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Overview of the ITER Tokamak complex building and integration of plant systems toward construction

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ABSTRACT

The ITER Tokamak complex consists of Tokamak, diagnostic and tritium buildings. The Tokamak machine is located in the bioshield pit of the Tokamak building. Plant systems are implemented in the three buildings and are strongly interfacing with the Tokamak. The reference baseline (3D) configuration is a set of over 1000 models that today defines in an exhaustive way the overall layout of Tokamak and plant systems, needed for fixing the interfaces and to complete the construction design of the buildings.

During the last two years, one of the main ITER challenges was to improve the maturity of the plant systems layout in order to confirm their integration in the building final design and freeze the interface definitions in-between the systems and to the buildings. The propagation of safety requirements in the design of the nuclear building like confinement, fire zoning and radiation shielding is of first priority. A major effort was placed by ITER Organization together with the European Domestic Agency (F4E) and the Architect Engineer as a joint team to fix the interfaces and the loading conditions to buildings. The most demanding systems in terms of interface definition are water cooling, cryogenic, detritiation, vacuum, cable trays and building services. All penetrations through the walls for piping, cables and other equipment have been defined, as well as all temporary openings needed for the installation phase. Project change requests (PCR) impacting the Tokamak complex buildings have been implemented in a tight allocated time schedule. The most demanding change was to implement a new design of the Tokamak basic machine supporting system. The 18 supporting columns of the cryostat (2001 baseline) were replaced at the end of 2012 by a concrete crown and radial concrete ribs linked to the basemat and to the bioshield surrounding the Tokamak. The change was implemented successfully in the building construction design to allow basemat construction phase being performed at mid-2014. The paper gives an overview of the final configuration of the ITER nuclear buildings and highlights the large progress made on the final integration of the plant systems in the Tokamak complex. The revised design of the Tokamak machine supporting system is also described.

1. Introduction

Design Integration Team within ITER Organization (IO) is responsible for the implementation and management of the whole reference technical baseline in the contextual environment. It includes the Tokamak machine and plant systems in nuclear buildings and a set of 30 auxiliary buildings that are part of the Site layout and *Installation Nucléaire de Base* (Basic Nuclear Installation). One of the key challenges is the management and freezing of all physical and functional interfaces between systems and ITER buildings. The overall reference baseline is controlled using the 3D Configuration Management Model (almost 8000 CMM) that defines

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the space allocation for each component and physical interfaces between the systems or components. The configuration includes also space reservations for the maintenance and assembly.

All changes impacting the configuration have to be documented through project change request (PCR) and/or deviation request (DR) or non-conformities (NC). A PCR is implemented in the technical baseline only after it has been recommended and approved by both ITER and the Domestic Agencies (DA). Implementation of systems requirements, nuclear safety, assembly and maintenance, health protection and safety, investment protection, are also part of the configuration control of the whole integrated project.

Significant progress has been made during the last 2–3 years in the integration of Tokamak components and plant systems in the nuclear and auxiliary buildings. Design was optimized and revised to solve remaining issues with respect to systems and safety requirements. As many of the plant systems located in the nuclear buildings are still in the conceptual – and preliminary design phase such as fuelling, diagnostics, test blanket system, cable trays or Tritium plant the definition and the freezing of the interfaces with buildings was a complex exercise with keeping the project schedule for the construction of the nuclear buildings. IO has worked very closely with the F4E (European DA, who is in charge of the delivery of all ITER buildings) and other domestic agencies in order to succeed in time.

2. Fixing the interfaces between the Tokamak basic machine and the building

2.1. Redesign of the Tokamak supporting system

Cryostat base supporting system was fully redesigned in order to cope with the updated revision of cryostat loads combination issued at the end of 2011 and the consequent transfer of reaction forces from Tokamak to building basemat in various normal and accidental conditions (e.g. cryostat shrinkage in case of in-cryostat helium ingress, vertical disruption event, seismic loads level 1 and 2). The 18 cryostat supporting columns issued through the 2001 reference baseline were submitted to high bending moment and were transferring very high loads to the 1.5 m thick concrete slab. This support scheme was not anymore compliant with the maximum building stress allowable limit defined by IO project team including safety margin of 1.5 and accepted by the nuclear regulator. Therefore a new design solution was proposed jointly by IO and by the Architect Engineer of F4E fully integrated by IO in the second half of 2012. The 18 columns were replaced with a 1.5 m thick circular concrete crown linked to the building bioshield through eighteen radial concrete ribs that help to transfer vertical shear loads and radial loads to the very stiff bioshield (see Fig. 1). It contributes to the reinforcement of the basemat structure.

