INDUSTRIAL CONTROLS FOR THE TEST SETUP OF THE ATLAS BARREL TOROID SUPERCONDUCTING MAGNETS

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Abstract

The Atlas B∅ superconducting magnet is a test-model for the barrel toroid coils of the LHC Atlas experiment. To verify the manufacturing concepts of the coil, it will be subject to a series of electric, magnetic and thermal tests at CERN starting early 2000. The controls of this test bed will integrate industrial process controls (PLCs with fieldbus) and laboratory-type data-acquisition systems based on LabVIEW® developed by different participating institutes. They must provide secure process controls together with easily adaptable test scenarios and an accessible data repository. The paper describes the system architecture and the solution chosen for integrating the different components.

1 INTRODUCTION

The Atlas Toroid test setup [1] will have several purposes:

- Validation of the manufacturing feasibility of the barrel toroid design via a complete analysis of a smaller size test model – same width and cross-section, but reduced length –9m instead of 25m - (denoted 'B∅');
- Testing the complete final series of 8 toroids;
- Finally, the cryogenics will be used to test the final end-cap toroids before their lowering into the cavern.

In contrast with carefully designed and engineered systems as found in process industries, experiment test setups have continuously changing requirements. The combined use of industrial process controllers and of LabVIEW® allow however to cope with the conflicting needs of (a) ensuring proper sequences and protection for controlling critical equipment and (b) allowing a maximum of freedom in the different testing scenarios and easy change in input channel configurations.

2 MAIN REQUIREMENTS

2.1 General constraints

The total running time of this test facility will span a period of about 4 years, starting around end 1999. A control system for the LHC experiment magnets will be tendered to industry, but will not be available for the B∅ tests. Due to the limited resources available, the initial controls must thus be built by re-using as much as possible existing control components, both hardware and software. One must however keep in mind that, during the long test period, elements of the final controls might be integrated into the setup.

The test setup, situated in a CERN experimental hall, will have room for 3 test stations, one of which being dedicated to the B∅ test coil, the other two for the progressive testing of the eight toroid coils, till spring 2003. The limited cryogenic and powering capacity of the system allows however only one station to be under power tests at 4.5K at the same time, another can in the meantime be cooled down to 100K.

Two fast data-acquisition systems are needed to analyze the magnet electrical and quench behaviour (with maximum sampling frequency of 1 KHz); they will be provided by the external institutes who are in charge of the coil design: INFN-LASA (Milan) and CEA-DAPNIA (Saclay); CERN is in charge of integrating the fast recorded data together with the slow monitored signals (e.g. temperatures) for archival and analysis purposes.

Manpower having been allocated only recently to the controls aspects of this project, a few months before the commissioning of the test setup, implies a maximum reuse of existing software and knowledge.

2.2 Hardware constraints

The controls of the cryogenic refrigeration and distribution are done by an independent system, based on ABB industrial controls re-used from a previous site, with limited connectivity (in particular, no standard fieldbus), which lead to using I/O channels for information exchange between the two systems.

The toroids will generate a high stray magnetic field (close to 1 Tesla in the neighbourhood of the coil, 100 Gauss in the control room area), which may affect the functioning of electronic devices.

3 ARCHITECTURAL CHOICES

Splitting the functionalities in two parts, a process control layer and a supervision layer, allows separate development paths, once the interfaces are properly designed.

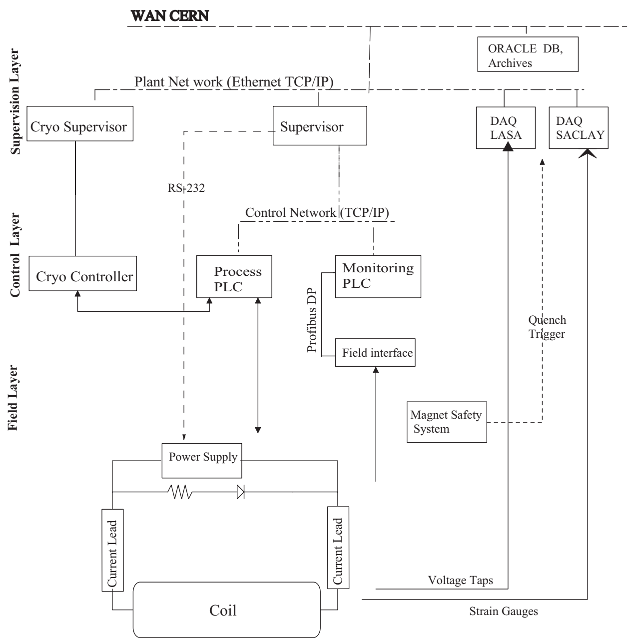

Figure 1: Proposed architecture.

