A NEW DISCHARGE MANAGEMENT SYSTEM FOR THE FRASCATI TOKAMAK UPGRADE

Arturo Buscarino, Luigi Fortuna, Mattia Frasca
Dipartimento di Ingegneria Elettrica Elettronica e Informatica
University of Catania
Catania - Italy
arturo.buscarino@dieei.unict.it

Giuseppe Mazzitelli, Maurizio Panella
Frascati Research Center
Management of Large Experiment Facilities FTU group, ENEA
Frascati, Rome - Italy

Abstract

In this paper, the problem of a suitable management of settings in a tokamak machine is considered. In particular, parameters and reference signals defining a discharge in the Frascati Tokamak Upgrade (FTU) plant have to be programmed through a VAX/VMS based software platform. Aim of this paper is to present the design layout of the new discharge management platform for FTU. The proposed system is based on a MySQL repository and exploits the flexibility of XML data structure to enhance the usability of the management system. Particular attention has been given to the choice of the suitable development environment in order to produce a management system which is relevant in the view of the realization of ITER, a last generation tokamak plant.

Key words

Plasma, Tokamak, Management and Control system.

1 Introduction

The research on the possibility to extract energy, in a usable form, from nuclear fusion has gained considerable attention in the scientific community during the last decades [Braams and Stott, 2002]. Nuclear fusion, in fact, has some significant advantages with respect to nuclear fission, such as, for example, the absence of radioactive waste material and the high availability of fuel, the hydrogen. However, the technology necessary for the full functionality of nuclear fusion plants is still costly and, often, is still at the research stage. Nuclear fission is based on the principle that splitting the nuclei of the fuel material exploiting neutrons results in the release of energy. On the contrary providing the energy needed to overcome the repulsion due to electromagnetic forces, two atomic nuclei are fused into one with a lower mass and consequent emission of energy according to the well-known relation between mass and energy. Since the energy that must be provided to fuse the two nuclei is proportional to their mass, hydrogen has been chosen as the most appropriate fuel for fusion reactions, since, besides being the lightest element, it can be also easily found in nature [Braams and Stott, 2002].

In order to obtain a self-sustained nuclear fusion it is necessary that certain conditions on temperature and density, originally established by the Lawson criterion [Lawson, 1957] and subsequently by the ignition criterion [Woods, 2006], must be fulfilled. Conditions defined in the ignition criterion can be obtained using toroidal machines, known as tokamaks, where the mixture of gases (usually deuterium and tritium, derived from hydrogen) is ionized creating the so-called pulse during which the formation of plasma occurs. Through appropriate magnetic fields the plasma inside the torus can be controlled, while plasma current can be used to raise its temperature (ohmic heating), triggering the fusion. Other methods of plasma heating are based on radio frequency devices [Woods, 2006].

The only Italian tokamak currently operative is the Frascati Tokamak Upgrade (FTU) located in the laboratories of the National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA) in Frascati (Rome). FTU is a high magnetic field and high particle density reactor with plasma heating systems based on radio frequency devices, where it is possible to study plasmas in specific experimental conditions. Currently, FTU is the reference plant in Italy for the study of nuclear fusion reactions in toroidal machines and it is considered of great interest also in the view of the forthcoming implementation of the International Thermonuclear Experimental Reactor (ITER). FTU can be considered, in fact, as a useful alternative for benchmark activities. In particular, new structural configurations and design techniques for next generation tokamaks can be implemented and tested.

Under this perspective, the existing FTU experiment management system, should be re–designed in the view of an ITER–relevant implementation. In this paper, the project layout of the new FTU discharge management system is presented, with particular attention to the structure of the underlying repository.

The paper is organized as follows: in Section 2 the operations related to the Discharge Manager Systems (DMS) are briefly reported, while in Section 3 the proposed ITER–relevant implementation is described. Finally Section 4 draws some concluding remarks and outlines the predicted implementing issues.

2 Operativity of the DMC

Before the actual experimental phase is started on the FTU, the user has to off–line define a set of parameters and analog reference signals, representing the so–called *discharge*. These values, which set up the pulse, have to be chosen according to specific constraints given by the physical limitation of the FTU. Hence, in order to avoid damages to the tokamak structure a discharge has always to be validated verifying a series of physical properties on currents, field intensities and temperatures. Once the discharge is validated, settings can be spread to the various FTU control systems. More in details, a discharge is created selecting the desired value for the controllable parameters and for a set of time–value pairs defining reference signals. These settings are stored in a series of files saved in a common network file system (NFS) folder which will be accessed by the control units of the FTU. This means that each validated discharge is associated to a folder, i.e. the DMS is based on a file repository.

The validation procedure follows five steps:

- check the feasibility of the fixed set of parameters and reference signals;
- calculate the maximum values for coils temperatures with respect to the settings;
- calculate the maximum values for currents;
- calculate the activation and de–activation time for transformers, toroidal and poloidal fields and switches;
- calculate voltages for commutation capacitors.

