THE LHC STRING2 SUPERVISION SYSTEM

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Abstract

This paper describes the implementation of the supervision system for the LHC Prototype Full-Cell also known as String 2.

The supervision application is based on a commercial package targeted to industrial controls, but because of the complexity and the specifics of such a system, integration with custom components is necessary in order to merge the industrial requirements with the specificity of the accelerator controls.

1 INTRODUCTION

The LHC Prototype Full-Cell [1], also known as String2, constitutes the last opportunity, before installation in the tunnel, to validate the Large Hadron Collider systems and investigate their collective behaviour in normal and exceptional conditions as well as during transients. The performance of the cryogenic and vacuum, the final design of the magnet protection and interlocks management and other technical choices will be validated.

Such a complex test facility needs a supervision system to control and monitor the processes involved via animated synoptics, trend curves and alarm validation. The supervision system also needs to keep daily reports where system variables are archived continuously at regular intervals and sent to a database repository. A Web access is also required for remote visualisation.

Most of the requirements can be matched by a PC-based [2] industrial Supervisory Control and Data Acquisition package such as PCVue32™ [3].

Integration with custom accelerator components used the opening features (standards such as OPC, program interfaces or files) provided by the package.

2 GENERAL ARCHITECTURE

Figure 1 shows the logical architecture of the String2 supervision system. Four major subsystems are integrated into a single unified database, only the cryogenic system, for historical reason, is independent. The communication between the equipments layer and supervision system uses a variety of protocols.

The controllers for the cryogenic, vacuum and interlock systems, based around Programmable Logic Controllers (PLC), are connected to a gateway computer using Profibus fieldbus. The gateway computer, which itself is a high power PLC maintains real-time data buffers which are accessed and updated from the supervision server over TCP/IP network using vendor specific protocol.

In the case of the power converters and magnet protection systems the equipment and gateway controllers are VME/LynxOS based embedded software systems that communicate over WorldFIP fieldbus. The communication between these gateways and supervision uses CERN-specific protocols over TCP/IP network using socket interface. In these cases specially developed driver software layers connect the PCVue32™ variables to the socket directly or through OPC.

Dedicated PCs running WINDOWS NT host the server function. The supervisor supports OPC server as well and the binding of the equipment variables to PCVue32™

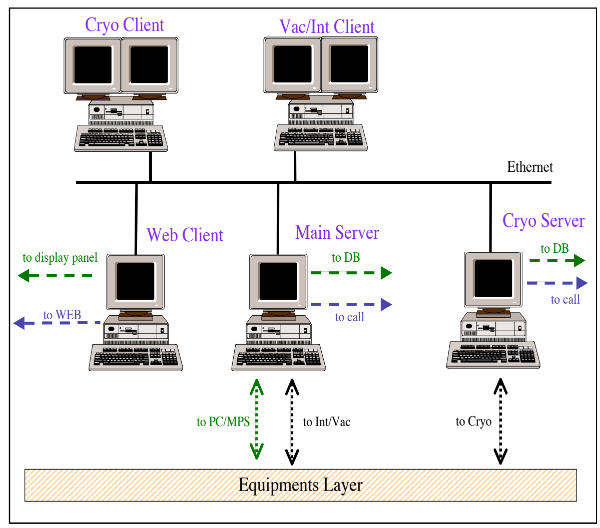

Figure 1: The String2 supervision architecture.

variables is done using user-friendly configuration menus.

Client stations provide the operator interface to each of the process groups. The client stations communicate with the server using TCP/IP and leverage the Internet infrastructure for global connectivity.

A dedicated client is used to access the supervision synoptic through web using a specific PCVue32™ functionality to monitor, but without control permission, the process remotely from office or from home. The same client also drives two display panels in the hall displaying the most important pressures, temperatures and information of the process.

In next sections a short description of every subsystem will be given.

