IMPLEMENTATION AND OPERATION OF THE ELETTRA BOOSTER CONTROL SYSTEM

M. Lonza, F. Asnicar, L. Battistello, S. Fontanini, V. Forchi', G. Gaio, F. Giacuzzo, E. Mariotti, R. Marizza, R. Passuello, L. Pivetta, C. Scafuri, G. Scalamera, G. Strangolino, D. Vittor, L. Zambon, Sincrotrone Trieste, Trieste, Italy

Abstract

A new injector based on a 100 MeV linac and a 2.5 GeV booster synchrotron has been built and commissioned at Elettra to provide full-energy and top-up injection into the storage ring [1]. The booster replaces the 1.2 GeV linac that will be used for the new 4th generation light source FERMI@Elettra currently under construction at Elettra [2].

A new architecture has been adopted for the booster control system based on the Tango software. The implementation of the control system and the tools developed to meet an aggressive commissioning time schedule are presented. The experience gained during the operation of the booster is also discussed.

INTRODUCTION

Since the commissioning of the accelerator in 1993, Elettra has been operated by injecting electrons into the storage ring using a 1.2 GeV linac. After the injection an energy ramping procedure allowed to bring the electron beam up to the final energy of 2 or 2.4 GeV. The demanding requirements for full energy injection and the possibility to reuse the existing linac for the FERMI@Elettra free electron laser, has lead to the decision of building a new injector based on a booster synchrotron. The civil works for the construction of the booster injector, which is placed in the inner part of the storage ring building, started in September 2005, while the first components of the accelerator have been installed in April 2007. After the commissioning of the booster, followed by a period of machine shut down to link the new injector and the storage ring, Elettra was able to provide again photon beams to the beamlines on the beginning of March 2008.

The existing Elettra control system operating since 1992 is based on obsolete technologies. For the booster control system a complete review was necessary starting from the choice of hardware platforms, operating systems and control software. The new control system, which is based on the Tango toolkit, will also be the basis for future developments at the Elettra laboratory, including FERMI@Elettra and possible upgrades of the existing control systems.

CONTROL SYSTEM ARCHITECTURE

The booster control system is based on a two-tier distributed architecture relying on an Ethernet network, where the first level is represented by field computers, called Equipment Controllers (EC), physically interfaced to the accelerator equipment, and the second level is made by control room consoles and servers [3]. The ECs are diskless VME crates equipped with Motorola PowerPC CPU boards, while consoles and servers are standard Intel-based PCs. A homogeneous software environment made of the GNU/Linux operating system and the Tango control system software running on all of the computers is the basis for the development of control applications. The Linux real-time extension RTAI (Real Time Application Interface) has been used in those computers running applications that require deterministic performance. Programmable Logic Controllers (PLC) with Ethernet interface have been employed for systems requiring robustness and reliability.

The booster data network is an extension of the storage ring network, which has been upgraded in 2001. A number of peripheral switches with 1Gbit/s fibre optic uplinks have been installed close to the field computers in order to minimize the length of the final copper cables. A wi-fi network provides wireless connection in all of the accelerator and equipment areas.

IMPLEMENTATION DETAILS

A large number of devices with several kinds of interfaces have been integrated into the control system. Examples of the most used interfaces are Ethernet, RS-232, GPIB, fibre optics, CANbus, digital and analog signals, etc. Interface hardware includes VME I/O boards, IP and PMC modules.

Each physical device has been modelled and a Tango device server providing the functionalities required for that device has been developed and deployed in the ECs. A number of Tango device servers were already available from the Tango community, ready to be used or requiring minor changes.

A general purpose sequencer has been developed using the Tango framework to coordinate complex actions according to a pre-defined execution scheme and timing. It is configured by a XML file where all actions, execution parameters and logics are defined. The sequencer has been employed, for example, to automate the switching on/off sequences of the linac RF plants.

A total number of 30 ECs have been installed for the booster control system: 3 for linac RF plants, 8 for magnet power supplies, 9 for diagnostics and timing, 4 for vacuum, 3 for injection/extraction and 3 for booster RF plant and distribution.

The RF plant and the injection/extraction systems have been interfaced using direct digital and analog I/O signals. Due to the high number and density of signals provided by IP modules, dedicated connection boxes have been

developed featuring signal conditioning, test points and status LEDs.

