THE LHC RADIATION MONITORING SYSTEM FOR THE ENVIRONMENT AND SAFETY

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Abstract

A state-of-the-art-radiation monitoring and alarm system is being implemented at CERN for the Large Hadron Collider (LHC). The RAdiation Monitoring System for the Environment and Safety (RAMSES) comprises about 350 monitors and provides rates of ambient dose equivalent measured in the LHC underground areas as well as on the surface inside and outside the CERN perimeter. In addition, it monitors air and water released from the LHC installations. Although originally conceived for radiation protection only, RAMSES also integrates some conventional environmental measurements such as physico-chemical parameters of released water and levels of non-ionizing radiation. RAMSES generates local radiation warnings, local alarms as well as remote alarms on other monitored variables, which are transmitted to control rooms. It generates operational interlocks, allows remote supervision of all measured variables as well as data logging and safe, long-term archiving for off-line data analysis and reporting. Requirements of recent national and international regulations in combination with CERN's specific technical needs were translated into the RAMSES specifications. This paper outlines its scope, its organization, its main functions and its basic design.

INTRODUCTION

The operation of CERN's accelerators inevitably results in the production of ionising radiation and radioactivity due, to nuclear interaction of high-energy beam particles such as protons with matter (air, accelerator components, tunnel structure…).

The radiation levels around the LHC, its supporting facilities and in the environment need to be monitored continuously. Protecting the public and persons working on-site from any unjustified exposure to ionising radiation is a legal requirement. It is also a legal obligation to check well in time that the annual limits set by the environmental regulations in force will not be exceeded. All reasonable measures will be used to minimize exposure (ALARA principle). Obviously, these measures must take into account the latest developments in science and technology [1] and therefore a state-of-the-art radiation monitoring system is required to enable CERN to run the LHC in conditions fulfilling CERN's safety requirements and other legal conditions.

Although the current radiation monitoring system is still performing well, the system is based on obsolete technology and it also has little or no flexibility for extension into new zones. Based on these observations, the RAMSES project was launched.

THE RAMSES PROJECT

The RAMSES project includes many aspects such as radiation monitoring, state-of-the art technologies, many system interfaces, compatibility with existing systems, and management of safety aspects. In this paper the main focus will be given to the scope of the system, the area monitoring, the environmental monitoring and the use of standards and directives.

Scope of the system

RAMSES contributes to minimize exposure and to document radiation levels by measuring the ionizing radiation dose rates and activity concentrations in released fluids as well as by signalling excessive dose rate levels via local and remote alarms. RAMSES monitors ambient dose equivalent rate at work places in and around the LHC installations and checks releases of air and water into the environment. Although originally conceived for radiation protection, it integrates some conventional environmental measurements. The system is one of CERN's main tools for avoiding unjustified doses to people or pollution of the environment and to verify that legal limits are not exceeded.

RAMSES is designed so that it complies with regulatory requirements for both the radiation protection and the environmental protection.

Area Monitoring

RAMSES measures the quantity $H^*(10)$, and thus is used for prospective dosimetry. This will facilitate radiation protection at CERN by enabling the designation of areas and workplaces, minimizing exposure (ALARA principle) and performing job planning.

In order to manage occupational exposure, RAMSES measures levels of ionising radiation, indicating the nature and the quality of the radiation in question. All measurements are recorded. The choice and position of the monitors in the surveyed areas has been derived from numerical calculations and long professional experience.

The radiation protection monitoring system will have to cope with two principal monitoring conditions related to the LHC beam modes: BEAM-ON and BEAM-OFF.

During BEAM-ON, RAMSES will monitor stray radiation (neutrons, relativistic charged particles, photons and muons) in areas accessible during beam operation.

During BEAM-OFF, RAMSES will monitor dose rates caused by radioactivity induced in accelerator components and their surroundings and by X-rays generated by RF cavity operation during shutdown periods.

Environmental monitoring

RAMSES provides the proper means to assess the effective dose to the population by measuring and logging stray radiation in the LHC surface areas (Photons, muons and neutrons), radioactive emissions (ventilation) and effluents (water), meteorological data and by collecting aerosol samples from the environment. The system also calculates the released activities of very short-lived radionuclides monitored on-line, such as ^{11}C, ^{13}N, ^{14}O, ^{15}O and ^{41}Ar in the ventilation, or ^{24}Na in liquid effluents.

Standards and directives

To take into account the issues of radiation protection legislation, quality, safety, operation & maintenance, project management and cost optimisation for the RAMSES project, standards and directives that summarize expertise and experience in the fields of safety and radiation protection have been chosen as guidelines for the project:

- The "Rapport préliminaire de Sûreté du LHC", 1999, describes radiological and non-radiological risks for the people and the environment.
- CERN's Radiation Safety Manual, Edition 1996, takes into account the legal requirements of CERN's two Host States.
- Directive EURATOM 96/29 [1].
- Swiss Ordinance on Radiological Protection 814.501, 22 June 1994, State 19 December 2000;
- Législation et Réglementation "Protection contre les rayonnements ionisant", Edition mise à jour au 31 août 2000 (ISBN 2-11-074950-4)
- Swiss Directive HSK-R-41 on the calculation of public exposure in the vicinity of nuclear installations due to radioactive releases (1997);
- IAEA Safety Reports Series No. 19 on generic models for use in assessing the impact of discharges of radioactive substances to the environment (2001).
- International Standard IEC 61508 [4] for global safety life cycle. This standard defines a generic approach and a technical framework for dealing systematically with safety related activities (to minimize system failures, optimise performance and to obtain homogeneity with the LHC site installations, maintenance and operation).

