THE LHC ACCESS SYSTEM

T. Ladzinski, F. Valentini, C. Delamare, S. Di Luca, S.Grau, T. Hakulinen, L. Hammouti, F. Havart,
J-F. Juget, P. Ninin, R. Nunes, T. Pettersson, T. Riesco, E. Sanchez-Corral Mena, G. Smith,
CERN, Geneva, Switzerland

Abstract

This paper describes the LHC Access System, built to protect the personnel working in the LHC from radiation hazards; the system's architecture and the experience gathered of commissioning, testing and using it. The system is made of two parts: the LHC Access Control System (LACS) and the LHC Access Safety System (LASS). Using redundant, fail-safe PLCs and a supplementary cabled loop the LASS guarantees the safety of the personnel in all events. Using industrial components, the LACS regulates the access to the tunnels and experimental areas by identifying users and checking their authorizations. It allows a remote or automatic operation of the access control equipment and restricts the number of users working simultaneously in the interlocked areas. Since the beginning of the operational phase, additional efforts and studies have been done to ensure the inviolability of this protection system by users not holding the required credentials. The design, procurement and installation of the entire system took more than 4 years and the commissioning phase lasted about 12 months. The paper presents as well the return of experience of the first 2 years of operations.

INTRODUCTION

The Large Hadron Collider at CERN has seen its first beam in September 2009. The access system is a vital component of the facility without which beams cannot be injected and accelerated in the machine. Its principal duty is to ensure that if there is beam in the machine no human being is inside or can enter and if there is a human inside that no beam can be injected. If a beam is circulating and a break-in occurs the access safety system has to guarantee the immediate stop of any beams circulating, any new injection and the activation of the beam dump system. The mechanical barriers of the access system as well as the logic of the interlock are also used by the control room operators to ensure that no person is put in danger during the potentially dangerous phases of commissioning of the accelerator hardware.

ARCHITECTURE

The LHC access system [1] comprises the LHC Access Control System (LACS) and the LHC Access Safety System (LASS). The separation into two distinct systems allows the use of different hardware and software solutions, each more suited for the specific needs of the subsystems. Moreover, it ensures that the safety functions can be executed unconditionally 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 the thorough testing of the safety functions.

The LHC Access Control System

The role of the LACS is to:

- provide a physical barrier enclosing the LHC perimeter and dividing it into clearly delimited access sectors;
- identify the person and verify the access authorisations delivered to the laboratory personnel that has followed the necessary safety training;
- supervise and control the various access equipment;
- provide a voice and video communication between the control room and the field access points.

The LACS infrastructure, built on top of Evolynx System from Cegelec comprises a central redundant server unit and local controllers located next to the access devices and doors. The Evolynx software provides a graphical user interface running on MS Windows system, hardware controller drivers and an Oracle DB central server to store personnel data and to log the access transactions. Customisation of the software included addition of a number of dedicated accelerator synoptic views, the implementation of the LHC access modes logic (general access, restricted access and closed mode) and custom drivers for the access points. Consumer-off-the-shelf products have been used in the field and the voice and video communication have been integrated into the application using IP transmission.

The LHC Access Safety System

The LASS is an interlock system ensuring that no beam can circulate or be injected in case of access operation and that every intrusion detected during the beam operation leads to an immediate stop of the accelerator in a controlled manner.

The LASS system controls the state of a number of Elements Important for Safety (EIS). The EIS-access comprise 40 personnel- and 29 material access devices, 203 doors dividing the underground areas into 82 sectors, 17 mobile shielding walls etc. The EIS-beam have been chosen among the vital LHC machine components and can, in parallel to the LHC beam dump system, stop any circulating beams and any injection of new beams. The EIS-beam 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 reinforced vacuum valves obstructing the beam apertures. This choice of the EIS-beam allows triple redundancy for each interlock chain with a geographical separation and technological diversity.

