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Scenario optimization and instability monitoring to reach the Q=10 ITER mission without disruptions

While disruptions caused by MHD instabilities occur only in the plasma scenario foreseen for the ITER high gain mission (ITER Baseline Scenario, IBS, q95˜3), and they are essentially non-existent in the high-betaN, high-q95˜5-6 Steady-State scenarios, disruptions caused by hardware failures can occur in any plasma. This presentation focuses on the physics causes for the disruptions in the IBS demonstration discharges on DIII-D, and illustrates the new method used to design a passively stable operating point.

Tearing modes with m=2/n=1, occurring on the betaN flattop, are the cause of the IBS disruptions, localised below the ideal no-wall MHD limit. These instabilities are caused by the shape of the current profile J in the outer region of the plasma. The q=2 surface is located just inside the current pedestal, near a minimum in J which deepens at constant betaN and at lower rotation, due to current diffusion and changes in local transport, causing the equilibrium to evolve towards a classically unstable state. These modes are not neoclassical in nature, and direct suppression by ECCD has consistently proven ineffective. However, by combining Ip ramp rate and H-mode transition timing changes, a new recipe has been developed for modifying the J profile, accessing a passively stable state sustained for >3 current relaxation times.

ECH depositions near the q=2 surface, which falls in the current "well"just inside the pedestal (⊠˜0.78), often trigger 2/1 tearing modes (as opposed to stabilizing them). This is found to be due to the grad(Te) contribution to the bootstrap current in the pedestal (strongly affected by the localized off-axis electron heating), which is much larger than the grad(ne) and grad(Ti) terms. This pedestal change causes the current "well"to deepen past a stability threshold set by the global current profile shape. A strong dependence of the maximum stable Teped on li points to a first order dependence of the stability on the global J shape, i.e. the "well"is more "filled"later in the shot, and the equilibrium can stably sustain a higher Teped.

Realtime Active MHD Spectroscopy (AMS) has been applied to IBS plasmas in large enough numbers to collect a representative database of stable and unstable cases. Given that the AMS amplitude signal by design responds to plasma betaN changes, and increasing betaN is not correlated with higher instability, a combination of amplitude and phase moving average signals is needed to design an indicator of the approach to instability. A generalized single signal method, monitoring the evolution of the quantities A*cos(phi) or d(*Acos(phi))/dt, can map an envelope for the stable space in each shot, while the unstable trajectories shoot out of the stable envelope before the mode onset.

Controls to maintain stability during the flattop phase, if needed, have to rely on non-standard quantities such as shaping and particle influx regulation, as betan is fixed and does not affect the mode onset. Recent results on new controls mimicking a reactor's requirement for simultaneous stability and fusion power and gain performance will be presented for the first time.

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