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The development of the physics and technology basis for the ITER Disruption Mitigation System

M. Lehnen and the ITER DMS Task Force contributors
ITER Organization
e-mail (speaker): michael.lehnen@iter.org

Although the thermomechanical loads generated by plasma disruptions in ITER require operations to strongly focus on disruption avoidance, these cannot be ruled out, especially during the early phases of the ITER Research Plan [1] when scenarios are established and the operational range is extended. Even at relatively low plasma performance, these disruption loads can be severe on ITER, particularly with regard to damage of plasma-facing components. Disruption mitigation is therefore critical, not just for the achievement of the ultimate goal of high current (15 MA), burning plasma operation (Q = 10), but also for the timely execution of the IRP to reach this goal. ITER's disruption mitigation strategy relies on the injection of multiple cryogenic pellets that are disintegrated into small fragments before entering the plasma, a technique called shattered pellet injection (SPI). The Disruption Mitigation System (DMS) is at the conceptual design level and consists of a total of 24 injectors distributed over 3 equatorial ports as well as 3 additional injectors in 3 upper port plugs. With its injection capabilities, the requirements on reliability and availability, and the demanding constraints imposed by the limited physical space and very harsh environment, the ITER DMS is a first-of-a-kind system.

An international Task Force has been established which drives an extensive programme to support the ITER DMS design by developing and testing key components and by validating design choices in experiments, theory and modelling. R&D under the technology programme covers issues such as: a) 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; c) the development and testing of shattering units to deliver the required fragment sizes; d) the development of a pellet launching unit consisting of optimised fast valve and punch mechanisms; e) the development of optical pellet diagnostics to diagnose pellet alignment, pellet integrity and pellet parameters. These technology developments are also strongly supported by dedicated lab tests performed at ORNL [2].

The Task Force experimental programme is supported by significant contributions through domestic activities within the ITER partners. It is primarily focused on answering three fundamental questions key to the ITER mitigation strategy: Can the density be raised efficiently by superimposing multiple pellets? Can the required radiation levels be reached uniformly enough to avoid melting of the first wall? What is the optimum fragment size for maximum mitigation efficiency?

Dedicated experiments in JET [3], DIII-D [4] and KSTAR [5] are addressing these questions. KSTAR is presently closest to the ITER configuration with an SPI system that can inject a total of 4 identical pellets from 2 toroidally opposite locations. Experiments on these devices, together with the tokamak J-TEXT, are providing information on size and energy scaling of SPI mitigation performance. Experiments now in preparation for ASDEX-Upgrade will focus on finding the optimum fragment size by injecting through different shattering bends at the end of the flight tubes. Adapting diagnostics on current devices for the characterization of the mitigated disruptions with their short timescales and high spatial asymmetry is essential. On KSTAR and ASDEX-Upgrade in particular, new dedicated radiation measurements and fast camera observations have been installed or are planned.

In support of the experimental activities, the theory and modelling programme within the Task force will provide physics-based extrapolation from the experimental results to ITER [6]. Whilst its primary focus is on 3D MHD simulations performed with the codes JOREK [7], M3D-C1 [8] and NIMROD [9], and the development of improved understanding of the generation and mitigation of runaway electrons, it also includes more simplified modelling permitting an assessment of the sensitivity to the various injection parameters, e.g. injection simulations with the code INDEX [10].

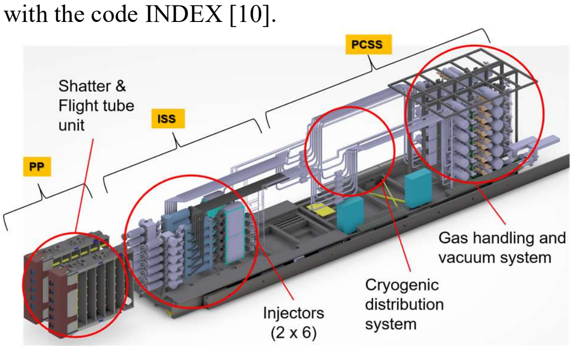

Fig.1 – Preliminary design of the ITER DMS in equatorial port 2 and the three distinct areas: 1.Port Plug (PP) 2. Interspace Support Structure (ISS) 3. Port Cell Support Structure (PCSS).

References

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