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Mode lock precursors from the electron temperature profile in plasma termination on JET

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The capability to terminate plasma pulses safely is an important goal towards the optimization of operational scenarios in tokamaks, so it is of great importance to study the physical phenomena involved in plasma disruptions and to develop precursors for avoidance and/or mitigation actions. The development of tearing modes (TMs) inside the plasma is a major cause of disruptions. It has been shown that there are two main TM destabilization paths in plasma termination on JET, connected to the problem of impurity control: the core accumulation of high-Z impurities, leading to a temperature hollowing (TH) and to a broadening of the current density profile, and the influx of low-Z impurities, which are mainly radiating at the edge, leading to an edge cooling (EC) and to a shrinking of the current density profile. The formation of an "outboard radiating blob"due to high-Z impurities accumulated in the low-field side can also be responsible for EC.
Following the picture of TMs generated by changes in the current density profile, reflecting the changes in the electron temperature profile, two parameters have been defined from ECE radiometry to highlight the occurrence of TH and EC, and the possibility of identifying locked mode precursors based on the two parameters has been preliminary explored, by evaluating, for a large dataset of pulses, the characteristic time intervals between the increase of such parameters and the mode lock, which is widely adopted as disruption precursor to trigger mitigation actions. The obtained advances with respect to mode lock signal (1 s for TH, 100 ms for EC) are associated to the effective resistive diffusion time linking the changes in the electron temperature profile and the changes in the current density profile leading to large mode amplitudes. This is the reason why the real-time implementation of such parameters (as already done for a temperature hollowness indicator during the current ramp-up phase) would offer the capability of obtaining alerts before the mode onset, when stability analysis indicate a stable MHD scenario. In particular, the TH parameter could provide alerts useful to attempt to correct the termination, avoiding the disruption, whilst the EC parameter could provide alerts useful to anticipate mitigation actions.
Additional information are provided by the dynamics of mode lock signals. Mode saturation is quite general for EC in peaked electron temperature profile and the thermal quench (TQ) is usually induced by disruption mitigation valve (DMV) intervention, so it is not crucial to anticipate DMV. However, an explosive growth of the mode amplitude is sometimes observed for EC in hollow electron temperature profiles, leading in some cases to unmitigated TQ, so even a small advance in DMV intervention would be essential. A detailed analysis of this behaviour is planned in view of ITER, where the unmitigated disruption rate should be reduced as much as possible. The possibility of combining information on electron temperature and radiation profiles is also discussed, and examples from recent DT and isotopic experiments on JET are shown.

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