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Fast ITER-relevant low-disruptivity rampdowns in DIII-D and EAST

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Recent experiments on DIII-D and EAST are developing the techniques and scientific understanding that ITER and future devices will need for safe, low-disruptivity shutdown. ITER needs options for reliable termination both in normal operation as well as in response to an off-normal event, where speed to soft landing is paramount. A large survey of ramp-down techniques in a variety of DIII-D plasma conditions shows disruptivity in fast (I_p ramp-rates of 2-3 MA/s), diverted ramp-downs is similar or improved compared to historical, limited ramp-downs with I_p ramp-rates typically ≤ 1 MA/s. The survey used the ramp-down phase of over 370 DIII-D discharges to develop improved soft-landing techniques scalable to ITER. The disruptivity is shown to be minimized by keeping neutral beam injection (NBI) power on for the duration of ramp-down, and at modest power levels roughly comparable to the average radiated power during shutdown. Experiments on ITER Baseline Scenario (IBS) plasmas have tested the limits of the planned ITER ramp-down as well as faster yet "full-bore" ramp-downs, in which the flat-top ITER shape is maintained through ramp-down. Disruptivity statistics for this scenario have been measured to inform ITER operation, and fast (2 MA/s), full-bore ramp-downs reduced the disruptivity to 25% from the historical rate of 58% using DIII-D's standard 1 MA/s, limited ramp-down method. The planned, shape-evolving (dropping elongation) ramp-down of the 15 MA ITER Q=10 scenario has been experimentally simulated at speeds scaling to the fastest ramp-down ITER is expected to be capable of (~60s [1]), and the scenario is found to be capable of maintaining the required l_i < 1 during the H-mode phase of ramp-down while the elongation is reduced. Experiments on the EAST tokamak have likewise identified robust, fast, diverted ramp-down techniques using sustained lower hybrid (LH) power for the duration of ramp-down. Surveys of plasma current ramp-rate and LH power were conducted in the ramp-down phase of EAST discharges to complement the ramp-down survey performed on DIII-D. By continuing application of 2 MW of LH heating power, the fastest ramp-down yet on EAST of 0.5 MA/s has been demonstrated.

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[1] A.C.C Sips, et al 2015 Physics of Plasmas 22, 021804

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