A steady-state scenario for ITER using off-axis Electron-Cyclotron-Current Drive

J. Garcia, F. Imbeaux, J.F. Artaud, V. Basiuk, G.Giruzzi, M. Schneider

Association EURATOM-CEA, CEA/DSM/DRFC, CEA-Cadarache, F-13108 St. Paul lez Durance.

The ultimate goal of magnetically confined fusion research is to develop commercial fusion reactors able to supply a continuous electrical power production of the order of 1.5 GW. A steady-state scenario with 100% of non-inductive current is desirable to avoid a pulsed power distribution system. For this purpose, scenarios with internal transport barrier (ITB) are adequate, since the bootstrap current provides a high current fraction whereas the heating systems can drive the rest of the current.

Several attempts have been made, by means of plasma simulation transport codes, to show that ITER will be able to demonstrate reactor scale steady-state operation. However, due to the challenging requirements (high bootstrap fraction, high beta limits, full non-inductive current drive, correctly aligned plasma current at $Q>5$ with burning time of $t\approx 3000$s) no completely satisfactory results have been obtained [1].

As observed in experimental results as well as in simulations [1], the formation of the ITB in negative magnetic shear plasmas is relatively easy to obtain. However, after some period of time, the ITB tends to move inwards, which means that eventually the high performance of the discharge in terms of bootstrap current fraction and fusion gain is not sustained steadily.

In this work, we present an analysis of steady-state scenarios for ITER carried out with the CRONOS suite of codes [2]. A new RF-only scenario has been developed: in the simulations, 20 MW of Ion Cyclotron Resonant Heating (ICRH), 20 MW of Lower Hybrid Current Drive (LHCD) and 20 MW of Electron Cyclotron Heating and Current Drive (ECH/ECCD) have been used to obtain a steady state plasma with 95% of non inductive current with $Q\approx 6$ and a burning time of $t\approx 3000$s. In this scenario, the main role is played by ECCD, which is used to trigger and keep the ITB robustly fixed at $\rho\approx 0.5$. This effect of ECCD has been experimentally demonstrated on DIII-D [3]. The existence of a threshold on the total ECCD needed for the creation of a steady state with ITB in ITER is also addressed, as well as the sensitivity of the scenario to the assumptions on the ITB (transport) model.

References

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