INTEGRATED APPROACH TO THE DEVELOPMENT OF THE ITER CONTROL SYSTEM CONFIGURATION DATA

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Abstract

ITER control system will rely on a large number of configuration data, coming from different sources. This information is being created using different tools, stored in various databases and, generally, has different lifecycle. In many cases it is difficult for instrumentation and control (I&C) engineers to have a common view on this information or to check data consistency. The plant system profile database, described in this paper, tries to address these issues by gathering all I&C-specific information in the same database and providing means to analyze these data.

INTRODUCTION

ITER control system, CODAC, has a major challenge of not being created by a single team in a single location, but instead split into different pieces according to the plant systems manufacturing and delivery process. This fact increases substantially the number of people involved in the I&C design, which leads to many different practices and approaches to the implementation of I&C systems. The CODAC team takes preventive measures to reduce diversity by standardizing procedures, hardware and software via its Plant Control Design Handbook (PCDH) and the software product called CODAC Core System (see [1]). The CODAC Core System [2] is a scaled down version of future CODAC, based on EPICS [3], providing essential software support for creating locally of a control system "island" of an arbitrary complexity. These pieces of the control system are called "plant system I&Cs" in ITER terminology.

The configuration data developed with the help of the Core System is conventionally called the "self-description data" (SDD) of particular plant systems, because it allows configuring many elements of the central CODAC by just reading these data (see more on the ITER SDD concept in [4]). The Core System comes with its own relational database, based on PostgreSQL [5], and the tool, called the SDD editor, to create plant system I&C configuration using a top-down approach. This database-enabled solution was initially released in February 2011 and it proven itself being well adapted to I&C engineers' needs. It should be noted that, with the dissemination of Core System installations around the globe, the number of such databases grows, and their content has to be collected and integrated. The workflow to collect these configuration data into the central database is explained in [4].

While the Core System SDD tools are mostly concentrated on the control software configuration part, there are quite a few other areas in the ITER design activities which have impact on I&C configuration. The I&C relies heavily on naming convention for plant components and signals, which is defined and maintained project-wide. The I&C hardware has to be properly allocated in racks and cupboards ("cubicles" in ITER terminology), and those, in turn, have to be assigned to the right locations on the ITER site. The I&C architecture design process is supported with 2-D diagram tool, which has its own database for drawings and I&C objects. The cabling accounting will also be supported by a database solution. Finally, the progress of I&C manufacturing and procurement has to be monitored, and the procured equipment has to be properly registered and accounted. All these tasks are often solved with the help of the tools which are best in their class for functionality, but inevitably bring some diversity with databases and data schemas that accompany them. There is an on-going effort at ITER to unify all engineering data under the umbrella of so-called "engineering database", but the solution has not arrived to production level at the moment and is not yet much I&C-specific.

These circumstances lead to a natural idea of a "syndicated" I&C-specific database which is capable to collect all the I&C-relevant data in a single place and present it in a coherent way. This is what we call a "plant system profile database".

SCOPE AND OBJECTIVES

The main objective was to provide the ITER I&C team with a tool to address immediate needs for configuration data collection and analysis. The scope of the data itself is not always well defined and highly depends on current priorities of work. Thus we opted for a flexible approach, which consists of: 1) providing a solution generic enough to work with any kind of structured data; 2) approaching areas of interest step by step, by determining their properties and implementing them in agreement with the rest of the database.

The most immediate needs at the moment are capturing some top level I&C design decisions and quantitative estimates, as well as tracking the progress of I&C design and procurement. Consequently, the scope of initial works was to handle the following data:

- breakdown of ITER into plant systems and plant system I&Cs;
- I&C estimates, like estimates of number of cubicles and signals;
- detailed lists of components, signals and I&C variables;
- tracking of procurement arrangements, design reviews, design deliverables, reference documentation.

The objective was attained, even though in many cases the data has not been entered in the database yet or simply does not exist at the moment. Details on the implementation are given in the next section. From this point we are looking forward to address more advanced topics, like:

- support of the remote CODAC Core System databases (a so-called "SDD repository");
- implementation of a workflow between the 2-D diagrams tool and CODAC databases;
- component life cycle management and inventory control;
- support for interlock functional analysis;
- automation of certain routine data imports and data quality checks.

FIRST IMPLEMENTATION

At the design phase, the current ITER infrastructure and CODAC practices have been evaluated, and the following architectural and software decisions have been made:

1) the database backend should be MicroSoft SQL Server [6];
2) the application should have web interface;
3) business logic and the user interface should be written in Java. PrimeFaces [7] should be used for the user interface, Spring [8] for transactional support and Java Hibernate [9] for interaction with the database;
4) data integration tool should be Talend [10].

