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Study of a plasma boundary reconstruction method based on reflectometric measurements for control purposes

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In-vessel magnetic sensors will be drastically limited, if present at all, in DEMO, due to the pulse duration and the neutron flux, so alternative diagnostics systems based on in-vessel non-magnetic sensors and ex-vessel sensors are under investigation to meet the requirements of a safe and reliable operation of the machine. In particular, the signals provided by a microwave reflectometry system are being considered for application in the plasma position and shape control, as suggested by the results of preliminary experiments carried out in ASDEX-U device [1]. In fact, local measurement of the distance between plasma boundary and first wall can be derived in correspondence of each reflectometric antenna. Indeed, reflectometric measurements are expected to be either missing or less reliable in some poloidal positions (top and divertor regions) and during transition phases (ramp-up, ramp-down) in DEMO. A crucial question to be answered is the minimum number of measurements and their poloidal position needed for a reliable plasma shape control. On the other hand, the knowledge of the whole plasma boundary allows a more accurate evaluation of geometric macroscopic quantities, such as plasma section, elongation, triangularity, which are of interest in the shape control and for an effective machine operation. Thus a plasma boundary reconstruction method, which uses only a limited number of local distances between plasma boundary and wall, was developed with the aim of contributing to answer the above mentioned questions. The plasma boundary is represented as a continuous curve to be reconstructed by applying an active contour technique. This approach has already been used in nuclear fusion research by exploiting the flux map provided by available magnetic measurements [2]. On the contrary, in DEMO case the boundary is reconstructed by deforming a curve so as to minimize a cost function given by the sum of the distances between each "real"boundary position derived by a reflectometric measurement and the currently estimated boundary position along the corresponding antenna line of sight. Among the proposed parametric contour models obtained as functional minimizing splines ("snakes"), B-splines were preferred for their compactness and because they implicitly force the curve smoothness. In fact, the resulting contour shape can be modified by just acting on a finite number of virtual control points related to the curve points through a time invariant matrix. The minimization of the cost function is an optimization problem, which was solved by a simulated annealing technique. Tests were carried out by assuming the number and positions of the antennas as foreseen in DEMO present design. A reliable reconstruction was achieved with the full set of 15 measurements except for the X-point region. The main equilibrium parameters were also computed and a satisfactory agreement was observed with the corresponding quantities of a DEMO reference equilibrium. Larger deviations were obtained with a reduced set of 10 measurements. Sensitivity of the results to measurement noise and antenna positions was also assessed.

[1] Santos J. et al., IEEE Transactions on Nucl. Science, 62, 3 (2015)

[2] A. Cenedese et al., FED, 66-68,675 (2003)

Eligible for student paper award?

No

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