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UNDERSTANDING THE LHC CONTROLS CHALLENGES

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Abstract

The analysis, design and construction of the LHC control system is a complex problem which will challenge CERN's capability to provide a modern controls infrastructure fulfilling the stringent operational requirements of this machine. The first part of this talk will review the present LHC project context in which several controls initiatives have already been taken. The second part will try to highlight the important technical aspects and engineering steps involved in the process of defining a control system architecture. The importance of understanding the major LHC operational challenges will be stressed along with some practical proposals and examples on how to conduct such activity with all stakeholders.

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1 INTRODUCTION

The operation of the future superconducting LHC machine will heavily rely on the services and quality of the control system. First studies of the LHC operational scenarios reveal a number of stringent requirements for such a control system:

- Several key machine systems like beam instrumentation, power converters and radio-frequency systems will have to be controlled online through feedback systems running at a few hertz [1]. As the exhaustive list of such parameters is not known today (i.e. exact speed of the ramp), the present LHC Dynamic Effects Working Group (DEWG) recommends building a control system offering a Real Time (RT) communication framework in which several systems could be included.
- As a consequence of the superconducting nature of the LHC machine, the coupling between beam related systems and technical services such as cryogenics will be very strong at both control system and control room levels. Therefore, a very close integration of these systems and combining of information will be mandatory [2]–[4].

In addition to these operational requirements, it is clear that in many cases, industrial control system solutions will be used for the control of major systems of the collider (i.e. cryogenics system). Therefore, the definition of clear hardware and software interfaces for each system, as well as a general policy for integrating these industrial solutions with the future control system, will be of paramount importance.

This paper summarizes the present controls context, stresses important aspects of a control system architecture and proposes strategies for addressing their first analysis.

2 THE PRESENT CONTROLS CONTEXT

The LHC project management has launched several working groups in charge of looking at various technical aspects of the future collider [5]. Several working groups are addressing specific aspects related to the control system.

- The Data Interchange Working Group (DIWG) is in charge of looking at all aspects related to the exchange and federation of information from all systems, including the LHC experiments, the technical services and the beam related systems.
- The Communication Infrastructure Working Group (CIWG) is gathering functional and performance requirements on the future LHC network infrastructure.
- The TIMing working group (TIM) is studying all aspects related to the accurate synchronization of the LHC systems and evaluates different technologies and approaches that could be used (i.e. absolute time reference versus event-based triggering system).

At the same time, in the CERN accelerator sector, a convergence project has been launched in order to provide common features for controlling the complete accelerator injection chain [6]. Two sub-projects of this convergence are very promising for the LHC era.

- The middleware project which will provide a new generation of communication paradigms based on the Object Oriented (OO) approach and based on industry standards like CORBA and message oriented middleware technology.
- The Java API project which already provides, today, a common OO Application Programming Interface (API) in the Java language. This API, coupled with a configuration management service, allows the seamless control of any equipment of both the PS accelerator complex and the SPS accelerator.

These two projects are the most significant technological steps forward since the development of the control system for the LEP machine at the beginning of the 1980s.

Yet another important project is the SL SPS-2001 project [7] which is producing new operational concepts and solutions to allow fast magnetic cycle changes in the SPS machine as LHC injector. Several of these concepts, like a standard set of contracts for accessing accelerator equipment, are also of very high interest for the LHC machine.

3 CONTROL SYSTEM ARCHITECTURE AND STRATEGIES

Building a control system for a new accelerator has always been a very challenging task. In the case of the LHC, the complexity of machine operation scenarios like the energy ramp, the very tight tolerances on beam parameters and the complex operation procedures in case of magnet quench will require a significant effort of investigation and functional requirements gathering. In parallel, the computing technologies and products evolve extremely rapidly and one can expect the emergence of several new concepts between today and the final commissioning of the machine in 2005. For these reasons, it is worth spending time to first concentrate on a good, technology-independent control system architecture and to study, as precisely as possible, the various operations scenarios this control system will have to support.

3.1 Control system architecture

Unfortunately, despite the fact that every engineer feels the need for it, no formal definition of a control system architecture exists. The literature provides, nevertheless, a set of recommendations and techniques for the iterative development of large-scale distributed control systems [8]. As shown in Fig. 1, three aspects are of particular importance: the definition of the hardware and software interfaces for each subsystem, the identification of generic services to be provided by the control system and, last but not least, a vision of how the complete system will be organized — the pattern.