If the discharge is feasible and all parameters and reference signals are correctly calculated, the DMS provides the corresponding files and stores them in the common folder from which the control units will collect the settings.

All the operations performed by the DMS are currently implemented on a VAX/VMS platform. This choice has been performed according to the specific control and measurement systems, based on LeCroy CAMAC modules, adopted in the FTU design. Furthermore, the idea of using a file–based repository for validated discharges is a strong limitation for the user: querying and selection functions on parameters, in fact, are not directly allowed and it is not possible to retrieve pulse settings starting from previously obtained results.

3 The new DMS project layout

In order to enhance the flexibility of the discharge management, a new DMS for FTU has to be designed. The project of the new DMS is based on a MySQL repository [MySQL] and follows the layout shown in Fig. 1.

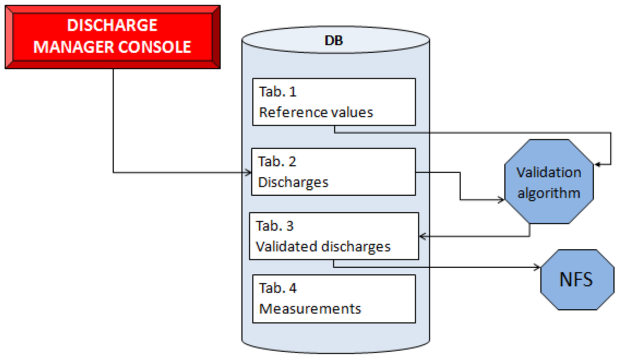

Figure 1. Layout scheme of the new Discharge Management System based on the MySQL Database.

The database (DB) is formed by four tables:

- **Table 1** contains the fixed parameters which define the FTU geometry and constitutive limits (these values will be used for the discharge validation process);
- **Table 2** is accessed by the user interface to store the discharge as defined by the operator prior to validation;
- **Table 3** contains the validated discharges;
- **Table 4** contains results and measurements acquired from the field during the pulse.

Each table is described by the same four fields:

- **Identifier** - table primary key, used for indexing;
- **TimeStamp** - entry creation time and date;
- **Sender** - operator or software module which creates the entry;
- **XML data** - XML text block.

The XML (eXtensible Markup Language) data field contains all the information related to each entry following the data structure definition contained in the appropriate XML schema. At each Table is associated a specific XML schema, except for Table 2 and 3 in which data follow the same schema. The DB has been implemented using InnoDB [INNO DB] and a MySQL environment in which advanced XML querying functions are available, allowing to perform analysis, classification, and filtering operations directly on XML data, reducing significantly the execution time of discharge selection and of the validation algorithm.

More details should be given about the XML schema used in Table 2 and 3, which identifies a discharge. In particular the following fields are defined:

- **dischargeID** - identifier of the single discharge and, thus, the parameter set;
- **dischargeTime** - time and date of the last change;
- **dischargeScalarParameter** - list of free and constrained scalar parameters;

dischargeAnalogReferences - list of time–value pairs defining the analog reference signals;
dischargeAliasNames - list of names identifying the same discharge;
dischargeOwners - list of operators who create the same discharge;
dischargeDescription - text containing a short description of the discharge.

As concerns the software modules, a graphical user interface (GUI) allows the operator to access the database and set the discharge. The GUI is based on the Control System Studio (CSS) suite [CSS], a collection of monitoring tools specifically designed for the accelerator community. CSS exploits the Eclipse [Eclipse] platform, an open–source development platform collecting tools and routines for managing software. The CSS adopts a Java-based language and, exploiting the Java DB Connector (JDBC) [JDBC], can be easily linked to the MySQL repository. This choice provides several advantages, in particular it allows to design a DMS compliant with the EPICS (Experimental Physics and Industrial Control System) standard adopted in the design of ITER.

Furthermore, CSS can be linked to user–defined libraries. The validation procedure can be, thus, implemented in a language more suitable for the mathematical calculation needed to obtain the validated discharge. As a new feature, the validation algorithm, exploiting the MySQL repository structure, will be able to compare the validated discharge with those previously validated and to merge identical parameter sets, maintaining trace of the different alias names. Furthermore, the link between Table 4, which contains measurements and results obtained from the tokamak, and Table 3, in which validated discharges are stored, allows the user to create a new discharge starting from results obtained by a previously recorded pulse.

4 Conclusions

In this paper, the project layout of the new discharge management system for the FTU has been introduced. The proposed implementation is based on a new specifically designed MySQL database which allows to manage, retrieve and manipulate the discharge setting in a fast and efficient way.

The definition of suitable data structure will overcome the drawbacks of the current DMS. Moreover, the completely renewed user interface is based on the Control System Studio, a development platform adopted in the design of ITER control systems, and, thus, allows the realization of an ITER-compliant management system.

References

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Eclipse - more information available on http://www.eclipse.org

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