LHC ACCESS SYSTEM: FROM DESIGN TO OPERATION

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Abstract

The paper describes the LHC access system project, the system's architecture and the experience gathered of commissioning it. This system is made of two parts: the LHC Access Control System and the LHC Access Safety System. Using state of the art redundant, fail-safe PLC's and a supplementary, cabled control loop the LHC Access Safety System guarantees the safety of the personnel against the risk of unwanted radiation exposure. Using industrial components, the LHC Access Control System, regulates the access to the tunnels and experimental areas by identifying the users and controlling their access authorisations. It allows a remote or automatic operation of the access control equipment, restricting the number of users working simultaneously in the interlocked areas. A first implementation of the architecture is now in production and ensures that only authorized personnel can enter the controlled areas of the LHC complex and this only after permission has been given by the CERN Control Centre.

INTRODUCTION

The Large Hadron Collider at CERN is being commissioned in 2007-2008 and is planned to be ready for operation with beam second half of 2008. The access system is an indispensable component of the accelerator for beam operation as it provides an integrated system for the LHC machine and experiments protecting the personnel against the radiation hazards.

ARCHITECTURE

The LHC access system comprises the LHC Access Control System (LACS) [1] and the LHC Access Safety System (LASS) [2]. The separation into two distinct yet complementary systems was a novel approach at CERN. It allows the use of different hardware and software solutions, each more suited for the specific sub-system. This concept is particularly important to demonstrate that the LASS ensures its safety function at the level required by the safety analysis. In the two system architecture complex access control algorithms do not compromise safety issues as the LASS system can at any time override the execution of any access control task. A different test strategy for each of the systems can be applied – focusing the resources on thorough testing of the safety functions, before tackling the ergonomics of the access control part.

LHC Access Safety System

LASS - (the white part in Figure 1) is an interlock system assuring that no beam can circulate or be injected in case

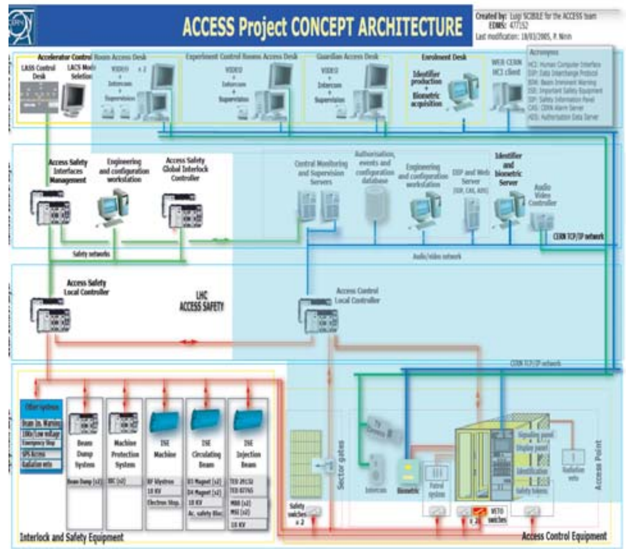

Figure 1 - LHC Access System architecture overview

of access operation and that every intrusion detection during beam operation leads to an immediate stop of the accelerator in a controlled manner.

To achieve this goal the LASS system controls the state of a number of Elements Important for Safety (EIS). We distinguish between EIS-access and EIS-beam. The EIS-access comprise the personnel and material access devices (air-locks), doors dividing the underground areas into a number of sectors, ladder-traps etc. The EIS-beam have been chosen among the vital LHC components and can, in parallel to the LHC beam dump system, stop the circulation and injection of beams. They are: the mobile beam dumps, horizontal dipole chains and injection septa in the two transfer lines from the SPS to the LHC, the separation magnets in the two collimator regions of the LHC and the modified vacuum valves obstructing the beam apertures. In case of all the magnets, the initial interlock-points were the high voltage cells upstream of the power converters feeding the magnets. This choice of the EIS-beam allows triple redundancy for each interlock chain, geographical separation and technological diversity.

The LASS control system has a distributed architecture and is based on the Siemens 400FH series failsafe Programmable Logic Controllers. At each of the LHC points a local controller monitors the state of all the EIS and calculates the site resultants that are forwarded to the global controller. The global processing unit monitors the information obtained from each of the nine local units and takes necessary safety actions, calculating the global resultant to enable or disable the global access veto.