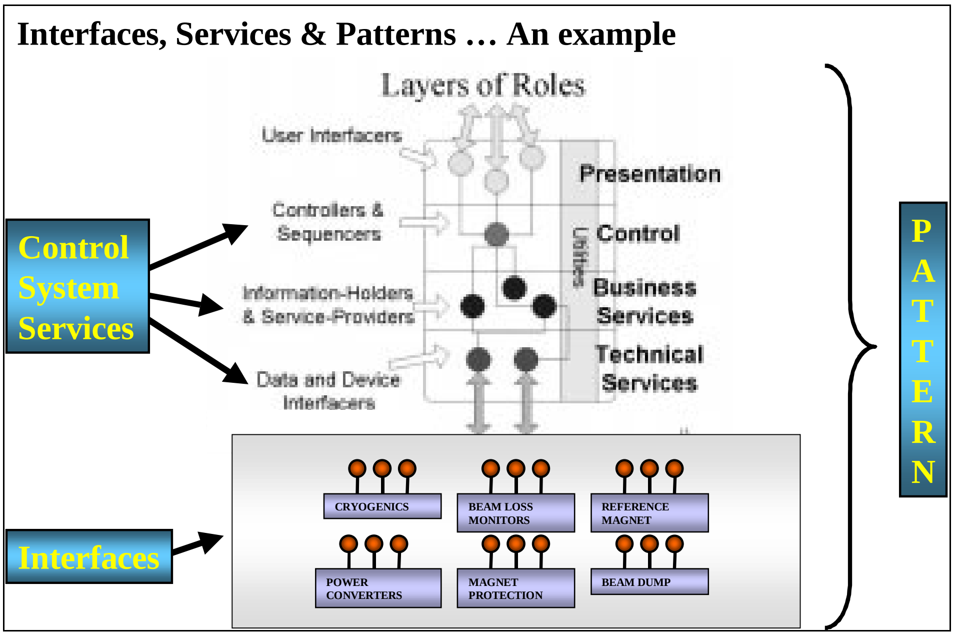

Fig. 1: Control system architecture.

- **Hardware and software interfaces:** As already emphasized in this paper, the operation of the LHC machine will involve complex operations and flows of information with specific levels of performance between a large number of systems. In order to allow the development of each system to take place as early as possible, it is mandatory to define, as first priority, the services each system will have to provide and to formalize them as hardware interfaces (i.e. hardwired interlock protection system) or callable software interfaces.

- **Generic control system services:** The high level operation of the LHC collider will require several communication facilities for acquiring data from the different subsystems (i.e. publish-subscribe or blocking I/O operations), mechanisms for logging and archiving data in Data Base Management Systems (DBMS),

- techniques for synchronizing processes with the machine magnetic cycles, frameworks for Real Time (RT) feedback loops, and so forth. Each LHC subsystem will heavily rely on several of these services.
- **Vision or pattern:** Developing a complete vision of how the control system will be organized is also important to bring confidence to the project. Several patterns exist today for building large control systems [8]: The layered pattern (system organized in hierarchical layers) and the repository-centric pattern (communications are organized around a DBMS) are two well-known examples of such patterns.

A control system architecture baseline will exist in practice when these three important issues have been specified and when decisions regarding the technological choices to be used for the design have been made (i.e. DBMS technology and products, middleware standards and products, network protocols, SCADA products, and so forth).

3.2 Strategies

Many different project strategies can be used today to develop distributed control systems. Recommendations exist for defining project life cycles, for good analysis and design, and so forth. This paper will not emphasize any of them in particular but will rather stress two important invariants in any controls project: the need to develop a system supporting the operational scenarios and the importance of focusing early on potential architectures in order to 'get the picture' before design starts. Architectural issues have already been discussed in the previous section. Some aspects related to the operational scenarios will be developed below.

As shown in Fig. 2, a practical study of an LHC operational scenario, an LHC Dipole Magnet Quench, was carried out with representatives of the different LHC subsystems and with people having a good vision at the global machine operation level.

