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Reliable access to, and termination of, burning plasma scenarios is crucial for the success of the ITER mission. DIII-D has simulated both the startup and rampdown phases by scaling the ITER shape and plasma current penetration time to DIII-D experimental conditions, and has explored improved scenarios. With electron cyclotron (EC) assist, ITER-like startup (E_ϕ = 0.3 V/m) is robust even when limiting on the low field side (LFS). One such experiment is shown in Fig. 1 where the discharge is Ohmically ramped to current flattop (flattop duration is not scaled), H-mode (ITER scenario 2) is achieved, and a controlled rampdown terminates in a "soft landing". The end of the rampdown phase scales to 1.0 MA in ITER, below the ITER specified value (1.4 MA) for a "soft landing". The control system maintains the strike points nearly fixed, corresponding to the divertor region in ITER while the discharge elongation is continuously reduced using the ITER prescribed rampdown scenario.

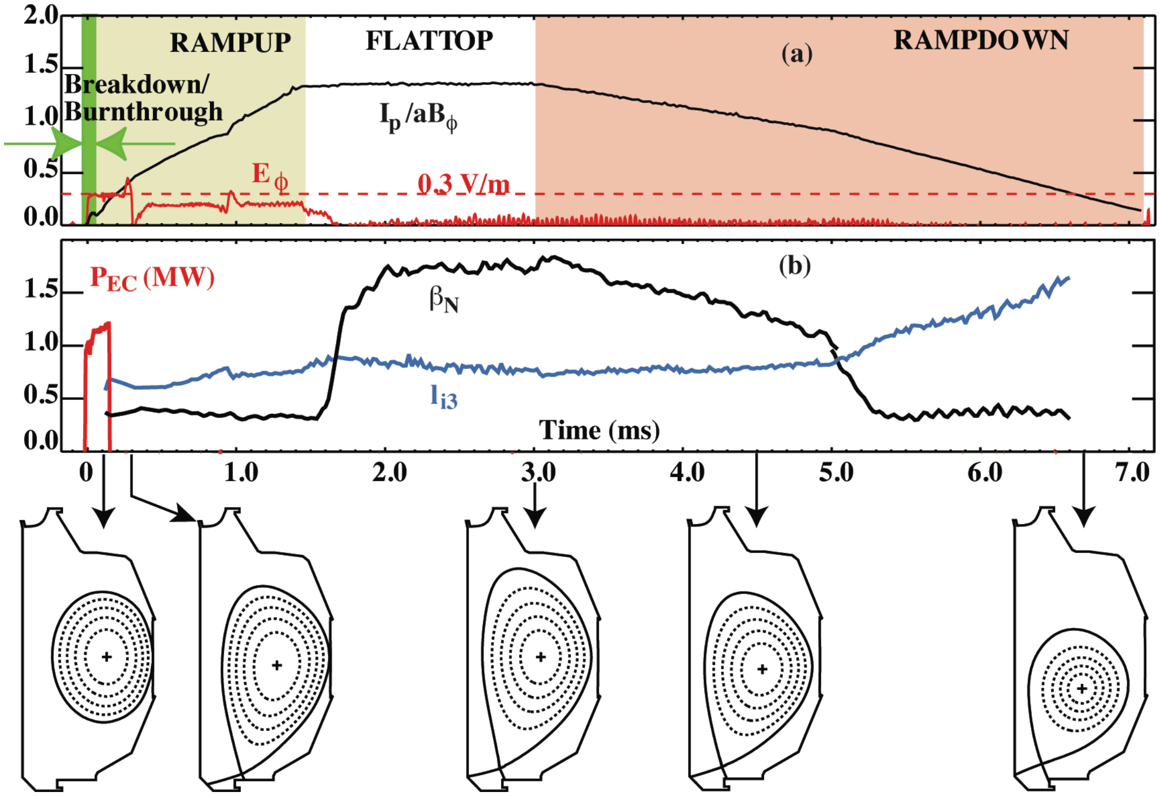

Fig. 1. DIII-D experimental simulation of an ITER scenario 2 discharge: (a) 4 phases are shown in different colors with E_ϕ and normalized I_p plotted, and (b) EC power, internal inductance, and normalized β.

