REMOTE ALIGNMENT CONTROL SYSTEM OF THE LHC LOW BETA QUADRUPOLES

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Abstract

The low beta quadrupole magnets in the CERN Large Hadron Collider (LHC) are installed in high radiation areas on either side of the experiments. The system is equipped with sophisticated hydrostatic levelling and stretched-wire position measuring systems. A UNICOS-based control system using motorized jacks was installed to correct the alignment of the magnets remotely. Dedicated monitoring and control applications have been developed to allow the LHC operation team to supervise this complex system from the CERN Control Center. This paper gives an overview of the present controls architecture and introduces the foreseen operational tools to assist the beam operation.

INTRODUCTION

One inner triplet, which consists of three low beta quadrupoles, (Figure 1) is located on each side of the four experimental insertions of the LHC, in a high level radiation area; therefore, access time by human operators must be kept to a minimum. As the requested alignment tolerances are particularly stringent (stability of positioning of a few microns concerning one quadrupole inside its triplet), each triplet is equipped with permanent alignment systems monitoring the quadrupoles position. [1] When the position offsets become too large, a remote positioning is performed, using the motorized jacks, supporting each quadrupole.

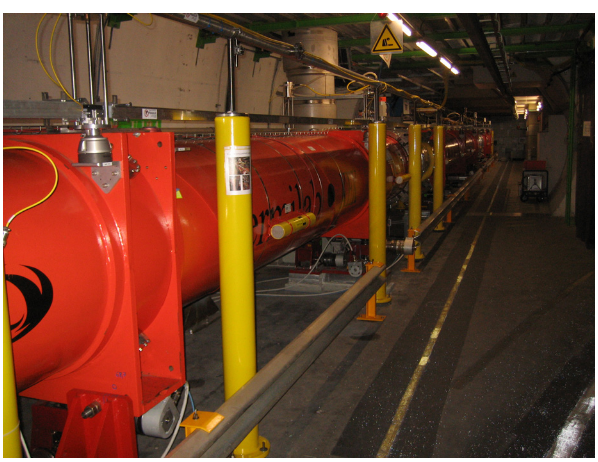

Figure 1: LHC low beta quadrupoles.

The paper introduces the instrumentation (alignment sensors and actuators) and describes the architecture of the control system. The control system is based on UNICOS, an open framework widely used at CERN. Special focus is made on the way the control system application was designed and developed.

QUADRUPOLES SURVEY EQUIPMENT

The low beta quadrupoles position is monitored using Wire Position Systems (WPS) and Hydrostatic Leveling Systems (HLS). The sensors are based on a capacitive technology providing a sub-micrometric resolution of measurement. They are located on alignment targets which have been pre-determined using Laser-Tracker measurements.

In addition, the transverse position of one triplet with respect to its opposite is monitored with Dimensional Offset Measurement Sensors (DOMS). Correction of the dilatation effects is performed using PT100 (Steiner) probes located all around the triplets. The instrumentation is listed in Table 1 below.

The remote positioning of the low beta quadrupoles is performed thanks to stepping motor gearbox assemblies that are plugged into the jacks which support the cryostat where the magnets are located.

Table 1: LHC Survey Instrumentation

Instruments	Range	Total
HLS (position)	5 mm	100
WPS (position)	10mm x10mm (2 axis)	68
DOMS (position)	10 mm	24
Steiner (temperature)	Various	128
Stepping motors	4mm	128

The optimal alignment is made without beam and kept during the run. No dynamic movement of the magnets is allowed when beam is present.

Signal conditioners (SAS), motor drivers and emergency stops agents are placed in racks located in radiation free areas. The instrumentation located in the hostile radiation environment has been validated to ensure that there is no significant loss of quality (precision, resolution, accuracy) of the measurement and of the performance of the actuators.

CONTROLS ARCHITECTURE

The control system for the alignment of the low beta quadrupoles is based on the FESA and the UNICOS frameworks. The architecture of the control system is shown in Figure 2. FESA is used, at the front-end level, to interface to the signal conditioners of the sensors and to the actuators both connected to a WorldFip network.

UNICOS is used to develop the Supervisory Control and Data Acquisition system (SCADA).

