RAMSES: THE LHC RADIATION MONITORING SYSTEM FOR THE ENVIRONMENT AND SAFETY

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ABSTRACT

A state-of-the-art radiation monitoring and alarming 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 ambient dose equivalent and ambient dose equivalent rates measurements 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 the monitoring of conventional environmental measurements such as physico-chemical parameters of released. All data is acquired by a distributed set of data acquisition and control units that also generate local radiation warnings, local alarms and operational interlocks. Some monitoring stations have processing units for the control of some complex measurement processes. A centralised SCADA application allows remote supervision of all measured variables and remote alarms on monitored variables. Data logging and safe long-term archiving for off-line data analysis and reporting as well as configuration management is realised with an integrated database storage, data analysis and configuration management tools. This paper describes the implementation of the software infrastructure, highlighting the different architectural choices with their benefits.

INTRODUCTION

The operation of particle accelerators produces ionizing radiation and induced radioactivity due to nuclear interaction of high-energy particle beams with mater. In the case of the Large Hadron Collider (LHC), high-energy proton beams will interact with air, accelerator components, concrete, soil, and so on, producing ionizing radiation and induced radioactivity.

CERN's radiation protection policy [1], in line with radiation protection regulations in force in the Host States, stipulates that the exposure of public, persons working on-site and the radiological effects on the environment shall be as low as reasonably achievable (ALARA principle). Radiation monitoring is one of the means put in place to achieve this goal.

The present radiation monitoring system in operation at CERN (ARCON) [2] is fully operational and performing well but is based on old technology and it is not flexible enough to be extended to the LHC. Therefore CERN launched the RAMSES project with the goal of supplying the LHC with a state-of-the-art radiation monitoring system for the LHC era that fulfils CERN's safety requirements as well as other legal requirements. This system will take into account the latest development in science and technology [3]. RAMSES will be the radiation monitoring system for LHC and CNGS and will replace the ARCON system that was introduced for LEP (about 15 years ago) and which is presently used at all existing CERN installations.

The RAMSES project applies the International Standard IEC 61508 [4] that defines a generic approach and a technical framework for dealing systematically with safety related activities and establishes the full life cycle of electrical / electronic / programmable electronic safety-related systems.

In this paper the main focus will be given to the RAMSES functional requirements, its architecture and its implementation.

SCOPE OF RAMSES

RAMSES contributes to minimize exposure and to document radiation levels by measuring the ionizing radiation and radioactive releases as well as by signalling the presence of excessive radiation via local and remote alarms. RAMSES monitors ambient dose equivalent rate at work places in and around the LHC installations. It also monitors the release 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.

FUNCTIONAL REQUIREMENTS

The RAMSES functional requirements are based on current legal requirements, the Preliminary Hazard Analysis (PHA) [5], and are partially inspired by the experience with the present radiation protection monitoring system [2]. 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 of RAMSES.

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

The implementation of the functions described above is mapped in the RAMSES functional diagram shown in Figure 1and in a conceptual architecture (see Figure 2).

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

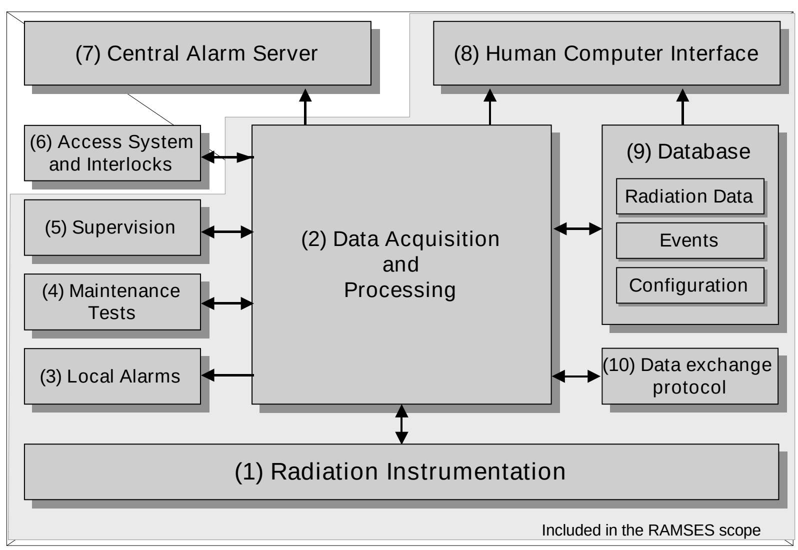

Figure 1 RAMSES functional diagram

The foundation of RAMSES is the *Radiation Instrumentation* (1). 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 Data *Acquisition and Processing* (2) is the brain of the system. It gathers data from the Radiation Instrumentation processes 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 *Local Alarms* (3). Remote alarms are generated in the CERN *Central Alarm Server* (7) via the central supervision.

