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Quench Thermohydraulic Analysis of Tore Supra/WEST TF Coil and Smooth Quench Occurrence in Tokamak

The Toroidal Field (TF) system of the Tore Supra/WEST tokamak comprises 18 NbTi superconducting coils cooled by a superfluid helium bath at 1.8 K and carrying a nominal current of 1255 A. On December 19th 2017, at the end of plasma run #52205, the quench of TFC-09, detected by a secondary thermohydraulic signal, triggered the current Fast Safety Discharge (FSD). The analyses revealed that the quench was induced by highly energetic runaway electrons which, colliding with the outboard plasma facing components, generated a high flux of neutron and gamma. A quench numerical thermohydraulic model has been developed with SUPERMAGNET (CryoSoft) code. The whole TFC-09 circular coil is modelled by THEA as a single large Cable-In-Conduit Conductor (CICC) with 2028 rectangular strands (real monolithic conductors). The external helium relief circuit (cold and warm safety valves, burst disk and magnetic valve with corresponding pressure set) is modelled by FLOWER.

The helium pressure inside the coil, upstream of the cold safety valve, has been used as comparison between measurements and calculations. The simulation results depend on the Minimum Quench Energy (MQE) applied in THEA with small initial heat deposition length (few tens of centimeters) at low field region (external leg). This energy (in the order of few kJ) is compared to the simulated shape and energy of neutron and gamma flux. The expulsed helium mass flow rate (nearly 6 kg/s during 5s) has also been evaluated. This event confirms on one hand the criticity and possible occurence of a so called "smooth quench"caused by small initial heat deposition length at low field region and on the other hand the importance of secondary signals for redundant Quench Detection System (QDS) and safe operation of other Tokamak magnets.

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