The task was launched in September 2010; in February 2011 the first version was put in production, and it was gradually introduced into CODAC processes in the following months.

The front page of the application is presented on Fig. 1. It presents an overview of data stored in the database at the moment. The key metrics are number of plant systems and plant system I&Cs ("control islands"), the number of their components and signals, the numbers of I&C controllers and variables handled by them. As one can observe, the population of the database has just started. It is worth noting that the database is not only about technical data – it collects and presents information about administrative aspects of I&C tracking – like procurement arrangements, design review and documentation status. Since the administrative data is available, the database application is able to offer a list of coming milestones right at the front page.

Various aspects of data can be studied using so-called "perspectives" (the names comes from Eclipse perspectives, similar by nature). The perspectives are views of the same data presented from different angles. The main perspectives defined today are:

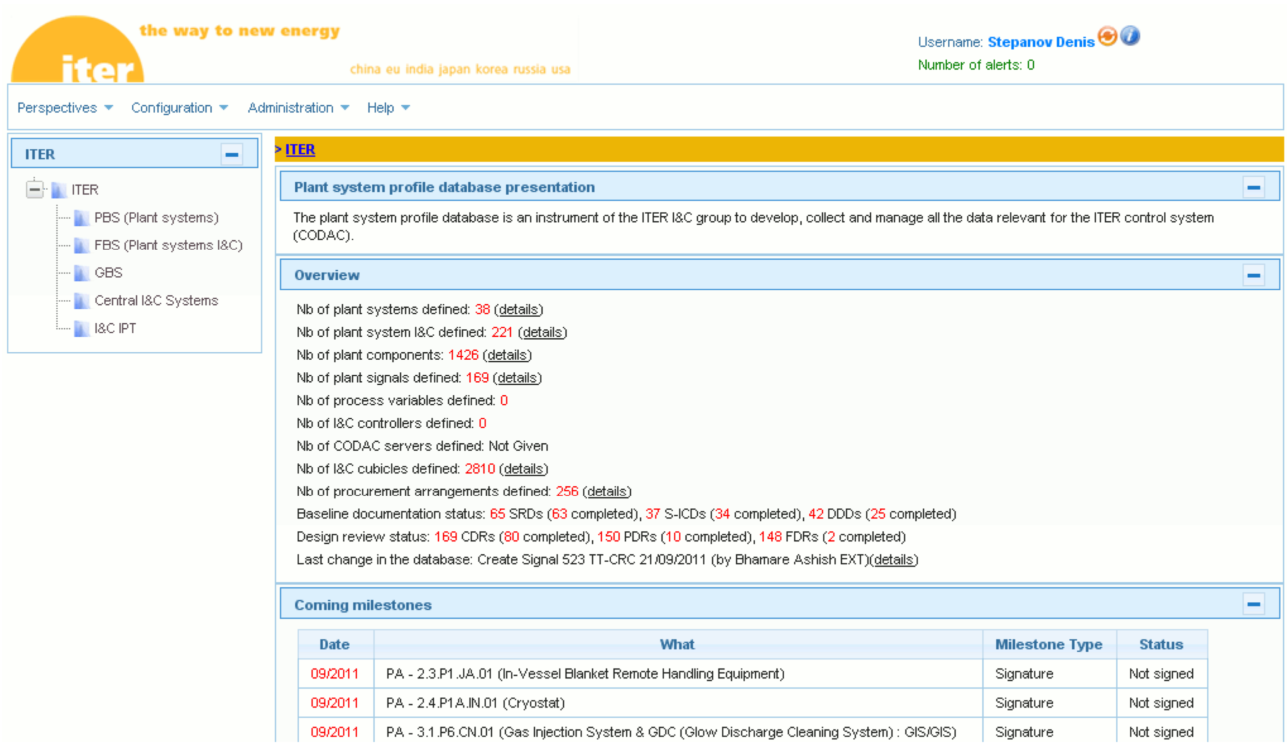


Figure 1: Plant system profile database entry page.

- PBS (Plant Breakdown Structure) perspective – seen from the point of view of plant systems;
- FBS (Functional Breakdown Structure) perspective – seen from the point of view of plant system controls;
- GBS (Geographical Breakdown Structure) perspective – seen from the geographical point of view;
- Central I&C systems perspective – view on configuration of central systems;
- I&C IPT (Integrated Product Team) perspective – organizational and administrative view.

The same object (e.g., a signal or a controller) can appear in various perspectives, with a focus on its properties valuable for that view.

