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Preparation for Assembly and Commissioning of ITER

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ITER Organization, CS 90 046, 13067 St. Paul lez Durance Cedex, France

Significant progress has been made in the fabrication of the tokamak components and the ancillary systems of ITER and in the finalization of the plant infrastructure at the ITER site since the 2018 Fusion Energy Conference. By an agreed measure, over 2/3 of the work scope required for First Plasma has been accomplished. Many key buildings, most notably the concrete structure of the tokamak building, are now complete. The steady-state electrical network, whose initial commissioning was previously reported, is now in routine operation and being extended. Other key systems, such as the secondary cooling water system, the cryogenic plant, and the reactive power compensation, are either in the initial phase of commissioning or will be in the near future.

The progress in completing manufacture of the essential components of the ITER tokamak is impressive. Magnet manufacturing has now demonstrated 'first of a kind'production of all the superconducting magnets (Toroidal field (TF), Poloidal Field (PF), Central Solenoid (CS) and Correction Coil (CC)) and feeders. The first two toroidal field coils have passed factory acceptance tests and will be delivered to the site in April. By the end of the year, 5 TF coils, 2 PF coils, two CS modules and 6 CC coils should be delivered. The cryostat base is ready for installation in the tokamak building, the lower cylinder is complete, and the upper cylinder is now almost complete. The first vacuum vessel sector will be delivered by summer; the first two vacuum vessel thermal shield sets were already delivered. The key contracts for assembly and installation have been placed in preparation for assembly activities in the second half of 2020.

Systems essential for the execution of the ITER Research Plan (IRP), such as Heating and Current Drive (H&CD) systems, in-vessel components, and diagnostics are advancing in their design and fabrication. The test beds for the Neutral Beam (NB) source have demonstrated beam extraction and acceleration at ITER requirements in hydrogen at ELISE and the start of operation with cesium. The MITICA test bed for the beamline will be completed in 2020, following successful demonstration at 1 MV of its high voltage power supply components. A new Ion Cyclotron Heating (ICH) antenna design has been elaborated and reviewed. The ICH radiofrequency sources have successfully demonstrated the required performance, ensuring the progress needed to have the ICH system ready for operation in Pre Fusion Plasma Operation (PFPO) 2 as required for the IRP. All eight Electron Cyclotron Heating (ECH) gyrotrons required for First Plasma (FP) are manufactured, and five have already passed the factory acceptance tests. The progress on the ECH system ensures the availability of the required partial system for FP (eight gyrotrons and one launcher) and the full system for PFPO-1. The final design of the First Plasma Protection Components has been completed in March 2020 with the plan to start fabrication by the end 2020. Relevant mock-ups and medium-scale prototypes of Blanket and Divertor components have been manufactured and tested beyond the design flux values; the manufacturing of full-scale prototypes is on-going so that series production can start in 2022-2023. The initial configuration of the Test Blanket Systems will include two water cooled (Water-Cooled Lithium-Lead and Water-Cooled Ceramic Breeder) and two helium cooled (both with a solid ceramic breeder) Test Blanket Systems. A special focus of the diagnostic design and procurement has been given to those who need to be installed before FP. Several magnetic diagnostics and trapped components, such as a neutron flux monitor frame and vessel attachments are already delivered. Many other FP diagnostic components are in manufacturing, including the in-vessel wiring and trapped supports for holding diagnostics in place on the buildings. The port plug structures are in manufacture and the final design reviews for the two FP port plugs have taken place with most of the diagnostics needed for FP being in the Final Design stage.

Experimental and modelling R&D has focused on the areas required to complete the design of ITER components/systems, to address high priority R&D issues for the IRP. Regarding the design of systems, a major effort has been started to refine the design of the Disruption Mitigation System (DMS), with notable success since the last IAEA FEC. Experiments at DIII-D, JET, and KSTAR have demonstrated many of the requirements needed for effective mitigation of disruptions at ITER by the Shattered Pellet Injection (SPI) scheme. DMS experimental R&D is supported by a theory and modelling programme to provide a physics-based extrapolation of results obtained in present experiments to ITER, alongside a technology programme to develop the SPI hardware to the level needed for Investment Protection. Specific modelling efforts have also been performed to consolidate the ITER baseline configuration for steady-state operation. This has led to the identification of NB and ECH heating and current upgrades as sufficient to achieve the Q = 5 steady-state project goal and, thus, the removal of Lower Hybrid Current Drive (LHCD) as an upgrade option from the baseline.

Following the public release of the IRP, the IO has identified and prioritized a range of issues where R&D is required to refine strategic assumptions in the plan, identify the best way to execute it and to refine the

details of its execution. This prioritized R&D has been used to refocus effort on the IRP at the IO and within voluntary programmes supported by the ITER Members. This is mainly centred on the International Tokamak Physics Activity, with the ITER Scientist Fellow Network providing an important route for theory and modelling development. Examples of significant progress in these high priority IRP issues since the 2018 IAEA FEC are the refinement of thermomechanical and runaway loads during disruptions and the assessment of integrated scenario aspects of ELM control by 3-D fields, including control of divertor power loads and access to the divertor detached regime with optimization for minimum impact on plasma performance.
Activities to prepare tokamak operation and ITER's scientific exploitation have focused on First Plasma and Engineering Operation (EO) and the development of the Integrated Modelling and Analysis Suite (IMAS), which facilitates integrated plasma scenario modelling and the analysis of experimental measurements of ITER plasmas. Developments for FP and EO have focused on the finalization of the design of the Plasma Control System, which will control the tokamak and ancillary systems to achieve FP, the identification of the major drivers for plasma start-up and their optimization to ensure robust FP operation, and the refinement of the strategy for blanket alignment in the Assembly Phase II by dedicated measurements during Assembly Phase I and in the FP and EO phase. IMAS capabilities have been significantly expanded to provide interfaces with modelling and data interpretation codes enabling the development of new workflows for integrated modelling and plasma analysis such as for H&CD and fast particle physics. Integrated modelling of ITER plasma scenarios has focused on PFPO scenarios to guide the refinement of the IRP in this phase. One important aspect is a re-assessment of neutron production in PFPO, including fast particle effects associated with the presence of beryllium impurities in the plasma and fast protons from NBI and ICH. A second is the development of fully integrated plasma scenarios including core, edge and plasma-wall interaction aspects with the ITER W divertor. This has demonstrated the conditions required for robust scenario operation in the PFPO phases, with specific aspects of edge power flow physics being addressed by sophisticated gyrokinetic codes.

References providing details can be found in comments

Country or International Organization

ITER Organization

Affiliation

ITER Organization

Author: BIGOT, Bernard (ITER Organization)

Presenter: BIGOT, Bernard (ITER Organization)

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