A large number of RS-232 serial lines have been used to interface various types of devices. A VME rear board developed in house provides clear connections and electrical insulation between multi-channel serial IP modules and the controlled devices.

In order to guarantee a protected environment and an exclusive access to the hardware, whenever a group of Ethernet based devices had to be controlled, a local network switch, connected to the second Ethernet port of the EC CPU board, has been used. A dedicated Tango device server for each physical device runs in the EC. This is the case, for example, of some groups of power supply controllers and of the booster beam position monitors.

The booster ring is not segregated in a shielded tunnel but shares the same technical gallery with the electric and electronic equipment. In order for a person to enter this area the beam must be switched off and a controlled access has to be carried out. For this reason special care has been put to improve the reliability of the control system and enhance remote diagnostics of the equipment. All of the VME crates are equipped with redundant power supplies and a monitoring module with Ethernet interface that allows for reading state, voltages and temperatures of the VME crate, and sending reset commands from remote. Moreover, one terminal server for each group of ECs has been installed to provide remote access to the console serial line of the CPU boards.

PLC BASED SYSTEMS

Equipment Protection System (EPS)

The EPS is designed to efficiently and reliably protect machine components and systems from damage. Controlled systems include linac RF plants, vacuum and cooling water systems.

The EPS is based on a Siemens S7 PLC and on 15 distributed I/O peripherals connected via Profibus. The PLC communicates with the control system through an Ethernet interface using the TCP/IP protocol and a dedicated Tango device server. Control room applications for the operator consoles (graphical panels, synoptics, alarms, archiving, logging, etc.) have been implemented using the Tango tools. In addition, small operator panels equipped with LCD touch screens for local control have been installed in the machine technical gallery.

Personnel Safety System (PSS)

The PSS protects personnel from radiation hazards by controlling access to potentially dangerous areas. Whenever an anomalous or dangerous situation is detected it switches off the electron beam and prevents it from being restarted until the danger has been removed.

The PSS architecture is similar to that of the EPS but, given the extremely high level of safety required, stricter procedures have been adopted in its design [4]. Fail-safe versions of PLC (Siemens S7 315F), fieldbus (Profisafe)

and I/O peripherals have been utilized. Component redundancy and diversification is implemented whenever possible.

A graphical supervisor running in the control room consoles provides operators with comprehensive information on the state of the PSS, including ongoing accesses and search procedures, as well as with significant details of every controlled device and of the PLC internal state machine.

Sulfur Hexafluoride (SF6) Gas System

A system for the distribution of the SF6 to the linac wave guides has been supplied by an external company and is completely controlled by a Siemens PLC system developed in house. It monitors the correct distribution of SF6 gas, manages the refill procedure, reacts in case of anomalous situations and generates interlock signals for the protection of linac components. The SF6 system can be controlled either by means of a local LCD touch screen or, through its Ethernet TCP/IP interface and a Tango device, from a graphical synoptic panel in the control room.

CONTROL ROOM APPLICATIONS

More than 150 control room applications have been developed. Most of them are graphical control panels dedicated to a specific device; they allow complete control of the device and provide extensive diagnostics information. This type of panels has been extremely useful during the commissioning phases of the new injector. A hierarchical browser panel allows the operators to look for and start the required control panel.

All the control room graphical applications are based on the Qt widget library [5]. On top of the Qt widgets a library of Tango-aware components known as QTango has been developed. This library handles the most common functionalities for building control panels, like device proxy, event subscription, polling threads, error logs, etc. The QTango library has also been integrated in the standard QtDesigner tool. By means of QtDesigner the developer graphically draws a control panel and then declares the connections to the field variables. The availability of the QTango library allowed for an extremely fast development cycle.

In addition to simple control panels, a number of dedicated applications for handling more complex operations have been developed. Some examples are described below.

SaveRestore is an application for taking snapshots of a set of control variables and saving them in a database. The snapshot can then be used to restore the same working condition. The SaveRestore application is based on the "snap" database developed under the Tango collaboration.