The PBS perspective allows navigating through the list of plant systems and finding out which components, cubicles, signals belong to it and what are the buildings which host the plant system. It also allows entering quantitative estimations, the people responsible for the system and references to the relevant ITER baseline documentation.

The FBS perspective is focused on I&C and presents it as a tree of control functions. It is possible to see the list of functions, control units and variables belonging to a plant system I&C, or enter estimations of those. With the information entered, the database, in principle, can derive a drawing of the I&C architecture. A very simple example, based on the tokamak cooling water system specification, is shown on Fig. 2.

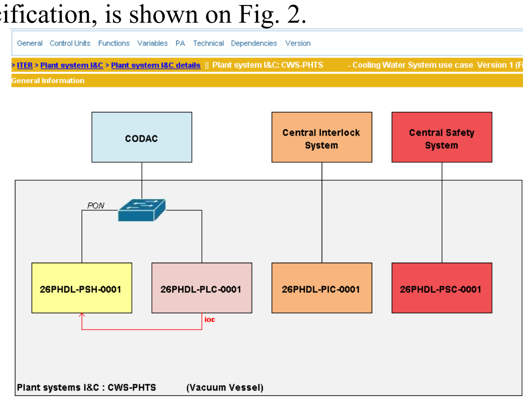


Figure 2: A sketch of a cooling water system I&C, generated by the database web application.

Here one can easily see that the plant system I&C has one slow controller (PLC) which is served by a plant system host running an EPICS Input/Output Controller (IOC). Interlock and safety controllers are equally declared. By clicking on the boxes, one can navigate to the definition of particular controller. The figures like this require zero effort from the end user and are ready to be used in various specification documents, or in presentations. One more advantage is that they use the same styles and PCDH methodology across all ITER systems.

The GBS perspective shows a map of the ITER site and allows going down to individual buildings and rooms and finding out the equipment, such as cubicles, planned to be installed there.

The central I&C systems perspective is focused on configuration of central systems. Currently it only shows the list of CODAC network nodes (“network hutches”) which interconnect different buildings. There will be more information added on CODAC special purpose networks, servers, as well as interlock and safety systems.

Finally, the I&C IPT perspective represents an administrative view on the systems. There one can learn the organizational breakdown of people assigned to work on particular systems, information on procurement arrangements, tracking of milestones and documents. One of important activities at the moment is participation of the CODAC team in various design reviews of the ITER plant system systems to make sure that I&C procurement is not forgotten and is designed according to the ITER standards. The reviews are normally structured per procurement packages and pass through different levels of maturity (conceptual, preliminary, or final design). Given the number of procurement arrangements which involve I&C (235 registered in the database at the moment of writing), one can easily understand the amount of work load incurred, which has to be properly planned and accounted. The I&C IPT perspective helps to manage this work by carefully recording all the planned or completed reviews together with the associated documents and remarks from the team.

DATA ANALYSIS AND REPORTS

In many cases it is not sufficient just to collect the I&C data; it is equally important to be able to perform data analysis and present properly certain information of interest. Topics of particular interest for ITER at this moment include:

- Analysis of plant system I&C design in order to understand and have under control the number of key I&C elements – I&C controllers, I/O boards, cubicles and to see if they respond to the envelops defined, such as footprints in rooms and areas designated to host the I&C equipment;
- Analysis of performance requirements and identification of possible bottlenecks in processing data transfer, or response times which may lead to refinement of requirements to the CODAC System or even prompt redesign of some systems;
- Tracking of the I&C design and implementation progress and comparison it with the overall project schedule in order to identify schedule slippages and take preventive measures;
- Estimations of cost of the control system based on average values of key parameters, like a cost of a data acquisition channel.

Here, different implementation approaches could be taken. Key indicators which need to be accessed daily and instantly can be built right into the web application interface, like in the case of dashboard on Fig. 1. More powerful, but less integrated way is to use a reporting services mechanism (MS SQL Server Reporting services in our case), which provides rich presentation layer and can be created relatively quickly on demand. This is a convenient way of managing reports which need to be accessed regularly. Finally, one can export data of interest into an Excel file and apply processing on his or her own, which enables full presentational power of modern office packages.

Below are some examples of reports created with the help of reporting services. Figure 3 shows a distribution of I&C cubicles among the buildings on the ITER site:

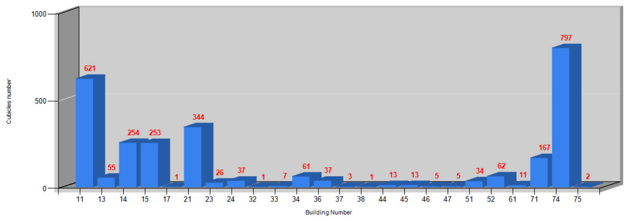


Figure 3: I&C cubicles broken down by buildings.

