A new equilibrium solver for the Fenix flight simulator

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Abstract

In this work, a new fast equilibrium solver has been developed to be used into the Fenix tokamak flight simulator [1,2,3]. Fenix is based on the coupling between Simulink™ and the ASTRA transport solver [4]. The flight simulator main purpose is to perform pre-discharge checks like: 1) show that the programmed feed-forward and feed-back time traces have been implemented as desired; 2) show that the discharges physics goals develop as planned, or if not, allows one to understand why and eventually correct the trajectories or modify the purpose; 3) show that the operational and physics limits are not overrun, otherwise one needs to modify the programmed trajectories.

In order to achieve these goals, the complete tool has to run in a reasonable time scale, e.g. a typical full ASDEX Upgrade 15+ s discharge scale has to be simulated in less than 5 minutes (the faster, the better). The main bottleneck of this computational time requirement is the equilibrium solver (2D Grad—Shafranov equation solver + circuit equations solver) because of the non-linear nature of this system of equations. Moreover, the equilibrium solver has to provide a smooth transition between the pre-plasma phase (during which coils are being charged) and the plasma phase (breakdown, ramp—up, ramp—down, plasma termination).

The newly developed equilibrium solver has been written specifically to be both fast and flexible in the choice of the operational mode, such that transition from the pre-plasma to the plasma phase is accomplished in the smoothest and most reasonable way possible. In this respect, it distinguishes itself from existing equilibrium solvers, which typically model the developed plasma phase only (i.e. the existence of stable closed field lines is assumed). In this work the details of the new code are presented and discussed, and application to both ASDEX Upgrade and DEMO machines are presented.

Lastly, the new code exploits a modernization of the ASTRA transport solver, which has been rewritten in Fortran 90 [5], and its also used in this work.

References

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[5] G. Tardini and E. Fable, private communication.