2.1 Cryogenic System

The system has to supervise the Electrical Feed Box (DFB) where the electrical leads from the power converters are cooled in a Liquid Helium (LHe) bath. The flow of LHe through each of the current leads as well as pressure and level in the DFB are under closed loop control using regulated valves. Each of the temperature controlled valve associated with a current lead is controllable using one of three possible sensors depending on the operation regime. Thus, each valve is associated with three Proportional Integral Derivative (PID) loops, only one being active at a time. There are more than 120 PID loops in all.

The system also supervises the magnet cryostat, a long thin section housing the superconducting magnets and instrumented to monitor inlet/outlet temperatures and pressures, and the Cryogenic Ring-Line (QRL), pipes carrying He at different temperature and pressure levels around the String2 connected to the magnet cryostat via jumpers. The QRL terminates at Cryogenic Return Box and is connected to the Cryogenic Feedbox (CFB). The QRL is instrumented with heaters, control valves and with a large number of temperature sensors. The CFB feeds Helium to QRL and DFB.

In this subsystem, each PID loop is made generic and configurable from the supervision, via the PID faceplate. The process input can be substituted by an operator set value during testing. Operator can select one of two setpoints for control. The rate of change of the setpoint can be programmed. The P, I and D parameters of the PID controller can be set by the operator. The actuators can be switched to manual mode and manual setpoint can be changed from the faceplate. The value of the measured variable and the manipulated variable can be displayed in real-time in text form and as trend graphs.

The alarms are generated within the PLCs. However, for each of the defined alarms, the operator is able to set and modify the associated threshold and mask the alarm. Alarm viewing and acknowledgement are through specific PCVue32™ alarm windows. Similarly, the thresholds for the large number of interlocks computed by the PLCs are programmable from the supervision. Required data are stored for online/offline trend analysis.

2.2 Vacuum

This system includes monitoring and supervisory control of the vacuum equipment for the QRL, beam-line and magnet cryostats of String2. The main equipment includes pumps, valves and vacuum gauges. The supervision system features animated process synoptic with pop-up status windows for equipment, alarm generation & annunciation, trending and archiving facilities with high degree of user configurability. The alarm generation logic is performed in the supervisor and alarms are grouped into three priority levels. Figure 2 shows the main vacuum synoptic.

2.3 Interlocks Management

The interlock system is designed to protect the components (magnets, power converters, busbars, current leads, switches) of the String2 in case of quench or malfunction of one of the components and to take preventive action to reduce the recovery times following a quench in one of the circuits or in case of a failure in the supply of helium.

The system also allows the shutting down of the power converters in case of unauthorised access to the String2 area during unattended operation.

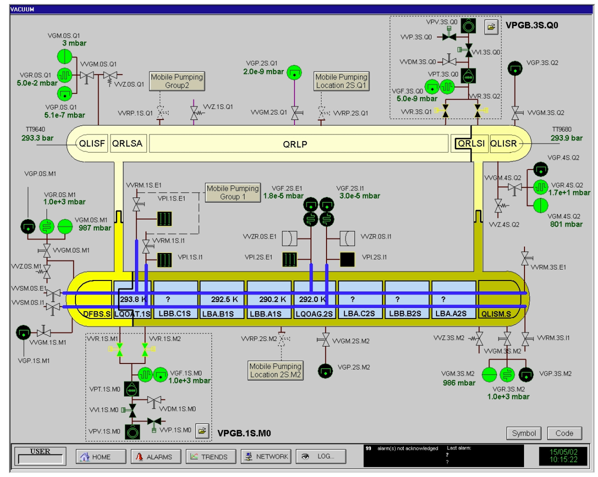

Figure 2: The Vacuum synoptic showing the String2 sketch.