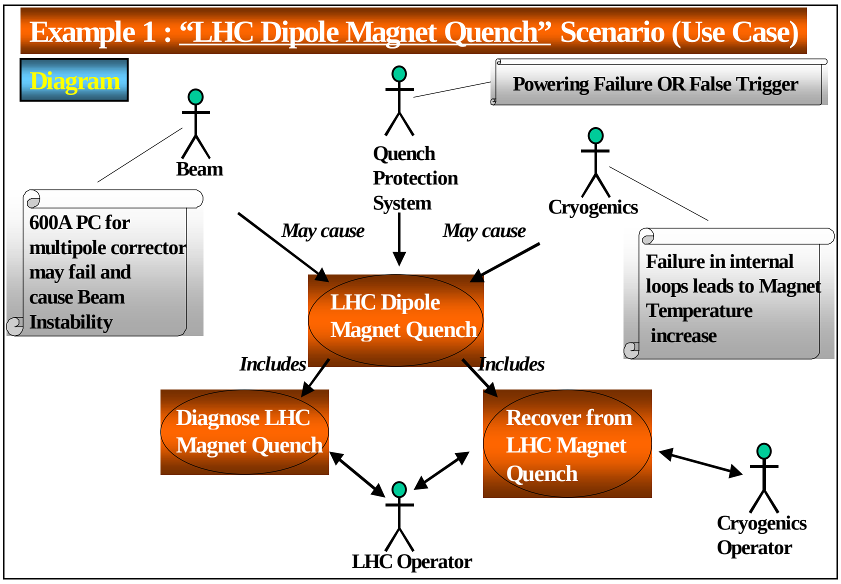

Fig. 2: UML use case modelling.

The actors or external systems taking part in this scenario were identified (in this case, the causes of potential LHC magnet quench) and the scenario was decomposed in three parts: a description of the triggering mechanism in case of a quench, the procedure for making quench diagnostics, and finally, the procedure for recovering from a quench. This exercise, also known as 'use case modelling' [9], proved to be very promising as it provides, as shown in Fig. 3, a clear description of the roles of each LHC subsystem involved in a particular operational situation, a first description of the data flows between these different systems along with some performance constraints, and the kinds of interfaces to be implemented by each system.

Working on LHC operational scenarios will also have the advantage of building, through a group activity, a common understanding and commitment towards the way the future collider will be operated. This dynamic technique for capturing requirements will also be a solid basis for clarifying, in the light of the complete set of major use cases, the generic services expected from the control system.

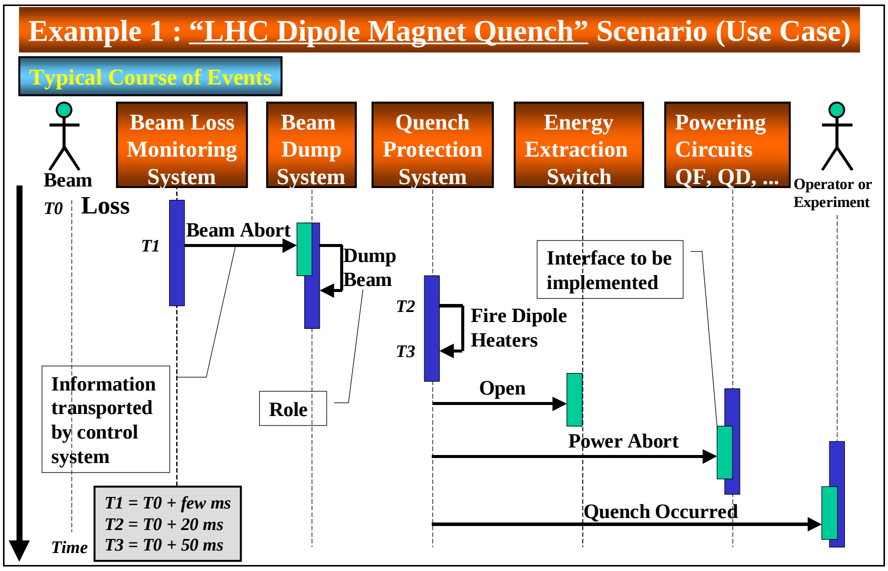

Fig. 3: UML sequence diagram.

4 CONCLUSIONS

Building a good control system for the future LHC machine will be very challenging in the light of the complexity of the foreseen operational procedures, the need for real-time feedback systems and the interfacing with industrial control systems. Studying the operational scenarios and proposing potential control system architectures are critical steps for reducing risk and moving towards the definition of a solid LHC operation and controls baseline. Building this vision together, with all parties involved, from the control room level, down to the equipment level will bring commitment and confidence to the whole project. The key role industrial control systems will play in the LHC will also require the definition and acceptance of CERN-wide techniques for interfacing all these systems together and operating them seamlessly.

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