IFMIF EVEDA RFQ LOCAL CONTROL SYSTEM TO POWER TESTS

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Abstract

In the IFMIF EVEDA project, normal conducting Radio Frequency Quadrupole (RFQ) is used to bunch and accelerate a 130 mA steady beam to 5 MeV. RFQ cavity is divided into three structures, named super-modules. Each super-module is divided into 6 modules for a total of 18 modules for the overall structure. The final three modules have to be tested at high power to test and validate the most critical RF components of RFQ cavity and, on the other hand, to test performances of the main ancillaries that will be used for IFMIF EVEDA project (vacuum manifold system, tuning system and control system). The choice of the last three modules is due to the fact that they will operate in the most demanding conditions in terms of power density (100 kW/m) and surface electric field (1.8*Ekp). The Experimental Physics and Industrial Control System (EPICS) environment [1] provides the framework for monitoring any equipment connected to it. This paper reports the usage of this framework to the RFQ power tests at Legnaro National Laboratories [2,3].

INTRODUCTION

The RFQ Local Control System (LCS) Architecture approved by the IFMIF-EVEDA Collaboration is designed to optimize reliability, robustness, availability, safety and performance minimizing all the costs related to it (purchase and maintenance). Following this philosophy and the IFMIF-EVEDA Guidelines, we realized a control system network composed by two different kinds of hosts:

- Physical machines for critical control system tasks;
- Virtual hosts in machines where no particular functional task or hardware is required.

The architecture realizes the 3-layer structure described in the Guidelines and each layer defines a proper hosts group (equipment directly connected to the apparatus, control devices, Human-Machine Interface) while the EPICS framework provides the interface between them.

LCS CORE SYSTEM

The core workstation server provides capabilities that enable controls engineers to deploy customized environments for their application perfectly aligned with the "Common Software Guidelines". All the regular EPICS services, are backed up regularly and can be moved and cloned easily. Key enabling technology for this is the virtualization and the provisioning; this approach allows the installation saves floor space, power and cooling.

In the IFMIF-EVEDA RFQ LCS, Logical Volumes are used to define main server's partition table and the virtual hard disks used to realize virtual hosts. In this way, it is possible to manage any resourceful saturation in according to the free resources provided by the main server. Because of the role covered by the server, all the unnecessary services and ports are switched off following an hardening policies to keep safe as much as possible the control system.

Archiver

The Channel Archiver is an archiving tool-set for EPICS based control systems. It can archive any kind of record available through the EPICS Channel Access. The deployable Archiver prepared into the manager server is ready to use. The retrieving interface is based on Control System Studio (CSS) framework. After the commissioning, this archiver will be switched off and replaced from the central one available from the Central Control System (CCS).

Figure 1: RFQ LCS Racks for Power Tests.

Deploy and Backup

In any control network, cases of hardware failure or breakdown can be very dangerous, especially in the case of infrastructure similar to the IFMIF facility. The need to restore the controls functionality in the shortest time is therefore fundamental. The manager machine is designed to realize an automated management for new machinery's configuration inside the RFQ LCS. In particular, it is possible to connect a new device to the network, indicate which type of play rule it must realize and the network itself will auto-configure it. The manager host uses dedicated open source software for provisioning the entire control system network, while backup service saves

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through proper customized scripts the principal files of interest associated with the main machineries (physicals and virtual) available in the LCS.

Surveillance

In a critical system like the RFQ LCS, administrators should be constantly updated on this state and must be able to intervene promptly if required. In the local control network an open source solution was chosen to perform this task: it provides computer system monitor and network monitoring software application. LNL developed a plugin that allows state supervision of EPICS Process Variables in a control network[4]; this involves the possibility to monitor both the EPICS control system network and the computer network. The entire network can be controlled through a proper web interface and, in case of warning or critical problem, email notifications are sent to the system network administrators.

