Architectural Concept for the ITER Plasma Control System

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The plasma control system is a key instrument for successfully investigating the physics of burning plasma at ITER. It has the task to execute an experimental plan, known as pulse schedule, in the presence of complex relationships between plasma parameters like temperature, pressure, confinement and shape. The biggest challenge in the design of the control system is to find an adequate breakdown of this task in a hierarchy of feedback control functions. But it is also important to foresee structures that allow handling unplanned exceptional situations to protect the machine. Also the management of the limited number of actuator systems for multiple targets is an aspect with a strong impact on system architecture. Finally, the control system must be flexible and reconfigurable to cover the manifold facets of plasma behavior and investigation goals.

In order to prepare the development of a control system for ITER plasma operation, a conceptual design has been proposed by a group of worldwide experts and reviewed by an ITER panel in 2012. In this paper we describe the fundamental principles of the proposed control system architecture and how they were derived from a systematic collection and analysis of use cases and requirements. The experience and best practices from many fusion devices and research laboratories, augmented by the envisaged ITER specific tasks, build the foundation of this collection. In the next step control functions were distilled from this input. An analysis of the relationships between the functions allowed sequential and parallel structures, alternate branches and conflicting requirements to be identified. Finally, a concept of selectable control layers consisting of nested “master controllers” was synthesized. Each control layer represents a cascaded scheme from high-level to elementary controllers and implements a control hierarchy. The master controllers are used to resolve conflicts when several control functions would use the same command signals as their outputs. They consist of a collection of potentially conflicting control functions from which one at a time is exclusively activated by a mode selector signal.

It can be shown that this architectural design is capable of implementing all of the presently known functional control requirements. Furthermore, this design takes already into account that the result of future experiments at ITER will create additional requirements on the functions or performance of ITER plasma control.