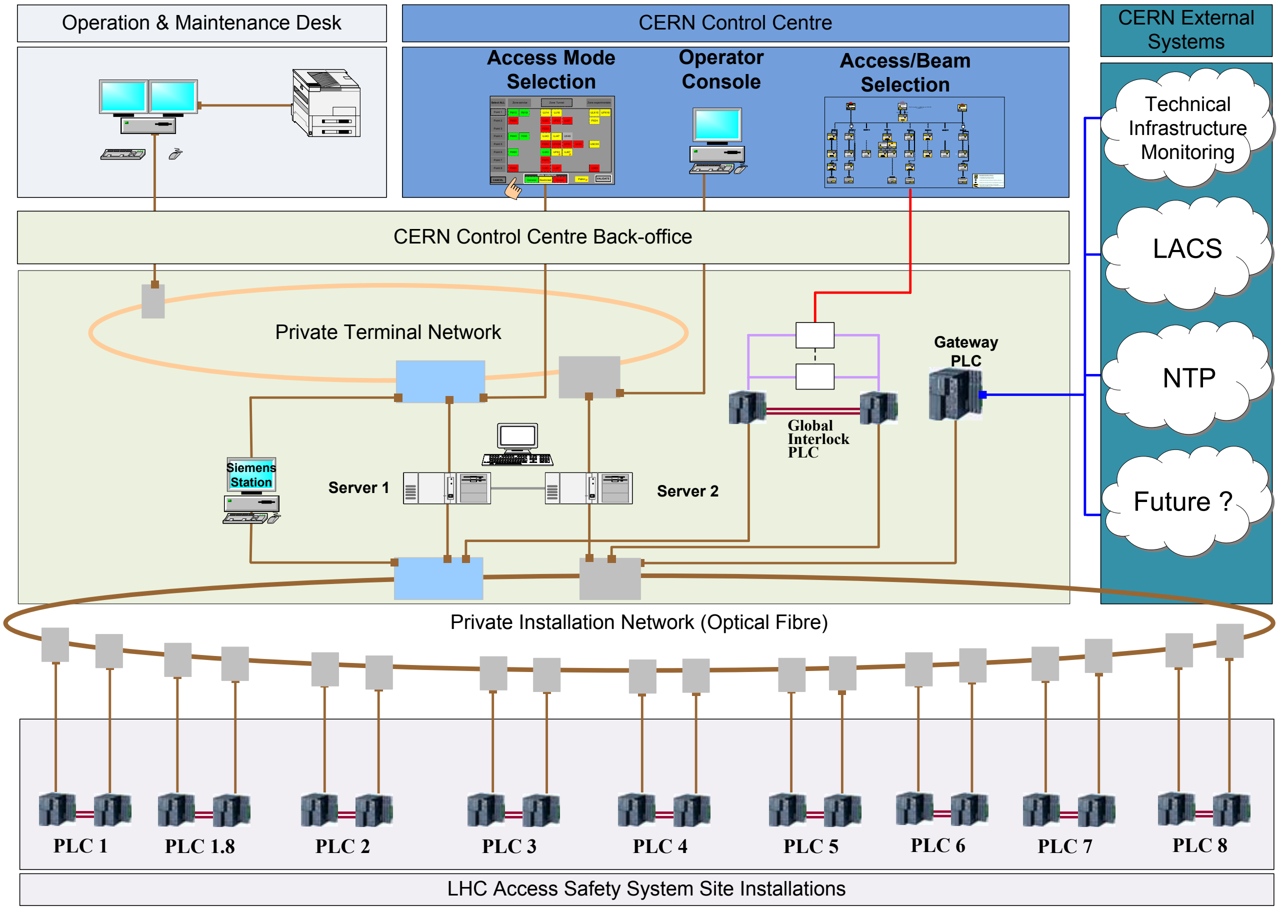

Figure 1: The LHC Access Safety System distributed control architecture.

The LASS control system has a distributed architecture and uses the Siemens 400FH series failsafe Programmable Logic Controllers (Figure 1). At each of the LHC points a local controller monitors the state of all the EIS of that point and calculates the site resultants which are transmitted to the global controller. The global controller acquires 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 safety veto. The many controller units are linked via a self-healing fibre loop network located in the LHC tunnel.

This architecture has been reinforced by the introduction of a cable-logic loop that provides a technologically redundant mechanism to stop the beams in case of an intrusion via the external envelope of the accelerator [2]. For most of the EIS-beam, the interlock points for the cable loop and the PLC control system are divided between the corresponding power converters and their power feeding cells.

FIRST TWO YEARS OF OPERATION

The system was installed and gradually put in operation over a period of three years, with an intensive commissioning and testing campaign [3]. A preventive maintenance plan was put in place, with 1’000 hours of scheduled work per month during the shutdown periods.

After the introductory phase in general access mode and following the needs of the accelerator hardware commissioning team, the restricted access mode started being heavily used in order to limit the number of personnel accessing the areas of the facility exposed to industrial risks (cryogenics, high voltage and currents).

Table 1: LHC Access Statistics 1 July-30 September ’09.

