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Designing a prototype of the ITER pulse scheduling system

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HIGHLIGHTS

► We designed a prototype of the ITER pulse scheduling system.
► Structure of ITER pulse schedules was designed.
► Validation and automatic value assignment functions were adopted.
► A prototype will be implemented in 2011.

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ABSTRACT

A prototype of the ITER pulse scheduling system that prepares and manages parameters for ITER plasma operations has been designed. Based on the analyzed requirements on the system, structure of the parameters and necessary functions were determined. Segment and module structures were tuned to the ITER requirements. Three types of validations assure sanity of the parameters. The design limits check and the operation window check verify whether the values of the parameters do not exceed the limits. The consistency check calculates dependency among parameters in accordance with logics described in a scripting language. The ITER pulse scheduling system provides interface with a physics model and simulator. Some abstract physics parameters are converted to engineering parameters with the physics simulation. The results of simulation such as plasma characteristics of specified parameters are also shown to the researchers. The tool to specify the parameters is data-driven. Therefore, it is flexible for changes of number of the parameters.

A prototype is being implemented in 2011. Using the prototype, this design will be verified and refined. The evaluation of the prototype will be a basis of the final production of the ITER pulse scheduling system.

1. Introduction

Pulse schedules determine parameters that characterize plasma operations. The ITER pulse scheduling system is an important sub-system of the ITER CODAC (COntrol, Data Access and Communication) system [1]. ITER will be the largest tokamak ever built. Many challenges have to be resolved [2]. The ITER pulse scheduling system was designed based on experience and knowledge from tokamaks and stellarators such as JT-60U, ASDEX upgrade, WENDELSTEIN 7-X, JET and DIII-D. This paper reported results of the design.

2. System overview

The architecture of the ITER pulse scheduling system is shown in Fig. 1. The server centrally manages pulse schedules to ensure security and integrity of data. It also hides the database management system specific structure or data types from the clients to reduce risk of replacement of the database system in the future. Definitions of the pulse schedule parameters are retrieved from the self-description data (SDD) database [3]. Modification and validation of a pulse schedule are performed at the client side to decrease turn-around time. The supervisory control system acts as a single point of contact to the plasma control system and plant systems. The system will be implemented based upon the technologies ITER recommends such as CODAC core system [4].

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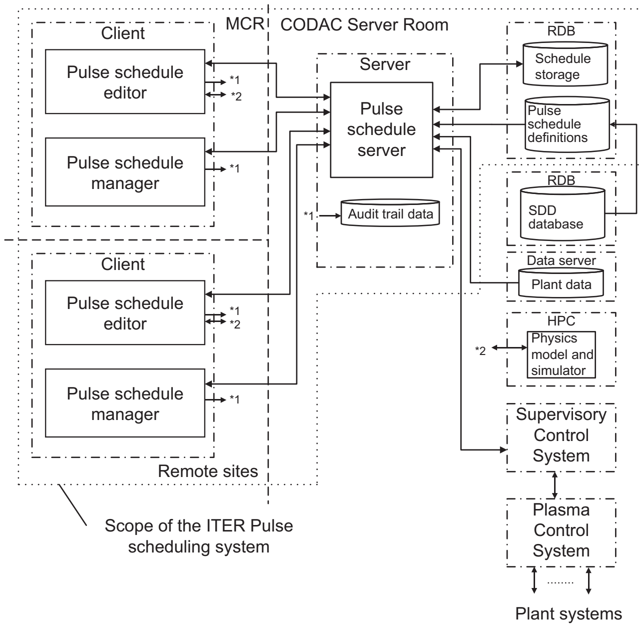

Fig. 1. System architecture of the ITER pulse scheduling system.

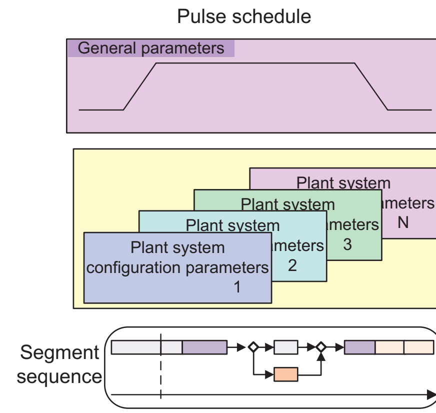

Fig. 2. Structure of an ITER pulse schedule.

3. Requirements

Operations of ITER should be well-managed and well-controlled to protect the machine and to conduct efficient plasma operations. The following requirements on the ITER pulse scheduling system were analyzed:

1) Pulse schedule parameters shall be validated at all the steps in pulse schedule management prior to execution;
2) Pulse schedule structure shall be flexible for changes of number of pulse schedule parameters;
3) An executed pulse schedule shall be utilized to create a new pulse schedule as much as possible with modifying some parameters;
4) Functions to lessen physics operators' effort for specifying and managing a pulse schedule shall be provided;
5) All pulse schedule parameters shall be defined in the central engineering database called the SDD.

4. Design of the ITER pulse schedules

The ITER pulse schedule structure was designed to satisfy the requirements on it. The design is described in this section.

4.1. Structure of ITER pulse schedules

Pulse schedule parameters defined in the SDD are classified into three groups, the General parameters, the Plant system configuration parameters and the Segments, which provide a clear hierarchy of constraints among parameters (see Fig. 2). The general parameters determine the purpose and the operational scenarios of an experiment. They also indicate necessary conditions of plant systems. The plant system configuration parameters specify the configurations and status of a particular plant system for each pulse. The configuration parameters are sent to the control systems of plant systems before execution of the pulse. A segment is a portion of a pulse and contains parameters that are used for plasma control. A segment also includes one or more modules. The general parameters constrain the plant system configuration parameters and the parameters of segments. Plant system configuration parameters constrain the segments. These constraints are confirmed by the consistency check function.

Simple rule is adopted to ensure flexibility for changes of pulse schedule parameters and utilization of executed pulse schedule. If some parameters are added to the latest pulse schedule, those new parameters shall be filled by the initial values defined in advance. Consistency among parameters is guaranteed by validation functions.

4.2. Segments and modules

Some tokamaks and stellarators use segment and module concepts [5–7]. A segment of ITER contains control parameters such as control timings, setpoint values including waveforms and validation algorithms. The segment also includes meta-data for the plasma control system (PCS), providing a mechanism, for example, to bridge segments. Example of segments is shown in Fig. 3. A pulse consists of one or more segments. The connected segments are called the segment sequence (see Fig. 4(a)). Segments in the segment sequence cannot be processed at the same time. The PCS selects a segment for execution from several segments at each decision point in a pulse (see Fig. 4(b)). The pulse length of ITER plasma will be up to around 3000 s. Therefore, segments may be changed according to plant system conditions or plasma characteristics to ensure the efficient conduct of experiments. When a single pulse is created collaboratively by more than one experimental group, the segment is the unit of collaboration, for which only one group may be responsible. A pulse may be integrated by merging segments under a responsible person.

A segment is made up of "modules", containing configuration parameters for the PCS. Modules also include indexes to identify algorithm implemented in the PCS. Several modules may be processed concurrently while the segment is being executed.

Only well-examined segments and modules shall be provided to researchers by the ITER Organization, because control parameters of segments and modules are restricted by operating constraints of ITER.

The flow of segments is controlled at a decision point. The PCS makes decision to change segments to be executed. However, in this design only planned changes of segments are allowed for machine protection according to the parameters specified by the researcher.