Each local controller supervises of the order of 150 EIS-access. This means mostly monitoring of double position contacts and double emergency exit contacts on each door and access device. The contacts and actuators are cabled via redundant copper cables. In addition up to three EIS-beam can be controlled by a local controller.

The controller units are linked via a self-healing fibre loop network traced in the LHC tunnel. The fibres are specifically monitored in the area where higher radiation level is expected. In case of a double network failure and loss of communication, each controller drives the whole set of EIS under control to a safe state, thus blocking both access and beam operation. In practical terms, the veto signal sent to the EIS-access and the EIS-beam means that the corresponding controller outputs are set to zero, as the system uses positive safety logic.

In spite of the highly robust and redundant LASS control system architecture, the French Nuclear Safety Authority has invited CERN to further reinforce the architecture to avoid a potential common mode of failure inside the PLCs. This conservative approach was due to a limited return of experience at the disposal of the auditors, as PLCs have only recently been introduced in the safety critical control systems. CERN has introduced a cable control loop that provides a technologically redundant mechanism to stop the beam in case of intrusion via the external envelope of the accelerator. Where possible the EIS-beam interlock points for the cable loop and the PLC control system were divided between the corresponding power converters and their feeding cells.

Access Control System

The role of the LHC Access Control System - LACS - (the bluish part in Figure 1) is to:

- provide a physical barrier enclosing the LHC perimeter and subdividing it into smaller access sectors by means of EIS-access;
- identify the personnel and control the access authorisations, delivered to laboratory personnel that has followed the necessary safety training;
- supervise and drive the EIS-access;
- provide a voice and video communication channel between the control room and the field access points.

Access control into the radiation controlled area has been reinforced by the installation of personnel access devices – air locks - replacing the LEP-era turnstiles. Introduction of the air-locks makes it impossible to trespass the interlocked area without a proper authorisation. Furthermore, iris recognition system has been put in place inside each air-lock that verifies a match between the access badge used and the identity of the access requester. The badge itself has been coupled with a personal dosimeter, using an RFID identifier, thus verifying that all the persons entering the accelerator premises carry their personal dosimeters with them. Consumer-off-the-shelf products have been used in the field, with the personnel and material access devices, door locks, signalisation panels, monitoring cameras coming from well known vendors. Contrary to the past systems, voice and video communication have been integrated into the same application using IP transmission. Whereas it has many user interface advantages, this solution is prone to network and processing saturation errors and is currently being optimized.

The LACS control system has been built on top of an industrial access control system: Evolynx from Cegelec. This system comprises a central redundant server unit and local controllers next to the access device and doors. The Evolynx software provides a graphical user interface running on Windows PC computers, the controller drivers and an Oracle DB central server to store the personnel data and to record access transactions. Customisation of the software originally designed for office building control included addition of a number of dedicated synoptic views, the implementation of the LHC access modes logic (general access, restricted access and closed) and automation functions of the access points. Unfortunately, introduction of the ensemble of new functionalities has sometimes led to performance degradation in the field. One might reconsider using the access control Evolynx system only for its initial purpose and complement it with industrial SCADA and controller systems for the synoptics and access point automation.

PROJECT MANAGEMENT ISSUES

The management of this project was a major challenge since it had failed to progress in an earlier attempt as user requirement documentation was nearly non-existent offering a fertile ground for problems of all kinds. By providing a clear project plan [3] and system objectives, with clearly defined milestones and deliverables and starting an extensive documentation effort a first move forward became perceptible. The project plan and the specifications, in particular for the software part and the safety system have rigorously followed the international standard IEC 61508 and the recommendations of the French Nuclear Safety Authority. The fact that all aspects of the proposed system would be subject to a very detailed scrutiny from the authorities became rapidly a very strong and positive incentive to all project participants.

A special web site and EDMS[*] framework were created to manage the baseline thus ensuring that the approved documents were always available to all the participants. Although CERN made both the global and the detailed technical design, the actual integration and installation of both the LACS and LASS was outsourced to a general contractor who in turn subcontracted for the different subcomponents. The general contractor had the overall responsibility for engineering the integration of the subcomponents into a homogenous, coherent and maintainable access control and safety system. A very close follow-up, technical analysis and support of the CERN project team has been necessary to achieve the

[*] EDMS=CERN's Engineering and Equipment Data Management system.

above mentioned integration and several quality audits were conducted to ensure the success of the project.