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

RAMSES stores the collected data in a *Radiation Data* database (9). 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, such as alarms levels, equipment addresses or interfaces, in the database. The system also stores in the database Events, like alarm information, change of settings, etc.

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

Finally, data are exchanged with other systems through the *Data Exchange Protocol* (10).

SYSTEM ARCHITECTURE

The RAMSES system architecture as presented in Figure 2is organized in three layers: (a) *Monitoring Stations* layer, (b) *Software Infrastructure for Supervision* and the (c) *CERN Integration Modules*. The following sections explain the architecture at each level and give details of the implementation.

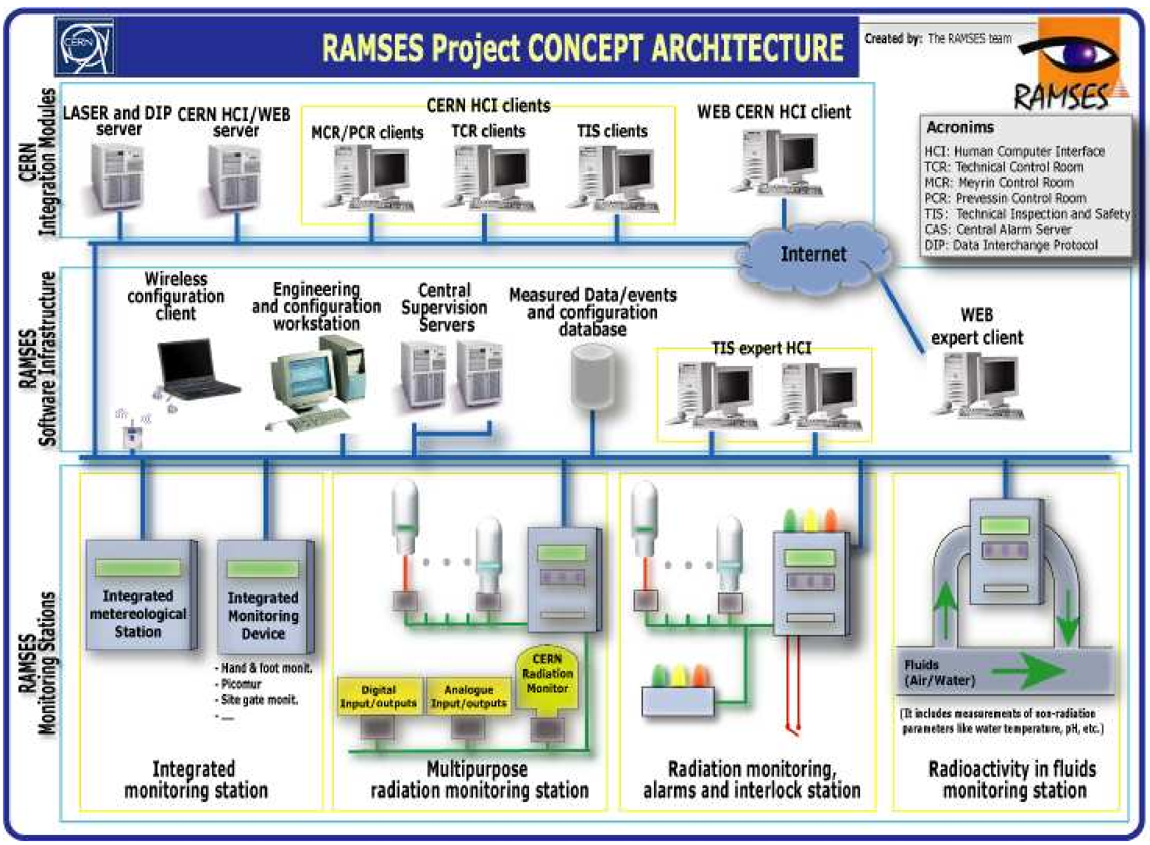

Figure 2 RAMSES architecture

MONITORING STATIONS

The Monitoring layer is composed of a set of Monitoring Stations (MS) of 10 different types. The monitoring stations are installed in LHC underground areas as well as on the surface inside and outside the CERN perimeter. The coverage of the complete LHC requires 104 monitoring stations controlling a total of 350 monitors. The monitoring stations provide data (measured values, time stamps, status, etc) at very different frequencies depending on the type of monitor going from 1 value every few minutes to 1 value ever 0.1 seconds. The values are provided 24 hours a day 365 days per year.