FESA is a real time object-oriented framework for the equipment specialist to design, develop, deploy and test his equipment software [2]. It creates source code to be deployed to Front-End Computers (FEC) allowing users to design and implement their custom code and, then, generating a complete application. FESA provides also a mechanism to import the user devices in a convenient XML format. It also allows rapid testing of the deployed devices instances

UNICOS is an industrial framework developed at CERN to produce control applications for three-layer industrial control systems [3]. UNICOS proposes a method to design and develop the complete control application from a configuration folder where all the I/O channels and field objects (e.g.: controllers, valves…) are described.

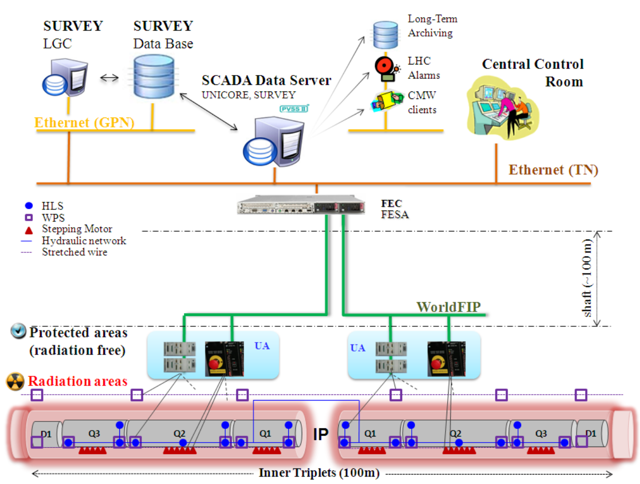

Figure 2: Control Architecture. Typical LHC IP.

One FEC is used in each experimental insertion. Two PCI WorldFip controllers (31.25 KHz) interface the equipment located on the left and on the right of the insertion. The total length of each bus does not exceed 150 meters, hence no repeaters are deployed. WorldFip is used mainly because of its radiation tolerance.

The FEC acquisition and calculation cycle is 1 Hz; this includes the capturing of the signal conditioner raw data and its conversion to engineering sensor information.

The four low beta quadrupole alignment systems (ATLAS, CMS, LHCb and Alice) are managed by a single data server running the SCADA system. The data server is an off-the-shelf HP ProLiant which runs Linux SLC4 and is equipped with a RAID system. Several Windows and Linux PCs have been deployed as Human-Machine Interface (HMI) clients both, for expert users in local control rooms and for the LHC operator crews to monitor the position of the low beta insertion magnets from the CERN Control Center (CCC).

Ethernet is used not only to interface the supervision and the control layer but also for the communication with the SURVEY database, which is used for the correction of the displacement measurements. The database contains the theoretical positions of the fiducials; it offsets and compensates dynamically the measurements using particular developped algorithms. Special attention has been given to the design of the network to optimize traffic between those actors by installing high-performance equipment (e.g. switches).

The management of the sensor data is done using MTF (Manufacturing and Test Folder of a Component), widely used for the components of the LHC. At generation time, this database is automatically interrogated to set the right configuration for each device. At run time, the expert may change those configurations in the database and request a reload.

UNICOS SURVEY PACKAGE

The UNICOS framework [4] provides a reusable environment composed of a set of components for the supervision and front-end layers (Figure 3). It includes the UNICORE (the core of the UNICOS environment), a basic package called UNICOS Continuous Process Control (CPC) to develop process control applications and tools to create new packages and/or new applications.

A package is set of generic software components combined together and configured to produce a control and/or monitoring application.

UNICORE

UNICORE can be deployed both in the supervision and the process control layers. At the supervision level it is based on the PVSS II® and the following functionalities are offered:

- Platform independence: distributed environment supported both in Linux and in Windows.
- Diagnostics: event and alarms managers to track all the changes, to diagnose the physical devices or processes (alarms, sms,...) and to monitor the integrity of the control application (e.g. front-end status).
- External connectivity to the LHC Software suite (LHCLogging, alarms, and Post-Mortem) and full CMW interface (Client and Server).
- Access control mechanism based on the Lightweight Directory Access Protocol (LDAP).
- Common Human-Machine Interface (HMI)

UNICORE was developed to offer UNICOS application developers and homogenous user interface which remains entirely customizable with features like navigation capabilities between panels and trends (WWW browser like, contextual buttons, pop-up navigation), access to the device without any development effort by the user.

