Controlled avoidance of disruptions in tokamaks: experience and developments in TCV

A. Pau[1], F. Felici[1], C. Galperti[1], M. Maraschek[2], G. Marceca[1], N. Rispoli[3], O. Sauter[1], B. Sieglin[2], C. Sozzi[3], T. Vu[1] and the TCV team[a].

[1] *Ecole Polytechnique Federale de Lausanne (EPFL), Swiss Plasma Center (SPC), Lausanne, Switzerland*

[2] *Max-Planck-Institute for Plasma Physics, Boltzmannstr. 2, D-85748 Garching, Germany*

[3] *Istituto per la Scienza e la Tecnologia dei Plasmi, CNR Milano, Italy*

Disruptions represent one of the highest concerns for next-step fusion devices based on the tokamak principle. Active disruption avoidance and off-normal event handling strategies need to be envisaged and carefully designed in modern Plasma Control Systems (PCS) to monitor and predict when the plasma approaches operational boundaries. In the recent years, in the context of TCV internal and EUROfusion WPTE framework programs, several real-time control algorithms for disruption avoidance and prevention, such as for NTM stabilization and control as well as for H-mode density limit (HDL) active avoidance, have been successfully developed and embedded in the TCV real-time plasma supervision system (SAMONE). An NBI-heated scenario for the HDL has been newly developed and tested in a large number of experiments carried out for different plasma currents and divertor baffles configurations, allowing to reproduce the same physics characteristic phenomenology observed also in other devices. A first demonstration of the concept of portability across different devices has been achieved by transferring from AUG to TCV the same control algorithm based on the distance with respect to an empirically defined disruption boundary in the space of the H-Mode confinement factor (H98y,2) and a normalized line integrated edge electron density. Such a distance metrics, combined with a deep learning model for energy confinement-state detection, allows to react in real-time activating different control tasks regulating NBI power and gas flux with the objective of recovering from the strong confinement degradation observed when approaching the density limit. This contribution will present an overview of the experimental results, modelling activities supporting density limit scalings, advances in algorithms for detection of proximity to operational limits as well as the advances in the development of a generic control architecture enabling the integration of active disruption avoidance strategies and exception handling.

[a] See author list of S. Coda et al Nucl. Fusion 59 112023 for the TCV team