ANALYSIS OF THE CONTROL SYSTEM OF ICE, THE INSULATION AND COOLING TEST FACILITY FOR THE DEVELOPMENT OF THE ITER NEUTRAL BEAM INJECTOR*

O. Barana[#], M. Breda, M. Moressa, C. Taliercio, P. Agostinetti, P. Barbato, M. Boldrin, F. Fantini, F. Fellin, A. Luchetta, W. Rigato, A. Rizzolo, Consorzio RFX, Padova, I-35127, Italy

Abstract

Consorzio RFX will host two experimental devices to address the main issues of the ITER heating neutral beam injectors: SPIDER (Source for the Production of Ions of Deuterium Extracted from Rf plasma), an ion source at low acceleration voltage (100 kV), and MITICA (Megavolt ITer Injector and Concept Advancement), a neutral beam injector at 1 MV. ICE (Insulation and Cooling Experiment) is a test facility developed at Consorzio RFX to tackle significant SPIDER and MITICA technological aspects that require a preliminary study. The ICE control system is mainly based on commercial off-the-shelf products. It is composed of four local units: automation and monitoring, supervision, data handling, and communication. The automation and monitoring unit is based on Siemens PLC technology. The supervision unit relies on the commercial PVSS-II SCADA system that is widely used at CERN. The data handling unit, the only part of the ICE control system not based on industrial products, extends the functionalities of MDSplus, a framework for the management of scientific data. The communication unit comprehends the network infrastructure and the timing system. The paper presents the ICE control system, its local units and the main performance and operational requirements.

INTRODUCTION

A new test facility, PRIMA (Padova Research on Injector Megavolt Accelerated), to be built at the fusion research centre Consorzio RFX (Padova, Italy), will host two new experimental devices with the purpose of addressing the main issues of the ITER heating neutral beam injectors [1]. These experimental devices are SPIDER (Source for the Production of Ions of Deuterium Extracted from Rf plasma), an ion source at low acceleration voltage (100 kV), and MITICA (Megavolt ITer Injector and Concept Advancement), a neutral beam injector with an acceleration stage of 1 MV. ICE (Insulation and Cooling Experiment) [2] is a new test bed designed at Consorzio RFX in order to preliminarily investigate critical SPIDER and MITICA technological aspects never tackled before: high-voltage insulation breaks and high-heat-flux water cooling. Another purpose of ICE is to test a prototype SCADA (Supervisory Control and Data Acquisition) system and a prototype continuous data logging system, in view of the realization of the SPIDER and MITICA control and data acquisition systems.

This paper analyses the ICE Control System (ICS) and is structured in the following way: the ICE and ICS breakdown structures; the control architecture, together with the local unit description; performance and operational requirements; conclusions.

BREAKDOWN STRUCTURES

The ICE breakdown structure is composed of six levels. This subdivision is also relevant for assigning names to components and signals. The basic components lie at the 5th level; a group of components functionally related constitute an elementary unit (4th level); a group of elementary units with a specific purpose constitutes a local unit (LU – 3rd level); a set of LUs functionally related constitutes a subsystem (2nd level); all the subsystems form the plant system (1st level). The 6th level is related to instrumentation and control (IC – signal level).

Five subsystems form ICE. The subsystems concerning the test bed equipment are four: experimental insulation (XI); experimental cooling (XC); technical supplies (TS); interlock and safety (IS). ICS, which can be considered a further, virtual subsystem, is subdivided into four LUs: automation and monitoring (AM); supervision (SU); data handling (DH) and communication (CO). Fig. 1 shows the current ICE layout. The XI, XC and TS subsystems are highlighted. The equipment non delimited by a line belongs to TS.

CONTROL ARCHITECTURE

The block diagram of the ICS architecture is represented in Fig. 2. The four main subsystems are depicted at the bottom. All of them are interfaced with ICS through the AM/Subsystems interface, which comprehends three kinds of interface: Physical input/output (I/O) interface for the signals exchanged through analogue/digital I/O cards; Profibus PA interface, for the signals exchanged through PA Fieldbus Network (PA-FN, Profibus [3] PA); Profibus DP interface, for the signals exchanged through DP-FN (Profibus DP).

The core of ICS is the Master Controller (MC), which is responsible for the process control and monitoring. On the field side, all the signals exchanged between MC and the plant equipment eventually transit on DP-FN, even if they originate from different sources.

