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EX/P3-12: Real-time Model-based Reconstruction and Control of Tokamak Plasma Profiles

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A new paradigm for real-time plasma profile reconstruction is demonstrated in the TCV tokamak. Predictions based on physics models are merged with available real-time diagnostic data to construct a self-consistent profile state estimate compatible with a time-dependent model of transport processes in the plasma. This is enabled by a new RApid Plasma Transport simulatOR (RAPTOR), implemented in the new TCV real-time control system. RAPTOR simulates the radial current diffusion including the ohmic coil transformer voltage and non-inductive sources in real-time, while the plasma physically evolves in the tokamak. This makes available an extensive set of quantities which are normally not known in real-time such as the bootstrap current fraction, safety factor, magnetic shear and loop voltage profiles. This approach represents a generalization of existing approaches for real-time equilibrium reconstruction with measurement-constrained current density profile, as transport physics knowledge is now included in the reconstruction.

The same rapid transport code is also used in predictive mode, including a model of the electron temperature evolution, for off-line studies of optimal actuator trajectories during plasma ramp-up scenarios. Constraints are included in the optimization to reflect realistic operational limits. These studies show that a plasma current overshoot combined with appropriately timed heating are beneficial for rapidly reaching a stationary q profile with flat central shear. The demonstration of this new paradigm paves the way for further integration of real-time tokamak plasma simulations for prediction, scenario monitoring, disruption avoidance and feedback control.

Country or International Organization of Primary Author

Netherlands

Primary author: Mr FELICI, Federico (Netherlands)

Co-authors: Dr DUVAL, Basil (CRPP-EPFL Association Euratom-Suisse);   Mr HOMMEN, Gillis (TU Eindhoven/FOM-DIFFER Association Euratom-FOM);   Dr MORET, Jean-Marc (CRPP-EPFL Association Euratom-Suisse);   Prof. STEINBUCH, Maarten (Eindhoven University of Technology);   Prof. DE BAAR, Marco (TU Eindhoven/FOM-DIFFER association Euratom-FOM);   Dr SAUTER, Olivier (CRPP-EPFL Association Euratom-Suisse);   Mr VOORHOEVE, Robbert (Eindhoven University of Technology);   Dr CODA, Stefano (CRPP-EPFL);   Dr GOODMAN, Timothy (EPFL - CRPP)

Presenter: Mr FELICI, Federico (Netherlands)

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