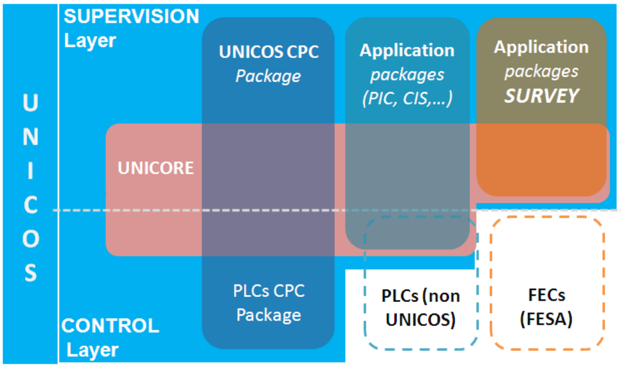

Figure 3: SURVEY package within the UNICOS framework.

The supervision hierarchy is based on a front-end device containing process devices. Typical examples of front-end devices are PLC, FEC (Font-End Computer), or OPC. A tool is provided to import the front-end and process device configuration into the supervision layer (PVSS).

SURVEY package

At the supervision layer, specific devices were implemented in the UNICOS frameworks. Those devices include all the instruments (HLS, WPS, DOMS, Steiner), the actuators (stepping motors) and additional devices like the emergency stop or the WorldFip agents and buses (Figure 4). These devices have their counterpart located in the FEC. Each device comprises new code libraries, a set of widgets (summarized device state), a faceplate (detailed device state) and the action list definition.

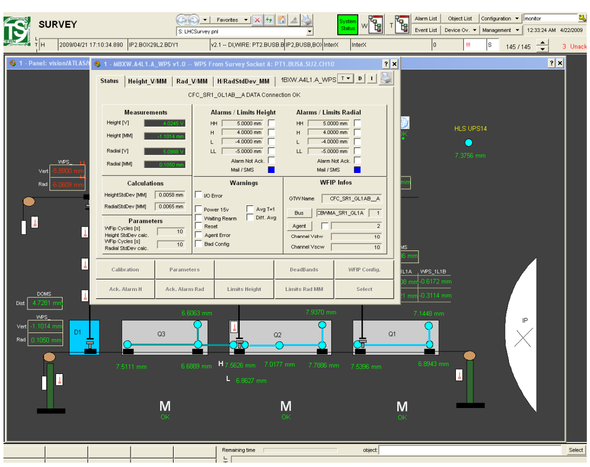
Figure 4: SURVEY application HMI.

The package allows a homogeneous interaction with all the devices by the specialist or the operator to monitor or configure instrumentation, obtain measurement data or send commands to the stepping motors.

The UNICOS common features allow an easy prototyping of a new package concentrating in the specific behaviour of the new devices and not in the framework features.

OPERATIONAL EXPERIENCE AND FUTURE IMPROVEMENTS

After the first implementation possible improvements have been identified and will be deployed for the next run.

Role Based Access Control (RBAC) has been implemented and configured to prevent unauthorized access to critical settings like configuration or motor movements.

The dynamic movement of the motors is disabled by monitoring the presence of the beam. An eventual movement in one of the magnets during a run will be treated as a machine interlock and will trigger the beam dump.

More calculated variables will be supplied for operational purposes. For each triplet magnet, the average horizontal and vertical offsets as well as the rotation angles with respect to the nominal position of the magnets recorded in the tunnel will be calculated.

CONCLUSION

The alignment of the inner triplets was yet another opportunity to demonstrate the openness and the flexibility of the UNICOS framework. The SURVEY control system package development was largely simplified because it was made reusing all the capabilities present in the UNICORE component and concentrating only on the dedicated SURVEY devices. Moreover the FECs development using FESA is also naturally integrated in the final solution. The package provided an invaluable tool to quickly commission sensors and actuators as well as the human machine interface.

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