	General Access	Restricted Access	No rights	Total
Service Area	65,777	4,657	902	71,336
Tunnel Area	19,390	5,643	29	25,062
Experiment Area	66,642	2,853	858	70,353
Total	151,809	13,153	1,789	**166,751**

Table 1 summarises the access statistics for the 3rd quarter of 2009. A total of more than 166 thousands accesses have been observed over a period of three months. Of those 13’153 were supervised by the control rooms’ operators in the restricted mode. These impressive figures are related to the on-going maintenance works of the accelerator prior to the 2009 start-up.

THE 2009 ENHANCEMENTS

Prior to any beam operation, the LHC access sectors are patrolled to make sure that no-one remains inside. The initial design specification assumed that the restricted access mode shall be used during the short technical stops of the accelerator (of the order of a few days). In this mode the person accessing any interlocked area gets an authorisation from the control room operator and is provided a safety token at the access point. The patrolling of the areas is thus no longer necessary, as the LASS will not permit beam operation until all the persons have left the LHC and all tokens have been returned. Any unauthorised entry automatically disarms the patrol memory and forces the concerned areas to be patrolled again. In 2009 certain double position magnetic contacts were exchanged for a more robust mechanical version to avoid spurious patrol drops originating from discrepancy errors encountered with the initially installed contacts. The sheer number of access transactions has also led to small modifications of other electromechanical elements.

A few improvements have been introduced in the LASS software, e.g. the interface with the SPS extraction chain elements important for safety. All the modifications have been grouped into one development package. Once implemented, the new software was tested on the test platform, deployed and then validated on-site. The LASS change requests are handled just as the initial project: following a very strict verification and validation policy.

Access Device Antifraud Measures

The use of the restricted access mode during the prolonged period of accelerator shutdown to limit the number of persons accessing certain zones and guarantee the safety of magnet powering tests has led to the need of enforcing antifraud measurers at the access points, especially the Material Access Devices (MAD).

The Personnel Access Device (PAD) air-locks make it impossible to trespass the interlocked area without a proper authorisation. Iris biometric recognition system inside each air-lock verifies a match between the access badge used and the identity of the access requester. A complex automatic system based on ground pressure sensors, infrared radar and photo-electric cells surveys the PAD interior at each passage to eliminate piggybacking and tailgating.

The MAD is also an air-lock chamber. It is closed by two mechanical doors that cannot be opened simultaneously and allows the introduction of bulky material into the interlocked zones. The door commands are located only on the outside of the device thus eliminating the possibility of someone trespassing into a zone alone through the MAD. The cameras placed on both sides of the device allow remote supervision of the premises. However, due to the number of transactions it proved impossible to individually monitor each MAD passage cycle. Several commercial solutions have been evaluated in order to disable the possibility of gaining access to the interlocked areas via this device: volumetric/infrared detection, human shape recognition, thermal camera analysis, CO$_2$ level detectors. All proved inadequate, either because of long detection time, inaccuracy or space requirements.

This situation has forced us to study and develop a custom technical solution resolving this particular need of the LHC environment. As it is extremely improbable for any person to be able to hold a perfectly immobile position for an undetermined amount of time (experimentally quantified to be of the order of 30 seconds), a Motion Detection System with a millimetre resolution was developed at CERN. It uses a high resolution digital camera (3M pixels) capable of covering the whole MAD volume (approx. 20m^3) and a custom algorithm. By analyzing the digital video frames in real time it estimates precisely the quantity of motion inside the MAD on the basis of small luminosity variations in the frame's pixels (Figure 2). A special analysis of any mutated pixels allows discriminating the real movement from the background noise inherent to all digital images.

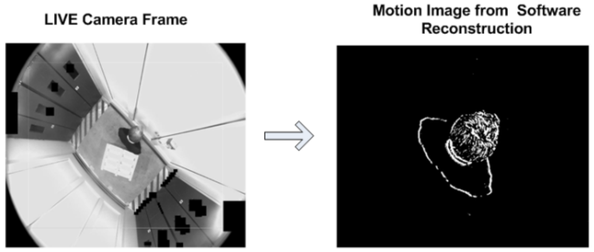

Figure 2: MAD Human Detection System.

CONCLUSIONS AND OUTLOOK

The LHC Access System is in production since early January 2008. Over the past two years it has been intensively tested and used. During the running-in period the architecture of the interlock system proved well designed and only a few electromechanical problems needed attention. The statistics gathered during the last months show that the system supports a much heavier load than initially foreseen. Additional developments are therefore necessary to automate certain tasks and remove the unnecessary strain from the control room operators. The first of this was the design and implementation of the MAD human detection system. A revision of the restricted mode logic and usage ergonomics is now planned in order to cope with the demand for a supervised access mode facilitating the protection of the laboratory personnel not only from radiation hazards but also from industrial dangers.

REFERENCES

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