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Progress on the ITER DMS design and integration

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The mitigation of thermomechanical and runaway loads during disruptions and Vertical Displacement Events (VDEs) in ITER is essential for the project to execute the ITER Research Plan culminating (1) in the demonstration of the fusion power production goals (Q = 10 inductive operation for 300-500 s and Q = 5 for 1000 s and in steady-state up to 3000 s). To mitigate these loads ITER is equipped with a Disruption Mitigation System (DMS). The original baseline concept for was found insufficient to provide the required degree of mitigation following a review by experts from the ITER Members in 2017 and this lead to major change in the development of the DMS for ITER both in the concept, now based on a Shattered Pellet Injection (SPI), and the design approach, now led by the ITER Organization for integration and design and with support for ITER Members institutes for R&D organized under a Task Force to address open detailed design issues. This presentation reports on progress on the ITER DMS technical design and integration while other presentations at this conference address specific tokamak experiments and modelling activities to address open R&D design issues (2 , 3, 4).

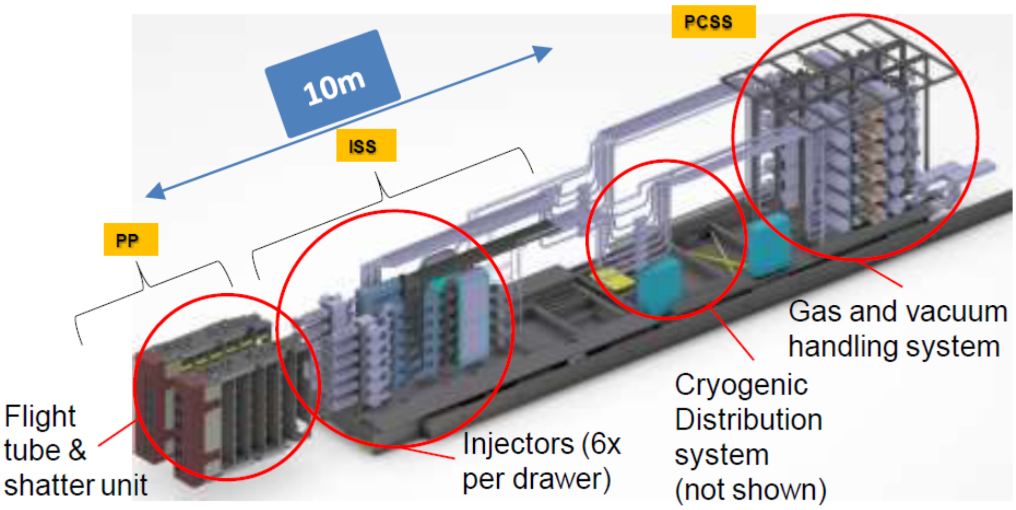

Figure 1: DMS in equatorial port (EP02)

The DMS is presently at the conceptual design level with its interfaces with other systems fixed at the preliminary design level not to affect the development of interfacing systems towards their final design or manufacturing level. The DMS utilizes toroidally distributed Shattered Pellet Injectors integrated in three equatorial and three upper port plugs (12 in EP02, 6 in EP08, 6 in EP17 and 1 each in UP02, UP08, UP14). While the injectors on the equatorial level are dedicated to thermal load mitigation, current quench control and RE prevention and RE energy dissipation, the purpose of the injectors on the upper ports are for late current quench mitigation. All DMS locations will be equipped with a dedicated gas supply providing the pellet material gases and high-pressure propellant gas, which is now integrated into the ITER design. An existing cryogenic supply system, as well as a gas venting system, are also incorporated in the ITER design to support the DMS needs in all required ports. In order to provide a DMS that performs with high reliability and availability, this first of a kind system has to fulfil key crucial requirements; these are the current design drivers of this system: a) defined and reproducible pellet integrity and pellet acceleration process; b) monitoring of pellet integrity and minimised interaction between the pellet and the flight tube wall; c) optimised shattering unit.

One of the main challenges for the DMS plant is the integration of the required components in a small and extremely harsh environment considering nuclear qualification and maintenance. The change of DMS concept following the 2017 review has lead, in addition, to integration challenges with diagnostic systems located in the same ports. To address these integration issues specific actions have been implemented: a) in the port plugs where the DMS are installed, pellet flight tubes'openings have been optimised to ensure pellet survivability and to reduce neutron streaming and activation of equipment; b) in the port interspace (small area inside the bioshield), the DMS injectors have been designed to minimise the impact on the neighbouring diagnostics, while providing sufficient human access; c) in the port cell behind the bioshield extensive gas handling and cryogenic distribution units enable the control of all relevant process variables, in order to reliably operate the DMS; d) in equatorial port two (EP02) integration issues are being assessed with respect to the Core Imaging X-Ray Spectroscopy diagnostic. This diagnostic provides measurements of ion temperature and plasma rotation and its design has been substantially modified for compatibility with the two DMS systems sharing the port. The analysis of this design change shows impacts on its measurement capabilities regarding spatial/time resolution and for the measurable magnitude of the toroidal rotation, which are being minimized by design iterations. Other diagnostics systems sharing ports with DMs, such as the visible infrared viewing systems in the upper ports are not significantly affected.

A DMS Task Force has been created to support the DMS design and has two main activities, the design validation through experiments and modelling and the optimisation of the SPI technology (5). The technology programme addresses the main DMS design drivers through development and optimisation of key components to fulfil the ITER mitigation requirements. R&D under the technology programme covers issues such as : a) fundamental studies, including systematic tests and optimisation of the pellet formation and release process; b) the creation of a support laboratory, providing a test bed to assess the performance of key components such as the shattering bend; c) the development of pellet launch to optimize release mechanisms (fast valve and punch); d) the development of optical pellet diagnostics to diagnose pellet alignment, pellet integrity and pellet parameters.

The DMS TF work program on design validation consists of dedicated experiments accompanied by theory and modelling activities. These efforts are supported by significant contributions through the domestic activities of the ITER partners. The ITER DMS strategy relies on densification of the plasma to avoid runaway electron formation and on radiating most of the thermal and magnetic energy spatially as uniform as possible to avoid first wall melting. Densification requires the injection of multiple pellets, a scheme that is tested in JET (2), DIII D (6) and KSTAR (3), for the latter with an SPI system that can inject a total of four identical pellets from two toroidally opposite locations. These experiments, together with the tokamak J-TEXT, are providing information on size and energy scaling of SPI mitigation performance for model validation. While the technology programme assesses the parameter space for pellet fragmentation, the experiments planned for ASDEX-Upgrade will focus on finding the optimum fragment size for maximum material assimilation. In support of the experimental activities, the theory and modelling activities programme will provide physics-based extrapolation from the experimental results to ITER (4). This will allow narrowing down design parameters for the ITER DMS such as the pellet velocity, the fragment size distribution, and the pellet composition and it will increase the confidence level that the ITER DMS can fulfil its purpose.

The paper will described status of the DMS design, its integration into the ITER baseline and the status of the technology R&D and will provide a summary of progress of the design validation experimental and modelling activities.

References

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