GenericTool is a dynamically configurable control panel for operating on groups of homogeneous devices. The configuration is performed at runtime by passing a list of devices, variables and commands. For example, it is possible to configure a panel to open/close all the

vacuum valves of the linac or to switch on and set the current of all the corrector power supplies of the booster.

Machine physics applications are based on a set of machine modelling and optics calculation libraries which transparently handle the interaction with the control system [6]. The graphical user interface of the machine physics programs is also based on the Qt library.

In addition to control room graphical panels, web interfaces have also been developed to access control system data from remote locations.

DEVELOPMENT AND COMMISSIONING EXPERIENCE

The booster control system is made of more than 800 running Tango devices, belonging to 104 different classes, and about 220 server processes.

A good design of the Tango devices is very important for allowing a fast and easy assembly of a complete and well integrated control system. For example, the design must put as much logic as possible into the device, instead of putting it in the client side, and present the data in a meaningful format with standardized units of measure.

The use of Tango abstract devices [7], i.e. common interface patterns for similar devices, proved to be useful also after the development phase. Thanks to the use of abstract devices defined for all of our power supplies, we were able, for example, to replace a faulty power supply with another one of a different supplier having a completely different software interface with no modification of control room applications. The only action required was the reconfiguration of the Tango database.

All the software resources of each application (source files, configurations, installation scripts, etc.) are stored in a central repository. We use Concurrent Version System (CVS). With CVS we keep track of all the releases and patches of the evolving applications.

For the commissioning phase, the booster control system consoles and servers have been kept separated from the Elettra ones. Successively, they have been unified. This operation has been carried out at the beginning of May 2008. The merging of the two original Tango databases has been done by means of a set of SQL scripts.

Most of the booster control system applications have been written in C++ language. However, Tango gives the possibility of writing control application in other programming languages. We currently use Matlab and Python. Both are interpreted languages, which allow shorter development times. We found these environments very useful and productive for performing complex measurements and to provide quick solutions to control problems which were encountered during commissioning.

STATUS AND OUTLOOK

After the commissioning of the new injector and the subsequent set into operation of the whole accelerators complex, a phase of further optimization aims at the achievement of the booster nominal performance. The main problems are related to the booster bending magnet power supplies that don't allow at the moment a reliable and stable operation at the nominal energy and repetition rate. For this purpose a refurbishment program of the power supplies is underway and is foreseen to be completed in August 2008.

With the achievement of full energy injection into the storage ring the first tests of injection with insertion devices closed have been successfully carried out. The final goal is top-up operations, namely frequent injections of small charges with beamline front-ends open in order to maintain the beam current almost constant during users operations. Besides aspects related to machine operations, such as injection efficiency with insertion devices closed and perturbation of the beam during injection shots, radiation safety issues have been addressed by implementing special functionalities in the PSS. In order to avoid electrons losses during injection with front-ends open, a series of redundant controls will be performed, like injection efficiency, radiation levels, matching of transfer line and storage ring energies, etc.

The control system of the new Elettra injector has worked well and reliably during the commissioning phase and is now in daily use for the standard operations of our facility. Tango is demonstrating to be a reliable and efficient platform for building a modern control system. We faced neither major problems or malfunctions due to the control system, nor performance limitations. In order to speed up and simplify repetitive operations we intend to design and deploy a set of new control room applications, such as automated sequences of complex actions (e.g. "turn on the booster"), panels oriented to high level operations (e.g. tuning the booster power supplies ramps) and synthetic global status displays with simple "good/bad" indication of entire subsystems. New control room applications will also be required for top-up operations.

REFERENCES

[1] M. Svandrlik, "Overview of the Status of the Elettra Booster Project", these proceedings.

[2] FERMI@Elettra Conceptual Design Report: http://www.elettra.trieste.it/FERMI/

[3] M. Lonza et al., "The Control System of the Elettra Booster Injector", ICALEPCS'05, Geneva, October 2005.

[4] K. Casarin et al., "The Personnel Safety System of the Elettra Booster", these proceedings.

[5] http://www.trolltech.com/

[6] F. Iazzourene et al., "Application Programs for the Elettra Booster Commissioning and Operation", these proceedings.

[7] A. Goetz et al., "Abstract Device Pattern and TANGO", ICALEPCS'05, Geneva, October 2005.