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Initial concept for the plasma diagnostic and control system for the European DEMO tokamak reactor

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The development of the plasma diagnostic and control (D&C) system for a future tokamak demonstration fusion reactor (DEMO) is facing unprecedented challenges. The DEMO D&C system has to operate with very high reliability, since any loss of plasma control may result in machine damage. On the same time, high accuracy of the D&C system is needed in order to allow for plasma operation near operational limits, where the fusion power is maximized. The implementation and performance of diagnostic components is however limited by space restrictions (optimization of the tritium breeding rate; integrity of the first wall and divertor against loads), and by adverse effects acting on the front-end components (neutron and gamma radiation, heat loads, erosion and deposition). Finally, the capabilities of the available actuators (poloidal field coils, external heating and fueling) are limited as well.

As part of the European DEMO conceptual design studies, the development of the D&C system has recently been launched [1]. A preliminary suite of candidate diagnostics for DEMO have been selected, aiming to cover all the main plasma control quantities with some redundancy, and choosing types and locations for diagnostic front-end components such that long-term durability with minimum need for maintenance can be expected under typical loads (e.g. neutron radiation, particle fluxes and fluencies). Specifically, only robust metallic or ceramics diagnostic components shall be used inside the vacuum vessel, while the more sensitive components shall be located at more remote (protected) positions. This initial plasma diagnostic suite comprises microwave diagnostics, magnetic coil based and Hall sensors, passive spectroscopy and radiation power measurements, divertor thermo-current measurement, infrared interferometry/polarimetry and neutron-gamma measurements. In the first R&D phase the possibilities and conditions for integration of diagnostic sightlines and front-end components into the machine have been investigated, and an understanding of the required number of channels and components has been obtained.

The conditions for controllability of the DEMO plasma are being analyzed by numerical simulations. To this purpose, the transport modelling code ASTRA, coupled to a radiation module, has been connected to the Simulink simulation framework, and the performance properties of diagnostics and actuators are being added [2]. Similarly, the existing CREATE equilibrium code is being amended to include limitations of diagnostics and actuators, such that the controllability e.g. of fast VDEs can be simulated under DEMO relevant settings. Furthermore, predictive control oriented models such as RAPTOR are being further developed as an alternative approach to analyze the controllability of DEMO. The common goal is to arrive at numerical simulations which closely mimic the control of the DEMO plasma such that the controllability based on the available diagnostics and actuators can be demonstrated quantitatively. Based on these R&D results, an initial version of the DEMO diagnostic and control concept has been elaborated and will be presented in this paper.

References:

[1] W. Biel et al., Fusion Engineering and Design 96–97 (2015) 8–15

[2] F. Janky et al., Fusion Engineering and Design, 2017 (submitted)

Eligible for student paper award?

No

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