SECTORISATION AND INTEGRATION

The size of the LHC underground structures - 27 km of machine tunnel, 4 very large experimental caverns and the associated connection tunnels - excludes a simple fence to avoid non-authorised entry. Moreover, the underground structures have to be divided into 82 sectors where access can be monitored more easily and which can be patrolled more efficiently to ensure they are empty of personnel before any beam injection.

The LACS and LASS also had to be integrated into the existing infrastructure – practically no civil engineering to accommodate the access system could be expected to be approved. This stringent condition posed a major challenge to the team. In close collaboration with the LHC integration group and other support suppliers all the necessary detailed drawings and 3d models were created – showing all concerned parties how and where each door, each access point and each patrol box etc. should be placed. Figure 2 shows an example of the sectorization document stored in the EDMS.

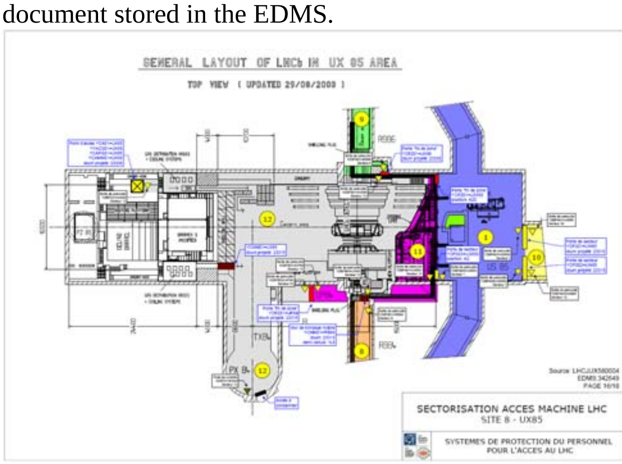

Figure 2 – Access Documentation for Point 8 in EDMS

COMMISSIONING

The commissioning of the access safety system started already with the factory acceptance test procedures. Once the LASS equipment and software for an LHC point (9 in all) was considered ready, the contractor and CERN performed detailed acceptance tests. After installation and integration on-site, an exhaustive test campaign was launched. All input signals and all output signals were tested both individually and system-wise [4].

All nonconformities were inventoried in the MTF[†] which is the CERN-wide tool used to trace any equipment from its inception through operation and maintenance to dismantling. The resolution of the non-conformities followed a strict procedure which was also managed by the MTF system. The commissioning of the global system – including all the LHC points as well as EIS-beam - was performed in early January 2008. The results of these were very positive, a number of minor issues were detected and only one major problem was identified.

INITIAL OPERATIONAL EXPERIENCE

The experience of the first months of operation has been mainly positive; many of the issues arising are considered to be part of the running in. The system has many electro-mechanical devices that have to be adjusted and exercised. Thousand passages per week have been registered with less than 1 malfunction occurring per day in the global system. However, as expected, the human interface will have to be improved as well as the system's response time to operator requests. A too slow reaction from the system on operator commands will inevitably cause unnecessary stress situations.

A fine tuning of the communication parameters between the 11 redundant PLC was necessary to avoid setting unnecessarily the system in the failsafe mode; meaning no access and no beam. The synchronisation of the LASS veto action - that can be triggered at any time by the loss of a safety condition - with the cycles of the LACS equipment needed fine tuning as well.

CONCLUSION

The LHC access system has been successfully commissioned after a project duration of more than 4 years. By following a detailed project plan which defined well in advance the different milestones and deliverables, including extensive documentation, the project team has managed to deliver a complex system in time for the LHC start-up. The initial start of the project was slow due to the general contractor's initial underestimation of the complexity and insufficient user requirements. The delays incurred were later recuperated when both CERN and the contractor added considerable amount of engineering manpower to the project. The fact that the system was subject to extensive audits from the French Nuclear Safety Authorities encouraged the production of high quality documentation and design efforts and can in hindsight only be considered as very positive. The LHC access control and safety system is in production since early January 2008 and will be ready to ensure the safety of personnel when the LHC starts taking beam.

REFERENCES

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[3] P. Ninin *et al*. Système de sûreté d'accès du LHC Plan de développement https://edms.cern.ch/document/455207

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[†] MTF= Manufacturing and Test Folder