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Studies on DEMO Toroidal Field Circuit

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The European demonstration nuclear fusion power plant (DEMO) is under conceptual design phase within the EUROfusion consortium. The most conservative design options in terms of science and technological developments with respect to ITER: with a Q=10, an operation with pulses 2 hours long lasting and the production of a net electricity power of 500 MW.
The toroidal magnetic field at the plasma centre of 5.7 T is produced with 18 superconducting toroidal field (TF) coils supplied by a current in the order of 65 kA, similar to the operating current of ITER TF coils, for a total stored energy of 136 GJ. This large amount of energy, more than three times the energy stored in ITER TF coils, has to be quickly dissipated in case of quench by the intervention of a suitable Quench Protection system (QPS). The time constant for the discharge for DEMO TF coils is 27 s, which is about 2.5 times the equivalent discharge time constant for ITER.
The energy, the current and the discharge time constant define the voltage to be applied to the coils; however, the peak voltage at the coil terminals in case of faults can be much higher, therefore studies addressed to estimate maximum stresses in different operating conditions and to evaluate the relative merit of different circuit topologies are very important to drive the design work, aimed at finding the best compromise between requirements for the coil insulation and cost and size of the protection system, busbars and current leads.
Fusion devices usually make use of earthing circuits to fix coils ground reference so that the voltage applied to the two terminals versus ground is half the total voltage across the coil. Both ITER and JT-60SA exploit this scheme, with different topologies, that have been considered to be used for DEMO TF coils.
For JT-60SA and ITER the QPC is composed of a dc circuit breaker (CB) which normally bypasses a discharge resistor (DR); in case of quench the CB is open and the current is transferred to the DR. In addition, a backup protection based on a circuit breaker actuated via explosive is also provided. For DEMO further topologies have been explored, with the discharge resistors connected in parallel to the coil; this connection leads to a couple of benefits: at the QPS intervention, each coil discharges on its own resistor independently, and an opening failure of one QPC CB does not reduce the total resistance of the circuit.
When QPS intervenes, the same voltage is applied to all the coils and it is equally divided between the two terminals, with all the topologies aforementioned thanks to the symmetry of the circuit. When a fault breaks such symmetry the voltage applied between the terminals and the terminal voltage to ground can be different for each coil. The peak voltages depend on the fault and on the topology adopted for the circuit.
The fault analysis for the different topologies considered for DEMO and the results discussion are reported in the paper.

Eligible for student paper award?

No

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