3.1 Process control

The functionality of the process control can be decomposed as follows:

a) the control, regulation and monitoring of the electrical system and auxiliaries takes care of:

- the cool-down and warmup of the magnet between 300K and 4.5K done with controlled temperature gradients,
- information exchange between the magnet process and the helium refrigerator controls,
- regulating the temperature of the magnet current leads,
- monitoring of all critical parameters,
- verifying the availability of the magnet protection system by activating its different components before enabling magnet powering.

b) the ‘slow’ monitoring of the coil under test, mainly through the different temperature sensors installed all around.

In order to reduce sensitivity to magnetic field, we plan to use an optical fiber fieldbus (Profibus) for connecting the process controller to the input/output elements close to the coil.

Magnet protection (in case of quench) is handled by a dedicated electronic system, which initially will be completely independent from the process controls. Quench diagnostic facilities will however be added later, and will then require a connection to the supervision system.

3.2 Supervision

Although the state of the art in industrial controls generally directs the choice of commercial Scada systems to implement the supervision layer, it was decided to base the supervision system on LabVIEW® for the following reasons:

1. The Power Controller provided by industry is delivered with a LabVIEW® interface for controlling/monitoring it via a serial (RS-232) interface.
2. The CERN LHC/IAS group has developed a library of LabVIEW® components used in similar acquisition systems collecting both transient and continuously monitored data (see ref. [2])
3. Some of the fast acquisition systems provided by external institutes are also programmed in LabVIEW®, the integration of which can be eased by using the client/server facilities of LabVIEW®.

The supervision system must have the following features:

- Display the main process parameters on a synoptic view and show control interface to power supply.
- Provide a configuration tool for the input channels (conversion, scale, acquisition mode); remote systems may use different scan rates, and according to the different phases of the process (cooldown, warmup, power off/on) the channels to be acquired and their rate or trigger dependency may change.
- Collect both the continuous and transient data from the remote systems.
- Allow visualisation of any collected data on trend charts.
- Archive collected data in a central repository.

3.3 Time synchronisation

In order to visualise and archive coherently the data acquired in multiple places, synchronisation of the clocks of the different systems collaborating to the data acquisition is required; this will be done through the network by regular distribution of the supervision’s master clock, allowing precision up to 10 ms. Whenever a finer time precision is required, the use of external signals (quench trigger) can be used to adjust time stamps at the supervision level.

3.4 Archival and remote access

A great deal of tests will be realized on these stations, the corresponding data files will need to be properly stored in order to be able to locate them easily.

In addition, as the teams which participate to the testing of the B∅ coil come from different institutes, it is important to provide good connectivity from remote sites.

The system already built for the LHC machine equipment data (magnets and superconducting cables) offers the appropriate facilities, and will thus also be used to archive and access the B∅ test data (see Ref[3]).

4 ENGINEERING

Collecting user requirements from such a test setup is not an easy task, the potential users being often unavailable – if not unknown! For this reason, the supervision software, based on existing functionality, will be structured to allow easy extensibility.

Although this test setup differs from the final magnet installed in the cavern, it is planned to use it as prototype for the engineering of the process controls.

In particular, a data-base grouping the static description of sensors, cables, connectors and PLC input/outputs is being designed, based on commercial asset tracking and management tools already used in several areas of the LHC project. This will allow, for example, to follow the complete path from sensor to PLC input/outputs with electronic tools rather than hand-made drawings. It will also be used as the source for signal and ‘tag’ list in the supervision layer. It has the additional advantage to keep the history of changes stored into the data-base.

5 CONCLUSIONS

The B∅ test bench will be commissioned early 2000, before reception of the B∅ coil during the first semester; it is hoped to provide by then the wide spectrum of functionalities required, thanks to the large reuse and integration of modular software developed for previous projects.

6 ACKNOWLEDGEMENTS

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