2.4 Power Converters

The supervision facilitates monitoring and supervisory control of the 15 power converters that drive the four major families of superconducting magnets of String2: main magnets, lattice correctors, orbit correctors and spool-piece correctors. A digital controller associated with each converter does the closed loop regulation of the magnet current. From dedicated client stations an operator can monitor the converter currents, voltages and states, control them individually or collectively, set reference currents to follow one of the many predefined functions. The supervision provides capability for entry, playback, editing, selection and downloading of magnet current profiles, real-time and historical trending of currents & voltages and their archiving in a database.

The commands are sent to the power converter gateway using a custom dynamic library loaded by the supervisor. This library manages the exchange of command/answers with TCP/IP and the publication of the status of all the power supplies using UDP.

2.5 Magnet Protection

The aim of the Magnet Protection System (MPS) is to detect the presence of abnormal behaviors in magnets, current leads etc., in order to protect them from damage or destruction. MPS includes quench detectors & protection equipment attached to main magnets, quench detectors attached to current leads, global quench detectors, main magnet energy extraction systems, switches for corrector magnets and a gateway between acquisition systems and supervision. It presents the operator with the general status of the MPS, informs and logs alarm status, allows command execution of several tasks and detects if from MPS point of view, a new current cycle is permitted.

Data are exchanged with the supervisor through a custom OPC server communicating through TCP/IP with the LynxOS gateway. Figure 3 shows the MPS main panel.

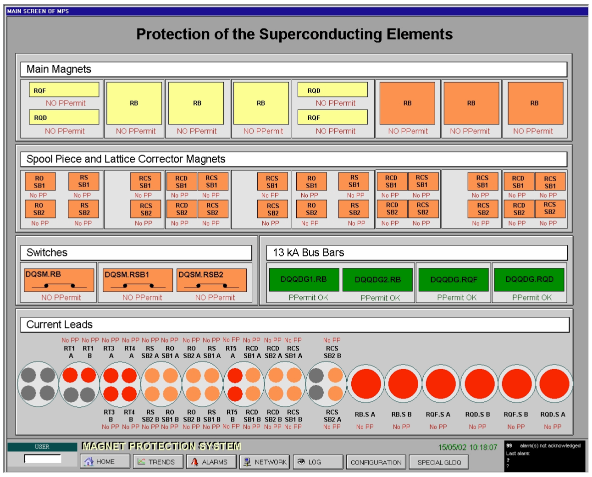

Figure 3: The main MPS panel.

3 CUSTOM COMPONENTS

As we have already discussed that, because of the specificity of the system, some custom components have been developed to adapt an industrial supervision system such as PCVue32™ to our requirements.

The specific communications protocol for power converter and magnet protection developed at CERN are not the only custom developments, but other components are integrated in our system such as email on alarm and database repository storage.

With the email on alarm system we can send an email or a SMS message when an alarm is detected by the supervision system. In this way users know when an intervention is needed and using the web export they can see from office or home what has to be done.

Another customization of the system includes the data acquired by the supervisor and stored locally on the disk. These data are written in a proprietary format and kept for a time configurable in function of the allocated disk space. After this time the circular archive is overwritten. To take care of the large amount of data produced by String2 we have developed a software that scans the PCVue32™ archive and sends them to an ORACLE repository.

For a maximum flexibility the system transforms the custom archive format into a XML file format. This file is then posted to a web page that interprets the data and stores them into the final repository.

The tool is awaked at regular intervals and sends the new data, manage already sent data and sending problems retrying the upload if last time a failure occurs.

The data can then be retrieved by a specific web application [4].

4 CONCLUSIONS

The String2 supervision system is only remotely related to the final LHC operator interface which will be used to run the accelerator. However, the work that has been invested in facilitating the job of experimenters to handle their complex subsystems remains extremely valuable [5].

By the way, the use of a commercial tool facilitated the sharing of the development work with BARC laboratory in Mumbai, India and in addition has provided an insight into the range of LHC machine applications that can be implemented satisfactorily with a limited effort.

5 ACKNOWLEDGMENT

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6 REFERENCES

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