasma disruptions and crossing of operational limits. It is based on the model-based interaction between control system, plasma equilibrium and transport. The transport models have to be physics based to be reliable, but also fast to be used as an inter-discharge prediction tool. This compromise can be reached employing analytical models which are derived from first principle theories. In order to give a complete description of the plasma, an integrated model including every plasma region, from core to divertor, has been developed. The confined region is modeled in 1D, while the scrape-off-layer has a 0D structure. For the core region, a normalized temperature gradient threshold model for micro-turbulence has been adopted, using formulas fitted on a wide database of TGLF [G. M. Staebler 2007 Physics of Plasmas 14 055909] simulations, while for the edge an average ELM model with a critical pedestal top β_p value has been used. In the SOL, for the power exhaust, a 2-point model has been used, based on heat balance including conduction and radiation between separatrix and divertor (i.e. no profile in this region is furnished). In the same region a 0D particle balance model with diffusion coefficients between 6 different interfacing regions has been built, considering the gas puff as a source and vacuum pump as a sink. Neutrals are included as well. These two models provide boundary conditions respectively for temperature and density at the separatrix. Most of the models have been validated against several stationary cases, by fixing some parameters as boundary conditions and matching experimental data, exploiting the modular structure of the integrated model. For the confined region a first experimental case has been matched by using both core and edge models. Future work needs validation of the total integrated model over a wide set of stationary simulations, followed by a test against ramp-up and ramp-down phases, needed to provide a prediction of the entire discharge.

Keywords

tokamak, flight simulator, integrated modeling, transport