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[#] oliviero.barana@igi.cnr.it

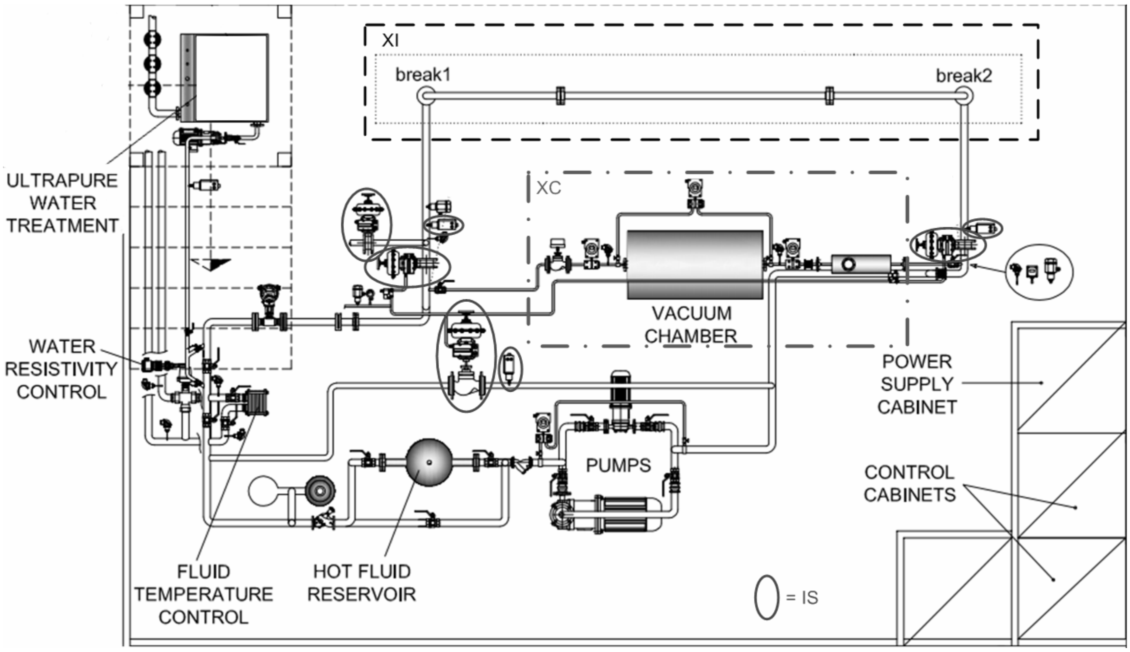

Figure 1: Layout of the ICE test bed.

MC exchanges signals with the Central Level through the so-called PLC (Programmable Logic Controller) Network (IEEE 802.3 Ethernet [4]) and the IC Bridge. The Central Level hosts workstations devoted to plant supervision and data management; the Control System Network interconnecting them is also IEEE 802.3 Ethernet. A workstation manages the supervision task and hosts an OPC (Object Linking and Embedding for Process Control [5]) server used as software interface with DH. Another workstation hosts an NTP (Network Time Protocol) server, used to dispatch an absolute time reference, and a DH thread (see below).

Automation and Monitoring Local Unit

AM embodies the hardware devoted to the ICE control and monitoring from an industrial point of view. It also manages the acquisition of data from the field. AM consists of MC and of a distributed periphery. Siemens PLC technology has been used at Consorzio RFX since many years and is also the ITER choice for industrial-type control. This is the rationale behind the choice of using hardware and software from Siemens for ICS too. MC is a SIMATIC S7-400 series PLC and equipped with Ethernet and Profibus-DP ports. The distributed periphery is basically managed by two SIMATIC ET200M interfaces (the Profibus DP interface in Fig. 2). Only a small amount of signals, exchanged between MC and the equipment, does not transit through the aforementioned interfaces but travel directly on DP-FN.

Supervision Local Unit

SU is basically constituted by a server workstation and one or more client PCs running PVSS-II, the SCADA package from ETM [6], which will be used to visualize the equipment state, the setting of the plant parameters, and the alarm and event handling by means of customized user interfaces (UIs). PVSS-II is multiplatform, but the server workstation is equipped with Microsoft Server 2003 as operating system, since it runs the OPC server.

PVSS-II was chosen because it is a SCADA package widely used at CERN. The experience gained using this software will be very useful in view of the final decision about the SCADA package to be used for SPIDER and MITICA.

Data Handling Local Unit

The purpose of DH is to handle and store data and to manage their recall for visualization and analysis. MDSplus [7] is the system for data management currently used at Consorzio RFX and one of the most used in the nuclear fusion community. A new MDSplus functionality, which exploits the possibility of storing time-segmented records, is used in order to provide continuous data acquisition, as required by ITER. DH stores data in a pulse file using the new “data appending” feature. Therefore there is just one pulse file per day, where data can be retrieved by means of their time interval.

A Java DH thread, running on a Linux workstation, is devoted to collecting data from the OPC server and sending them to a remote mdsip [7] server hosted on a storage station (see also Fig. 2). The mdsip server is also used to recall data for post-pulse analysis and visualization.