Project Management Documentation Server

Software projects become larger and more complicated; set up of agile project management methods to realize an effective software configuration management (SCM) environment improve both quality and productivity. With this target the RFQ LCS development it's managed and documented using these tools, which are widely used and recognized in Open Source development.

- Bugzilla is a "Defect Tracking system" based on MySQL and managed by a regular web browser;
- Wiki service is provided by MediaWiki, the largest used wiki which provides the engine of the famous Wikipedia. MediaWiki uses MySQL and Apache;
- Subversion server will contain all software development usually, but can be used to manage the revision of document like this one. A nice server named WebSVN has been setup to have the access of SVN by web pages.

EPICS softIOCs Virtual Server

In subsystem where the acquisition rate is the most critical requirement or where dedicated devices must be integrated, the control system is developed directly in EPICS. To realize and manage the IOCs particular hardware is not required, a properly configured virtual machine equipped with the entire EPICS environment is developed; in this way system administrator have a centralized server to supervise. This machine is created for having two tasks:

- Realize a EPICS IOC for every device and system which require it
- Provide a Boot Server for the VME system in charge of realize the RF acquisition

LOCAL CONTROL SYSTEM

The RFQ system is complex apparatus composed by many kinds of subsystems (radio frequency, vacuum, water cooling, etc.) developed using different hardware solutions. As consequence, every part of this structure must be properly integrated to obtain the desired degree of control. Following these criteria, the system has been designed and realized using these assumptions:

- PLC hardware is chosen in tasks where security is the most critical feature;
- VME system is used where the acquisition speed rate is crucial;
- Common hardware (such as embedded systems) is chosen when only integration is required.

In Figure 2, it is possible to observe that for every subsystem a particular solution based in one of the three assumptions mentioned above is adopted. The LCS could be resumed by the following functionalities:

- RF signal generator;
- Fast acquisition system for the RFQ cavity power;
- Surface Temperature Monitor (STM) system;
- Bunch length monitor system;
- Vacuum system;
- Cooling system;
- Machine Protection System (MPS)
- Personal Protection System (PPS).

To drive the 220kW RF Amplifier, used during the power test, a RF signal generator is necessary. For this reason an EPICS driver was written to integrate that.

The fast acquisition is based on VxWorks real time OS which run over a VME architecture. The most important signals about RF power are sampled with a maximum rate of 1MEvents/s. To perform the automatic calibration of the acquisition channels a useful tool was developed.

The surface working temperature of a RFQ has never been analyzed before on other RFQs; we will map the temperature distribution along the RFQ with a high defined mesh, saving economic and wiring efforts. To this purpose 1-Wire® devices [2] provide simple and cheap technology; a dedicated EPICS driver was developed to integrate them. We will use 96 sensors for the high power test and 432 for the entire RFQ.

IFMIF-EVEDA requires a system to measure the micro bunch length. A slim embedded solution with the needed ADCs/DACs is enough to this measure.

Vacuum, Cooling, MPS and PPS functionalities are realized by PLCs while the EPICS framework is in charge of graphic user interface (GUI), archiving and alarm managements.

The vacuum control system is already done; PLC software and GUI, developed in CSS, was fully tested on the high power test vacuum system, which is composed by 1 of the 10 RFQ's pumping stations.

The cooling system will be used on RFQ cavity with the double purpose of power removing and frequency tuning by means of an extremely precise water temperature control. Five different working modes have been implemented on PLC's SW to satisfy all the required combination of these control functions.