This graph allows grasping quickly which buildings will be the most I&C-loaded and thus will require particular investment into cabling and network infrastructure.

Another example (Fig. 4) shows a distribution of I&C-related procurement arrangements among the plant systems and the ITER domestic agencies.

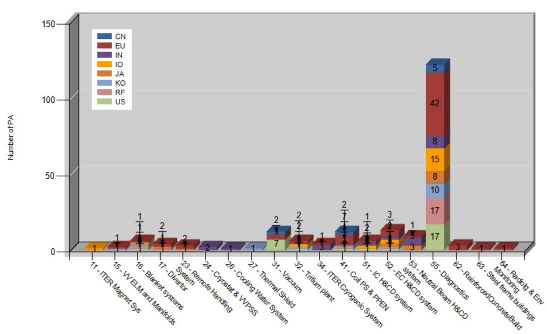
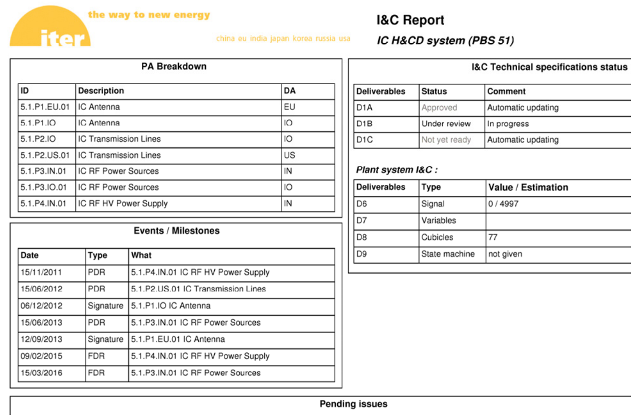


Figure 4: I&C procurement breakdown per plant system.

Finally, to support the I&C progress meetings, where the status of I&C procurement is reviewed and discussed, a specific dashboard was defined. This page, shown on Fig. 5, represents procurement organization, key performance indicators, deliverables and milestones for a given plant system and allows quick understanding whether the I&C procurement is on track and what are the particular issues that have to be resolved. The history of reports can be maintained, e.g., on a weekly basis, so one can go back in time at any given moment, or build a progress graph of key performance indicators evolving with time.



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I&C Report

IC H&CD system (PBS 51)

PA Breakdown

ID	Description	DA
5.1.P1.EU.01	IC Antenna	EU
5.1.P1.IO	IC Antenna	IO
5.1.P2.IO	IC Transmission Lines	IO
5.1.P2.US.01	IC Transmission Lines	US
5.1.P3.IN.01	IC RF Power Sources	IN
5.1.P3.IO.01	IC RF Power Sources	IO
5.1.P4.IN.01	IC RF HV Power Supply	IN

I&C Technical specifications status

Deliverables	Status	Comment
D1A	Approved	Automatic updating
D1B	Under review	In progress
D1C	Not yet ready	Automatic updating

Plant system I&C :

Deliverables	Type	Value / Estimation
D6	Signal	0 / 4997
D7	Variables	
D8	Cubicles	77
D9	State machine	not given

Events / Milestones

Date	Type	What
15/11/2011	PDR	5.1.P4.IN.01 IC RF HV Power Supply
15/06/2012	PDR	5.1.P2.US.01 IC Transmission Lines
06/12/2012	Signature	5.1.P1.IO IC Antenna
15/06/2013	PDR	5.1.P3.IN.01 IC RF Power Sources
12/09/2013	Signature	5.1.P1.EU.01 IC Antenna
09/02/2015	FDR	5.1.P4.IN.01 IC RF HV Power Supply
15/03/2016	FDR	5.1.P3.IN.01 IC RF Power Sources

Pending issues

Figure 5: Example of the I&C design and procurement status for the ion-cyclotron heating system.

CONCLUSIONS

The extensive work done by the CODAC team to support the I&C design of the ITER plant systems highlighted the need to supplement this activity with a database application. The plant system profile database, put in production in 2011, has just barely started, but already allows filing the I&C design data in a unified way and calculating useful data metrics. The work is now focused to put the entire information collected so far under the control of the database and to continue integration activities with the CODAC control software and the rest of the ITER databases.

The authors wish to thank the CODAC team and the I&C IPT for their support and suggestions which helped to define and continue to steer the development of the plant system profile database.

The views and opinions expressed herein do not necessarily reflect those of the ITER Organization.

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