Analytic Modeling of Axisymmetric Disruption Halo Currents

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Abstract

Currents which can flow in plasma facing components during disruptions pose a challenge to the design of next generation tokamaks. Induced toroidal eddy currents and both induced and conducted poloidal ‘‘halo’’ currents can produce design-limiting electromagnetic loads. While induction of toroidal and poloidal currents in passive structures is a well-understood phenomenon, the driving terms and scalings for poloidal currents flowing on open field lines during disruptions are less well established. We present a model of halo current evolution in which the current is induced in the halo by decay of the plasma current and change in enclosed toroidal flux while being convected into the halo from the core by plasma motion. Fundamental physical processes and scalings are described in a simplified analytic version of the model. The peak axisymmetric halo current is found to depend on halo and core plasma characteristics during the current quench, including dimensions, resistivities, safety factor, and vertical stability growth rate. Two extreme regimes in poloidal halo current amplitude are identified depending on the minimum halo safety factor reached during the disruption. A ‘‘type I’’ disruption is characterized by a minimum safety factor comparable to the critical safety factor at which the thermal quench occurs in a vertical displacement event and a relatively low poloidal halo current. A ‘‘type II’’ disruption is characterized by a minimum safety factor comparable to unity and a relatively high poloidal halo current. Model predictions are found to agree well with halo current measurements from VDE disruptions in DIII–D.