MF1-I10 AAPPS-DPP2020

4th Asia-Pacific Conference on Plasma Physics, 26-31Oct, 2020, Remote e-conference

Plasma initiation and synthetic diagnostic development for ITER First Plasma operation

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ITER First Plasma (FP) operation aims to produce a plasma with current higher than 100 kA for a duration longer than 100 ms, which corresponds to the plasma initiation phase of ITER operation [1, 2]. This requires a successful integration of the Plasma Control System (PCS) and the important tokamak plant subsystems (the cryogenics for the superconducting magnets, power supplies of the central solenoid and poloidal field coils, gas injection system, vacuum pumps, etc.). To diagnose the plasma state and assist the PCS, a limited set of diagnostics, such as magnetic diagnostics, H_α spectrometer, density interferometry, hard X-ray monitor, visible camera, etc., will also be available. However, plasma initiation from the breakdown to magnetically confined plasmas is a complex and dynamic process that is usually not well diagnosed due to the low density and temperatures with which it is associated. It is therefore essential to develop models for the available diagnostics for ITER FP operation to determine the necessary measurement ranges for plasma initiation and use them as inputs for controller development and assessment within the PCS. In addition, an improved diagnosis of the plasma state is possible by combining the measurements from the different diagnostics.

This presentation will explain the plasma initiation process in ITER, the influence of the planned Electron Cyclotron (EC) pre-ionization on this phase, and the control and diagnostic needs for the ITER FP operation. It will show how the use of accurate diagnostic models helps to optimally prepare for and analyze ITER FP operation and how an improved diagnosis of the plasma state during initiation is possible by combination of the measurements which will be available. It will discuss in particular a simple model developed for the H_α spectrometer, which estimates the H_α emission during plasma initiation by considering the contribution due to neutral H_2 and H^+ ions only. The results from the model show that it is possible to measure H_α emission soon (~5 – 10 ms) after breakdown for plasma temperatures higher than 3eV and densities higher than $5x10^{17}m^{-3}$. The PCS can use these measurements for plasma detection. The diagnostic model for the interferometer shows that for the proposed ITER FP scenarios, accurate measurements are also possible for plasma densities higher than $5x10^{17}m^{-3}$. The results from modelling of the hard X-ray monitor demonstrate that runaway electrons (RE) with maximum energy of 2.5 MeV and currents of approximately 10-15 kA can be detected with 10 ms time resolution. These measurements can thus be used effectively by the PCS for RE detection.

References

[1] ITER Research Plan within the Staged Approach (Level III - Provisional Version), Reference: ITR-18-003
[2] P.C. de Vries, Y. Gribov, Nuclear Fusion 59 (2019) 096043