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Examination of the Entry to Burn and Burn Control for the ITER 15 MA Baseline and Other Scenarios

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ITER will reach the burning regime Pfusion/Pinput of ~10 by operating in an ELMy H-mode. Control of the flattop burn phase is a critical demonstration for ITER, showing the simultaneous regulation of the plasma core fuel density, fusion power gain, and consistent divertor operation, under several constraints and perturbations. The ITPA-IOS group is doing time dependent integrated simulations (TSC/TRANSP, Corsica, CRONOS, ASTRA/ZIMPUR, RAPTOR) of the burn regime in ITER to understand impacts of physics uncertainties and to develop and test control strategies for the device. Entry to burn simulations are performed to examine the dependences on injected power, rate of rise of the density, argon impurity timing and amount, and feedback control. At SOF densities of n20(0) ~ 0.45 showed marginal access for 43 MW of injected power, while 73 MW was capable of entering and sustaining an H-mode regardless of the density rise trajectory. Simulations examining early, medium, and late Ar injection showed that with 73 MW of input power the earlier injection did not hinder or significantly affect the entry to H-mode, while at 43 MW the timing and amount of Ar strongly affected the access. Simulations examined the impact of the multi-regime H-mode by considering type I ELMy H-mode for Pnet/Pthr > 1.3 with H98 = 1, type III ELMy H-mode with H98 = 0.8 for 0.5 < Pnet/Pthr < 1.3 , and hysteresis that maintains H98 = 0.8 until Pnet/Pthr < 0.5 where H98 drops to 0.5 (L-mode). With 73 MW of input power, and 0.05 and 0.15% argon, fractions the plasma could enter type I H-mode and remain there, for 0.05%, while it dropped back to type III H-mode or lower, with lower energy confinement, at 0.15%. Simulations of a steady state scenario in flattop were conducted with simultaneous multi-variable feedback of the density by fueling, the fusion power by NB injection, power losses to the divertor by Ar impurity seeding, and the loop voltage with lower hybrid current drive power. Perturbations were introduced as an impurity burst at low and high levels, 0.7% and 2.0% to the electron density. The diagonal version of the controller could be used, and simulations of similar perturbations were examined at high Q, all showing good plasma controllability. Work is partially supported by the US Department of Energy under DE-AC02-CH0911466

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Author: Dr KESSEL, Charles (PPPL)

Co-authors: Dr FELICI, Federico (Eindhoven University of Technology); Dr KOECHL, Florian (Austria); Dr KIM, Sunhee (ITER Organization); Dr CASPER, Thomas (LLNL); Dr LEONOV, Vladimir (NRC Kurchatov Institute)

Presenter: Dr KOECHL, Florian (Austria)

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