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THE INTEGRATED DESIGN OF THE ITER MAGNETS AND THEIR AUXILIARY SYSTEMS

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The final design of the magnet system for the International Thermonuclear Experimental Reactor (ITER) [1] has reached a high degree of integration to meet performance requirements, achieve a cost effective design and strike an optimum balance between the magnet design requirements and the constraints imposed by auxilliary systems such as power supplies and cryoplant. Magnet operational reliability and availability, safety considerations and magnet maintainability have also deeply impacted the final design solutions. The magnet design is supported by a large R&D programme focussed on the manufacture of model coils [2, 3].

The poloidal field (PF) system configuration which has been selected, is close to the one described at the Montreal IAEA conference in 1996. The Central Solenoid (CS) design has been maintained as a monolithic, layer wound coil, and plasma shaping and control is achieved by a set of 9, rather than 7, PF coils. The choice of the CS design was dictated by structural reasons to limit stress induced by torsional loads. The increase in PF coil number has allowed the use of NbTi for all PF coils, thus decreasing the total cost. The 9 PF coils give also some improvement in plasma shaping.

The magnet system structural concept is based on mutual support between the various coils to shorten the load paths and achieve a compact and robust design. The mechanical loads acting on the vacuum vessel (VV) are also directly supported by the toroidal field (TF) magnet, and as a result, all loads on in-vessel components, the VV itself and all coils are reacted and contained within the magnet structure. The structure fulfils the requirements for allowable stress and fatigue life, but there are 3 areas where stresses are close to the allowed limits: a small region of the lower inboard TF coil case, torsional shear in the CS and bearing stress between TF coil case and lower crown.

For a machine like ITER, operational reliability and high availability are essential. Since most magnet faults are caused by insulation failure, the ITER magnet insulation system includes a number of novel features to achieve a high reliability. Double insulation and the ability to monitor insulation quality are provided for the TF and PF coils. In certain cases, safety considerations have been the driver for reliable design solutions. For example, the TF coil terminals and feeders have been designed to eliminate the risk of a short of an entire TF coil.

The magnets and structures are surrounded by thermal shields which intercept thermal radiation from components that are at temperatures well above cryogenic levels. The VV thermal shield is located in the narrow gap between the TF coils and the VV. This shield is a thin stainless-steel, self supporting structure which is silver-plated for low emissivity and cooled by helium gas at 80 K. The shield and TF coil designs have been integrated such that one TF coil and a shield sector form a single unit for assembly. The tokamak is installed inside a large (33,000 m^3) vacuum vessel, the cryostat, which provides the vacuum for the thermal insulation of the magnets and structures. The cryostat thermal shield surrounds the entire tokamak and is also cooled by 80K helium gas and is supported on the cryostat.

Magnet maintenance, if required at all, should be essentially concerned with access to and repair inside the "break boxes" which contain the terminal joints, helium manifolds and their insulating breaks and instrumentation. These break boxes are located close to the coils, inside the cryostat, and their design and lay-out have been optimized for easy access and relatively short intervention times. Time-limited, controlled access into the cryostat should be possible for hands-on repair, and permanent access platforms have been integrated into the magnet and cryostat designs [4].

The lay-out of the superconducting busbars and protection switches for the TF coils has been optimized by allowing the coils and switches to be series connected in the immediate vicinity of the tokamak, just outside of the bioshield. This lay-out minimizes the length of bus work and avoids crossing any seismic gap with superconducting busbars. The power supplies for the CS and PF coils are for plasma current, position and shape control and require a local HV electrical grid able to provide 500 to 650 MW. Plasma control waveforms have been optimized to reduce the peak power and power derivative requirements and careful design of the power supplies has reduced the reactive power and harmonics generation. The most critical power supply components are the high current switches for plasma initiation and coil protection, and in particular, the CS current switches which must interrupt currents up to 170 kA. R&D is in progress in this area.

The magnets and structures are cooled by supercritical helium at about 4.5 K. The large pulsed heat loads due to conductor AC losses, eddy currents in structures and nuclear heat deposition must be smoothed for reliable operation of the cryoplant. This is partly achieved by using the tokamak structural components as thermal buffers. To this end, the helium flow is controlled to allow a temperature rise, within allowed limits, of these structural components during a plasma pulse. Further thermal load smoothing actions are provided by LHe buffer tanks and cold compressor control within the cryodistribution system, and also by warm compressor control within the cryoplant.

REFERENCES

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