Communication Local Unit

This LU is basically constituted by the network infrastructure: the communication networks and the IC Bridge. The communication networks are the aforementioned FNs, the PLC Network and the Control System Network. The IC Bridge is an off-the-shelf

Ethernet switch (Hewlett-Packard ProCurve 2510 [8]). The NTP server, hosted on the Linux workstation and devoted to the timing, is also part of CO.

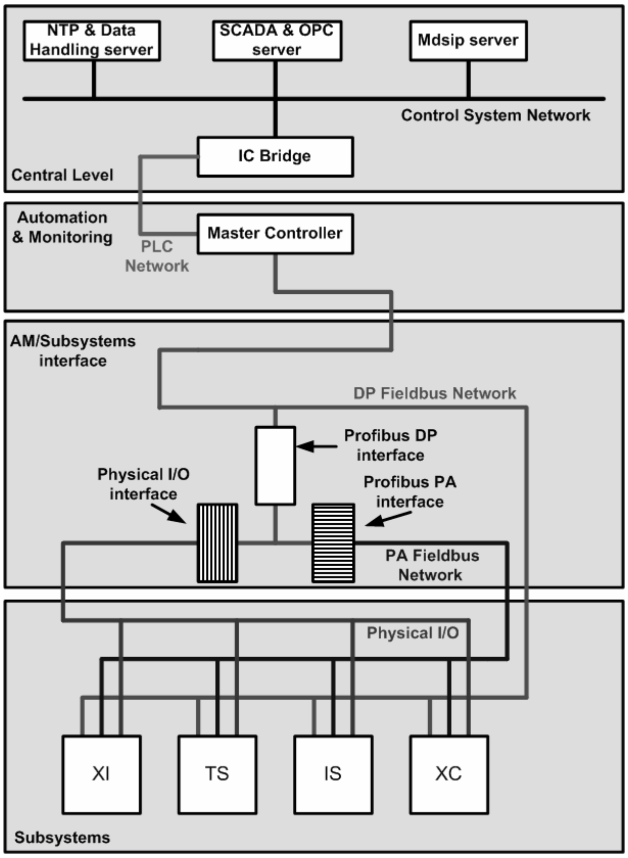

Figure 2: Block diagram of the ICS architecture.

REQUIREMENTS

The ICS architecture is the result of its functional, performance, operational and interlock and safety requirements. It is interesting to have a look at the main performance and operational requirements.

Performance Requirements

ICS has been designed to handle ICE experiments with duration of up to 28800 s (8 hours). It has to guarantee a minimum control cycle time of 100 ms and to provide the possibility of real-time feedback control with a maximum frequency of 10 Hz. ICS has to distribute a low-accuracy absolute time with accuracy of the order of some milliseconds (through the NTP server).

On the data acquisition side, ICS will handle the acquisition of: a) about 100 analogue signals with a maximum frequency of 2 Hz, producing a data logging throughput of about 2.4 kB/s (i.e. 4 bytes per signal plus 8 bytes for the associated time stamp); b) about 200 digital signals with a maximum frequency of 2 Hz, producing a data logging throughput of 3.25 kB/s (considering also the 8-byte time stamp for each signal).

ICS has also to supply a refresh of data on the UIs with a frequency of at least 1 Hz.

Operational Requirements

The ICE operation states are *OFF* and *Running*. In normal-operation conditions ICS is always in the *Running* state and has to maintain the equipment within its operating limits and conditions.

Three levels of access to the SCADA UIs were foreseen: a) root, when the user is allowed to implement any kind of modification, to change all the parameters and to force values in real time; b) operator, when the user is allowed only to change experiment-relevant parameters; c) viewer, when the user is only allowed to monitor the state of the ICE equipment.

Since ICE is a standalone plant with just one controller, no distinction between local control mode and remote control mode was implemented. ICE will be always in ICE control mode, which allows to operate either locally, close to the equipment, or from a remote control station. An interlock, to prevent simultaneous operations locally and remotely, will be implemented.

Manual operations are allowed both outside the normal conditions, for test and commissioning purposes, and in the *Running* state, but only performed by a user with root-level access and only in special cases.

Recipes will be used as far as possible so as to standardize the parameter-setting phase and reduce the possibility of human errors.

CONCLUSIONS

The development and implementation of ICS is very important in order to be able to evaluate the PVSS SCADA package and to test and ameliorate the new MDSplus continuous data acquisition feature in view of the development of the SPIDER and MITICA control systems.

The ICS design phase is already terminated as well as the set-up of the control cabinet and of the SCADA workstation. The next steps will be the development of the SCADA, PLC and DH programs and the preliminary test of the field signals.

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