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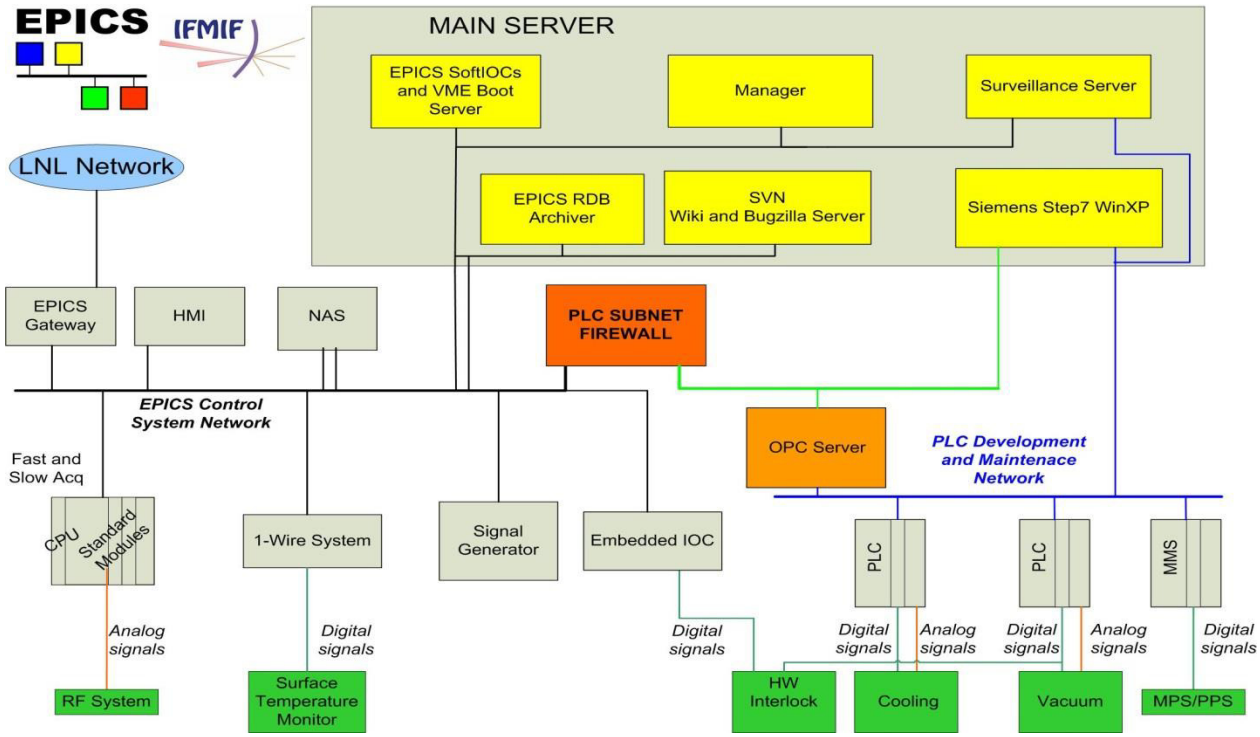

Figure 2: Control System Architecture for IFMIF EVEDA RFQ power tests.

PPS, for area access management, and the slowest part of MPS are in charge of a: SIEMENS® modular safety system (MSS) [5] which is SIL3 compliant. PPS and MPS main task is to stop the RF amplifier in case of any abnormal condition. PPS and MPS functionalities have been fully tested before the RF couplers high power test.

The Graphical User Interface (GUI), developed in CSS, is composed by a set of panels which let scientists to remote control the apparatus. Main panel give the global view of the experiment, while specific panels and pop-up windows, divided according the subsystems, give detailed information. A remote control using a mobile smart phone has been already tested. A dedicated machine host the EPICS Archiver which stores the data used by scientists. Under EPICS environment, there is almost one EPICS database for every subsystem, except for the mathematical side, which is composed by a set of database where each one performs a particular calculus.

The following table resumes the size of the whole EPICS application realized.

Table 1: Summary of EPICS Application Size

Objects	Numbers
Server EPICS	3
IOCs	8
Databases	24
Process Variables (PV)	2173
PV Archived	ca. 600
GUI Panels	27

CONCLUSIONS

Preliminary tests on the singular control system tasks are done with positive results. During RF Coupler High power test the main part of LCS, with exception of vacuum and cooling system, was utilized. Subsystems connected to RF signals generation and acquisition have been widely used and appreciated. Because of the importance of the power tests for the RFQ apparatus, this is a great test-bench for the entire control system architecture and a good feedback for the work realized.

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