One of the challenges was to limit the changes impacting the Tokamak basic machine. As it is illustrated in the Figs. 1 and 2, the new reinforced concrete crown has rectangular shaped openings that allow the magnet feeders penetrating the new crown to the coil terminals. The most demanding change was a redesign of the feeder for poloidal field coil #4. The benefit was to implement a full axisymmetric crown and radial ribs. The change on feeders design is now fully implemented. Feasibility of the assembly and welding of the feeders with considering the new environment has been demonstrated at ITER site using the virtual reality (VR) platform [1].

The impact onto the cryostat itself was minimized, not impacting the manufacturing process and manufacturing schedule of the cryostat base that is expected to be delivered on time by the Indian Domestic Agency (INDA). The built to print approved detailed design of the cryostat was delivered by end of July 2012 to the

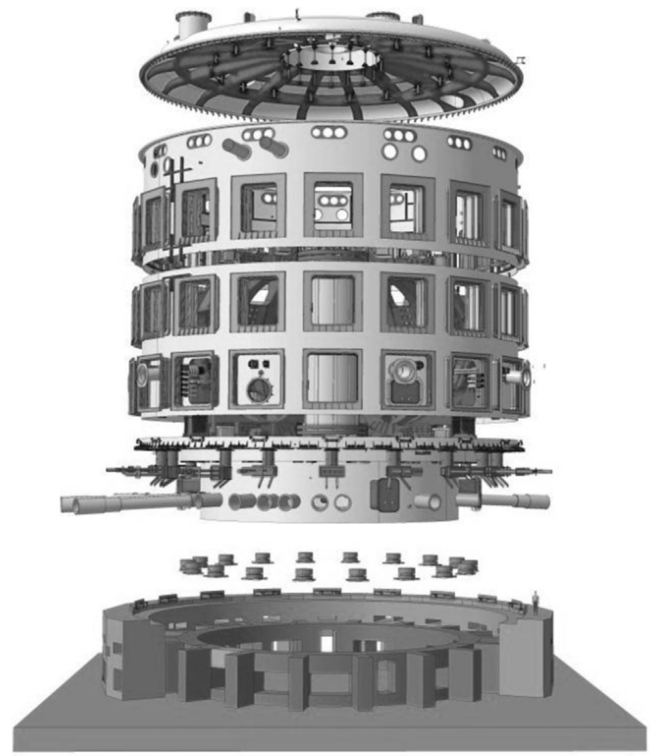

Fig. 1. Exploded view of the cryostat and the new supporting concrete crown linked to the bioshield through 18 radial transverse ribs.

INDA domestic agency. The cryostat base pedestal ring is seating on the crown through 18 sliding spherical bearings (see Fig. 2) that limit the reaction forces onto the crown in case of helium ingress and consequent shrinkage of the cryostat itself. Maximum radial displacement of the cryostat because of shrinkage is of 25 mm. The spherical bearings are designed to compensate any misalignment between cryostat and building and to accommodate deformation of the cryostat pedestal ring during disruptions.

2.2. Optimization of cryostat base restraining system

Both cryostat base toroidal and vertical restraining systems to building bioshield were optimized and finalized in parallel to the redesign of the whole Tokamak supporting system described above. The high vertical uplift and toroidal forces occurring through severe

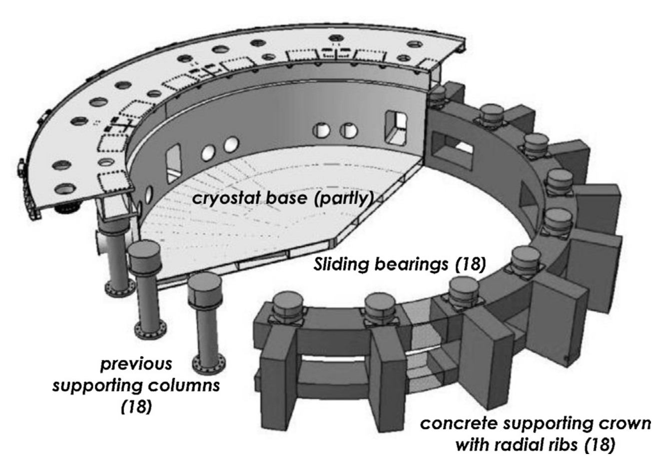

Fig. 2. Detailed view of the previous and current Tokamak supporting system (cryostat base is shown partly).