Control-oriented dynamical model of disruption generated RE beam

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Preliminary results on the definition of a control-oriented dynamical model for position and energy of disruption-generated runaway electron (RE) beams are presented in this paper. RE beams constitute a serious problem for the integrity of plasma facing components (PFC) in ITER: during major disruptions, they can potentially cause critical damages to the vessel’s structure by transferring extremely high energy to localized areas due to their small pitch angle. Therefore, the research community is currently concerned with RE energy models able to predict the RE beam energy evolution and to define possible suppression strategies. Several models have been then developed to describe the current of a RE beam, especially related to dissipation mechanism associated to plasma impurities involved in the massive gas injection suppression strategies (MGI). However, MGI requires optimal deposition locations of the fast valves, reliable disruption prediction precursors and correct amount and pressure of the injected gas that, if not in the correct ranges, can even increase the avalanche generation of REs or cause excessive heat loads due to halo currents. In FTU a different strategy for RE beam suppression has been investigated (similar results have been obtained also in DIII-D): the position of a disruption-generated RE beam is stabilized, while its current is ramped-down in a controlled way to minimize damages to the PFC. Preliminary experiments have shown the viability of such strategy although the control system should be suitably tailored to manage RE beam instead of standard plasmas. To this aim, we present a novel horizontal and vertical RE beam displacement dynamical model, endowed with a simplified model of RE energy evolution, able to capture the main RE beam features that will allow the design of specific controllers with enhanced performances. The displacement models are obtained by employing grey-box identification methods and the dynamics have been defined by first principles (scalable to other tokamaks). Effectiveness of the estimated RE beam position and model parameters identification are discussed. Stability analysis of the proposed energy model is presented together with a discussion on the hysteresis that characterizes the relation between the RE beam energy distribution, the loop voltage and the electron density. The proposed model could improve the design of a feedback control system in such a way that the adverse effects of RE beam on PFC are minimized. Furthermore, studies on MGI techniques on formed RE beams could be performed in safer conditions.

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