Most of the MS share the same architecture: a central unit (PLC) controlling a group of up to 8 detectors and/or measurement devices (radiation monitors or others devices), some of them also equipped with a set of alarm *units i.e.*, devices that display local visible and audible signals that are aimed at evacuating personnel from areas in case of elevated radiation levels.

Very often, in order to cover large areas, detectors and alarm units are installed at distant positions from the controller and connected to it through two separate RS485 field-buses, one for detectors and one for alarm units.

How do monitoring stations work? The controller collects measured values from the monitors, locally processes the data and decides to activate alarm units in case of exceeding established alarm thresholds. MSs are also able to provide interlocks to external systems in case of high radiation. The measured values and alarms are locally stored and transmitted to the central supervision servers.

In order to fulfil safety requirements, each MS is an autonomous cell in the way that it is able to perform its monitoring/alarming/interlocking role independently of other components of the RAMSES system. The MSs are equipped with uninterruptible power supplies that allow them to work without external electrical supply at least for 2 hours. This time allows the system to deal with short power cuts and assure alarm units to be powered if necessary. In addition, in case of network outage and consequently the lost of connection with the central database, the MS are able to locally archive measured values for 5 days.

The MS implements auto-check and auto-diagnose functions (detectors, alarm units, UPS, communication) so that any fault state is displayed by the alarm units and signalled to the supervision layer. This capability is extremely useful to monitor the correct functioning of the system and so reduce fault diagnose and recover times.

Redundancy is a common feature of many safety systems. In the case of RAMSES redundancy can be achieved at the monitoring layer by duplicating monitoring stations.

SOFTWARE INFRASTRUCTURE FOR SUPERVISION

All the monitoring stations are connected to the RAMSES servers by a TCP/IP network. Central servers are in charge of collecting measured values, radiation alarms, system faults and other status variables from the monitoring stations. The data is provided by the monitoring stations in different formats according to the detector type. However, all data are standardized at the central supervision level.

Measured values, alarms and system faults are stored in the central database for off-line analysis and reporting. Measured values are intended to be stored ‘forever’. RAMSES provide software tools to display and analyse the data as well as export capabilities to other software tools.

The RAMSES database is also the central repository for system configuration and maintenance, for this reason, the configuration of the system itself is stored *i.e.*, alarm thresholds, monitoring station configuration and the configuration values of the different detectors.

RAMSES provides users with a user-friendly interface made of a collection of synoptic views that presents the LHC underground and surface areas. Each view displays live radiation values and radiation alarms at the place where they are measured, and allows users to display measured values in plots or tables. In addition the user is provided with centralized view of the RAMSES installation facilitating as well as a set of tools for diagnose of system faults. The user interface has specific functionalities for remote configuration of the monitoring stations, radiation monitors and alarms.

The central supervision has been implemented by a redundant SCADA server communicating with the monitoring stations using OPC. For performance reasons, some important functions have been implemented outside of the SCADA program. In particular, the constant follow of data (24 hours a day hours 365 days per year) coming from the 350 monitors (measured values, time stamps, status information, etc) for some of them at a rate of 0.1 seconds, reaches the limit of what the SCADA program can inject into the database. For this reason the insertion of data into the database is done by a dedicated mechanism external to the SCADA application.

CERN INTEGRATION MODULES

RAMSES is able to work standalone but it integrates the LHC control infrastructure by exchanging data with the Control Room:

- An interface to LASER [8] allows RAMSES to inject radiation alarm and technical alarms that are of interest for the accelerator to the LHC central alarm servers.
- A DIP [9] interface Data Interface Protocol makes possible the exchange of data with external systems.

CONCLUSION

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.

Here after some pictures of the RAMSES at work:

Picture 1. Inside the control unit of a monitoring station.

Picture 2. Monitoring station: control unit, detector assembly and ionization chamber.

Picture 3. Central supervision: redundant servers and screens.

Picture 4. Monitoring station ready to be installed in the CERN environment.

ACKNOWLEDMENTS

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