Does tokamak have a chance to avoid disruptions

Since the first observations of disruptions on TM-2 tokamak in 1962 with their specific characteristic "negative"(i.e., opposite in direction to plasma current) spike in loop voltage, the disruptions became and remain the most troublesome effect in tokamak projections to the power sources. Tolerable on middle size machines, disruptions in TFTR powerful supershots sometimes led to two months of recovering. In 1995 JET discovered the danger of vertical disruptions combined with toroidal asymmetry, resulted in large sideways forces on the vacuum vessel. Other effects, associated with disruptions, like runaway electrons and localized deposition of magnetic and thermal energy to the wall, became very evident on large scale tokamaks.

The inductive voltage spike in disruptions unambiguously indicates their magneto- hydrodynamic (MHD) nature, combined with magnetic flux conservation. According to S.V.Mirnov, the spike is related to polodial magnetic flux, thrown by the plasma to the wall. I personally dismiss interpretation based on internal MHD. Instead, the Hiro currents, introduced in 2007 for JET sideways force analysis, which are inductively driven and consistent with the sign of spike, represent the direct mechanism of its generation.

Regardless of interpretations of the voltage spike, the main practical problem is at a deeper level, i.e., in understanding of how to avoid disruptions. Unfortunately, for the next step projects all concerns related to disruptions are only amplified, while being mixed additionally with growing issues related to the plasma-surface interactions (PSI). In fact, after 55 years since TM-2, it is necessary to recognize that there is no hope to prevent disruptions on large tokamaks with their present complicated plasma physics and with even more complicated PSI.

A different regime, realistic for tokamaks, is related to suppression of recycling to 50 % and, accordingly, to suppression of plasma cooling by neutrals, recycled from the walls. In application for JET-like parameters with Ipl = 3 MA, Btor = 3 T and only 4 MW 120 keV NBI heating, this regime should lead to fusion gain factor QDT > 5 and fusion power PDT > 23 MW. Unlike efforts from the present PSI to reduce the plasma edge temperature, in this low recycling regime the edge is at □ 20 keV. Starting from only 2 keV, the Scrape off Layer (SoL) becomes collisionless and the entire complicated PSI is replaced by interaction of individual energetic particles with materials, what is much simpler. Of course, instead of present high-Z divertors, this requires the different ones, based on continuously flowing lithium (24/7-FLiLi).

In addition to PSI, the thermal conduction is dropped as a player in the core plasma physics, which is reduced to particle diffusion (as the energy transport), MHD, and α-particle physics. No sawteeth, no ELMs, and the plasma itself is simpler, predictable and controllable. This is a regime which gives realistic hopes on learning the disruption prevention, including burning plasma.

The talk explains the physics of low recycling regime and design guidance for its divertor, compatible with high plasma edge temperature and burning plasma while leaving the He-pumping for future,

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Track Classification: Prediction and Avoidance