Scans have been carried out to evaluate the potential operating space for ITER startup. For example, the most robust startup using EC assist was obtained by applying a vertical field before plasma initiation, shown in Fig. 2. While this reduces the field null region, breakdown and burnthrough are prompt and reproducible and the initial rate of I_p rise is increased. A good field null is required for Ohmic startup alone, but EC assist relaxes this requirement. Both radial and oblique toroidal (required for ITER) EC launch angles have been evaluated. While radial launch is best, oblique EC launch (tested to 24°) is also effective if the neutral fill pressure is high enough, ($1.5\mathrm{x}10^{-4}$ Torr in Fig. 2). Oblique launch at lower fill pressures ($<1.0\mathrm{x}10^{-4}$ Torr) exhibited a much narrower range of launch angles for effective EC assist [1]. We note that EC-assisted startup in helium is not as robust as in deuterium (Fig. 2).

Several studies in DIII-D have explored the startup phase of these scaled ITER discharges. Total flux consumption can be reduced 20% by applying modest amounts (1.2-1.4 MW) of either EC or neutral beam heating. A resonance scan of the EC location (varying toroidal field) has been carried out for $1.34 \leq R_{X2} \leq 1.84$ m [$R_{\mathrm{wall,DIII\text{-}D}}$ = 1.02 (inner) and 2.35 m (outer)]. Without EC assist, inner wall limited Ohmic startup was achieved at the ITER prescribed value of 0.3 V/m, but outer wall Ohmic startup could only be achieved at higher toroidal electric field, 0.41 V/m. A fast D_α imaging camera has allowed detailed observations of breakdown, plasma expansion, and current channel formation phases in these ITER-like discharges

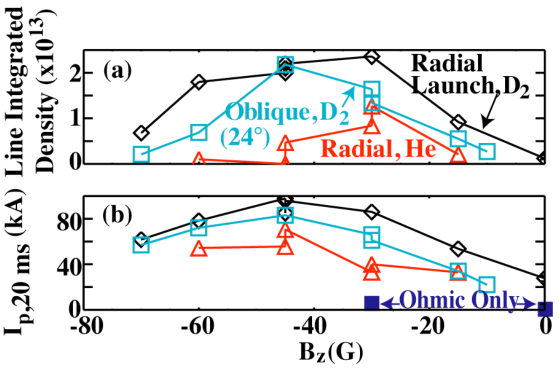

Fig. 2. Maximum line integrated density, (a) during the breakdown phase before inductive voltage is applied, and (b) plasma current measured during the early discharge evolution as a function of initial applied vertical field. P_{EC}=1–1.2 MW (2nd harmonic), either radial or oblique (24°) launch, E_ϕ = 0.3 V/m, and B_ϕ = 1.9 T. Two Ohmic attempts (no burnthrough) with similar parameters are also shown (b).

Controlled rampdown to $I_p < 0.14$ MA ($I_{\mathrm{ITER,equiv}} < 1.4$ MA) has also been achieved and a comparison of the rampdown in DIII-D is in good agreement with DINA code simulations of the ITER scenario, scaled to DIII-D parameters [2]. However, in this scenario additional flux is required from the solenoid or poloidal field shaping coils. Additional flux consumption in rampdown can be eliminated with a faster I_p rampdown than the prescribed ITER scenario; however, if rampdown is too fast, then MHD can cause a disruption at relatively high current. The ITER high-Q 17 MA scenario has also been successfully demonstrated with a "soft landing" and no additional flux consumption during the rampdown phase. Vertical stability during the rampdown phase is especially important, and DIII-D has explored both the stability range and the growth rates when vertical feedback control is disabled. Vertical feedback stabilization algorithms have been tested to determine the minimum controlled I_p attainable without loss of control.

The Corsica free boundary equilibrium code, TRANSP, and ONETWO have all been used to benchmark these DIII-D discharges with the eventual goal of providing predictive modeling for ITER. Corsica modeling predicts the approximate time of sawteeth onset ($q_{\min}$=1) and reproduces electron temperature evolution during the startup phase. Details of the current profile and internal inductance have been shown to be sensitive to the conductivity in the outer portion of the discharge.

In summary, experiments in DIII-D have demonstrated an ITER-like scenario that can ramp to plasma current flattop, achieve stable high performance discharges in both H-mode and hybrid scenarios, and successfully rampdown without disruptions or additional flux consumption.

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[1] G.L. Jackson, *et al.*, Fusion Sci. Technol. **57**, 27 (2010)

[2] P.A. Politzer, *et al.*, submitted to Nucl. Fusion (2009)