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EX/1-2: Real time ELM, NTM and Sawtooth Control on TCV

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TCV's real-time (RT) control system uses a range of diagnostic signals to detect plasma events and react with programmable, controllable actuators such as orientable ECH power and Tokamak control actuators. Three examples of MHD phenomena control are presented with RT recognition of temporal and/or spatial extents of events controlled by synchronous modulation of the power or heating position displacement.
ELM energy release changed with ECH in the plasma edge. Although these ELMs satisfy the Type I designation, their frequency increases, the relative energy loss per ELM decreases, although the coupled power decreases. ELM pacing was achieved by cutting the heating power at the ELM event for a given time before turning the power back on to trigger the arrival of the next ELM. The delay before the ELM appearance is found consistent with type-I ELM frequency vs average power scaling.
At sufficiently high beta, ST crashes of sufficient amplitude generate NTM seed islands that grow. NTMs can be avoided by destabilising ST (the foreseen ITER strategy), or be stabilised altering the current distribution inside an island i.e. "healed"by localised ECH or current drive (ECCD). NTMs may be mitigated with continuous pre-emptive ECCD in the expected region, predictive ECCD if the generating ST crash time is known, and/or reactive ECCD when a NTM is observed.
Stabilising individual STs was demonstrated on TCV by applying ECCD near the q=1 surface for a set duration after a ST crash. A new ST event is triggered a short, and relatively constant, time after the ECCD is then removed. Using the RT system, the ST period was changed on a crash to crash basis by varying the stabilising ECCD injection period. Pacing through destabilisation was also achieved by applying ECCD inside the q=1 surface with opposite phasing.
Longer ST, that trigger NTMs, can now be generated. A second gyrotron providing ECCD at the q=3/2 surface just before the ST demonstrated efficient pre-emptive NTM stabilisation. An integrated control system simultaneously controls the ST period, preempts NTM formation and suppresses any NTMs that appear. The combination of RT identification and multi-actuator reaction has been demonstrated on TCV using a combination of targeted ECH and ECCD to efficiently pact, pre-empt and/or "heal"MHD modes.

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