THE RAMSES FUNCTIONAL DIAGRAM AND ARCHITECTURE

The system functional requirements of RAMSES are based on current legal requirements, the Preliminary Hazard Analysis (PHA), [2] and are partially inspired by the experience with the present radiation protection monitoring system [5]. In the PHA document, specific LHC hazards are identified, risks are evaluated and safety functions are allocated to reasonably reduce the identified risks. A similar approach has been applied to the conventional environmental protection functions.

The system can achieve its safety objectives by implementing the following set of functions: monitoring, radiation alarms, operational alarms and interlock. Details can be found in ref. [6].

The implementation of the functions described above is illustrated in the RAMSES functional diagram shown in Figure 1 and in a conceptual architecture (see Figure 2), which considers three equipment categories: RAMSES Monitoring Stations, RAMSES Software Infrastructure, and CERN Integration Modules.

For the sake of simplicity, the functional diagram is explained only for the radiation protection functions of the system. The conventional measurements are handled in a similar way.
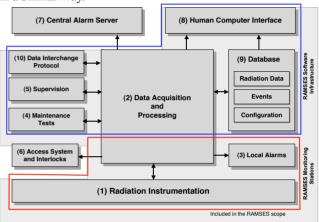

Figure 1: RAMSES functional diagram

The core of RAMSES is the **(1) Radiation Instrumentation**. It represents the radiation detectors and radiation monitoring equipment that are capable of measuring the dose rate due to the ionising radiation of various types occurring around the LHC. About 350 detectors need to be installed for the LHC. A complete description is given in [7].

The **(2) Data Acquisition and Processing** is the brain of the system. It gathers data from the Radiation Instrumentation, processes these data and generates local and remote alarms. It is a scattered system with a central supervision. Local control units work independently of each other and of the central supervision for safety reasons. The local control unit can generate visible **(3) Local Alarms**. Remote alarms are generated in the CERN **(7) Central Alarm Server** via the central supervision. The data is acquired in different formats according to the detector type. However, all data are standardized at the central supervision level. The central supervision will interface to the present radiation monitoring system.

Another function of the system is the communication with the **(6) Access System** and providing **Interlocks** for systems that present high radiation risks (i.e. RF systems).

To carry out off-line analyses, RAMSES stores in a **(9) database** the **Radiation Data**. In addition, to achieve the required homogeneity and to avoid data incoherence between different local control units, the system also stores its own **configuration** data in the database, such as

alarms levels, equipment addresses or interfaces. The system also stores in the database **Events**, like alarm information, change of settings, etc.

A global **(5) Supervision** manager monitors various parts of the system for diagnostic coverage and ensures that they work correctly. RAMSES provides a user-friendly **(8) Human Computer Interface** for handling and analysing the data under various conditions. It also provides means to carry out **(4) Tests, Maintenance and Calibration** of the detectors.

Finally, data are exchanged with all Control Rooms through the **(10) Data Exchange Protocol**.

CONCLUSIONS

The RAMSES is an ambitious and complex project that will provide CERN with a highly reliable, homogeneous and state-of-the-art radiation monitoring system for the LHC era. The main challenges of the project are the constraints of integrating a wide range of radiation monitors, including old systems with new ones into the same safety concept, the reliability and availability requirements and the large area to be covered.

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REFERENCES

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[3] G.R. Stevenson "Design Values of Doses and Dose Rates outside the shielding of the LHC", CERN/TIS-RP/IR/99-28.

[4] International Standard IEC 61508 "*Functional safety of electrical / electronic / programmable electronic safety-related systems*" *(E/E/PE) system*.

[5] The ARCON description and User guide, CERN document, EDMS No: 308877.

[6] RAMSES Functional Specifications, LHC Project Document No: LHC-P-ES-003, EDMS No: 384721.

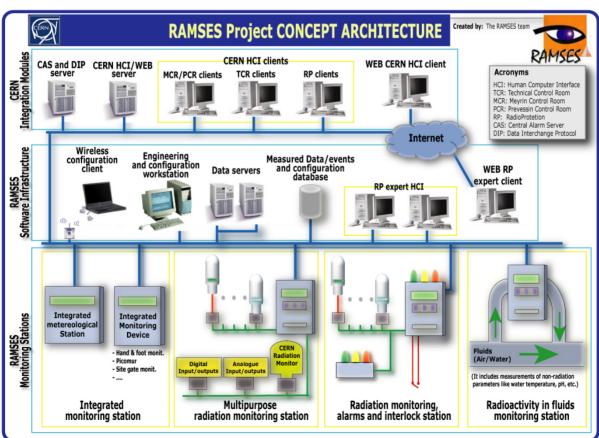[7] RAMSES Technical specifications, LHC Project Document No: LHC-P-CI-0002, EDMS No: 384719.

Figure 2 - RAMSES Project CONCEPT ARCHITECTURE