

CONTROLS SOFTWARE FOR THE LHC RADIATION MONITORING SYSTEM

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Abstract

This paper describes the software that is used to control and read out 400 radiation monitoring devices distributed along the 27 km long tunnel of the Large Hadron Collider (LHC). The entire system is database driven and provides on line information on the radiation levels at a rate of Hz. Particular attention will be given to the various databases, operational alarms, timing and data viewers including a new data visualisation tool.

INTRODUCTION

A large amount of semiconductor electronics is needed to control and operate the LHC accelerator. To optimize the S/N ratio and to reduce the cabling costs, approximately 13500 electronic crates have been placed under the superconducting magnets close to the two counter rotating proton beams. During operation of the accelerator, some protons will interact with material and this will create particle radiation at the location of the electronics. The exposed semiconductor electronics will suffer from instantaneous damage from Single Events and cumulative radiation damage from neutrons and total ionizing dose.

Approximately 400 radiation monitors [1] have been placed close to the electronic crates to measure the total ionizing dose and the low and high energy neutron fluencies on line at a rate of 1 Hz. The spatial and temporal resolution is sufficient to provide insight on how the machine is operated and how the radiation levels evolve as a function of time. In addition, they provide early warnings when the radiation levels start to rise. In case of electronics failure, the system will allow to separate between the various damage mechanisms. Finally, radiation monitors will help to evaluate the actual performance of the radiation tolerant systems when the machine is operating.

The controls software that is described in this paper, communicates with the monitoring devices located in the underground tunnel over a WorldFIP fieldbus to the 24 Front End Computers (FECs) that are located in the surface building in each of the 8 octants of the machine. The FECs are connected to the CERN gigabit Ethernet backbone for accelerator controls. After some local processing at the level of the FECs, data is stored in an ORACLE based logging database [9]. Upon request, users can access the raw data via a general user interface. Alternatively, the expert data viewer provides the user with the possibility to process the data further and perform a more detailed data analysis.

The FEC software has been in use since 2005 and has been continuously upgraded to extend the functionality. It has allowed first successful data taking during the startup of the LHC in September 2008.

SYSTEM ARCHITECTURE

A total of 24 fieldbus segments constitute the basis of the system architecture (Fig. 1). Each segment can host a maximum of 32 monitors. The WorldFIP [2] fieldbus protocol was chosen for this application because of its real time performance and because it can cover large distances of several kilometers. The distance of a WorldFIP fieldbus segment for the system present here can be more than 2 km long. Moreover, WorldFIP interfaces are relatively immune to Single Event [2].

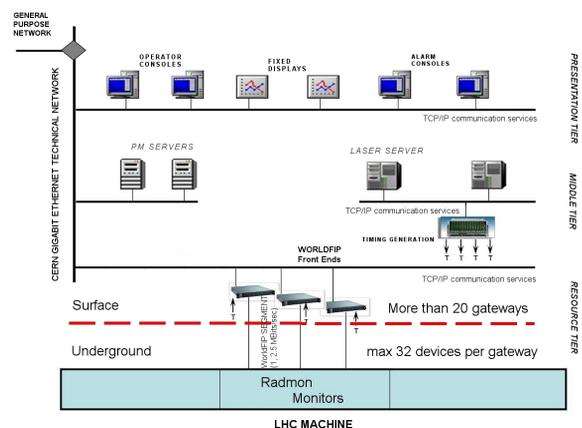


Figure 1: Schematic view of RadMon Fieldbus segments and the associated Front End Computers (FECs). The FECs are connected to the gigabit Ethernet backbone.

Each WorldFIP segment is connected to FEC that acts as the bus arbitrator for the segment. The FEC is equipped with a timing receiver card which is connected to a dedicated accelerator timing network [3]. The network distributes the UTC time for data time stamps and timing events for synchronization as well as a number of information about the status of the machine.

The FECs are standard commercial industrial PCs [4] with a Linux operating system. The FECs are diskless and boot over the gigabit Ethernet backbone. This network is dedicated for accelerator operations.

The network connectivity also provides easy access from the FEC to the CERN wide computing services such as the settings database, the short and long term logging and the post mortem database.

SOFTWARE ARCHITECTURE

The software architecture (see Fig. 2) is currently deployed in the Front end computers.

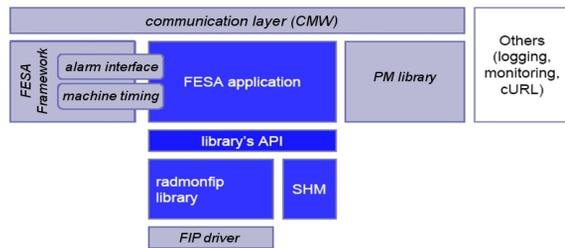


Figure 2: RadMon Front End Computer Software architecture.

The Radiation Monitoring C/C++ application (RadMon) has been developed in the FESA [5] framework (Front End Software Architecture). FESA is a comprehensive framework whereby front-end software is to be designed, developed, deployed and maintained according to an in house CERN standard. FESA facilitates and homogenises the integration of front end devices such as PLCs, VME modules, CCD cameras in the CERN control system. It provides a stable and homogeneous environment for development; a CVS based source code management, automatic code generation and a graphic interface to define properties, actions, events. The main advantage for the developer is the access to different kind of services (e.g alarms, timing, post mortem) via predefined classes. If needed, the user can write custom made classes for specific use. Each user is responsible for the software implementation and maintenance of his front end and can adapt it according to its own requirements. The end result is an executable program (device class), which operates on one or many user's front-end CPUs (FEC) and which performs all of the required tasks.

Shared Memory (SHM)

The inter process communication on the FECs is based on a large Shared Memory which has the advantage of speed and avoids copying the data. The data that is stored in the shared memory is the raw data from the RadMon devices. An external library provides direct access to the data in the shared memory. This facility is used mainly during the installation and commissioning phase to debug the installed tunnel hardware.

Radmonfip Library

The radmonfip library provides the low level communication with the radiation monitoring devices in the tunnel via the WorldFIP fieldbus. This includes tasks like initializing the devices, configuring the bus arbitration tables, definition of the macro cycles, definition of the type of messages, read and write commands and a get status command. The library also provides access to the shared memory within the FESA classes.

FESA Application Classes

The RadMon project has got two distinct Fesa classes, which are related. The first class is the RadMonDev class which describes the details of the device data and presents the data. The second class is the RadMon class which provides the following main functionalities:

- Communicate with and retrieve data from RadMon devices located in the underground areas using the radmonfip library
- Representing the data in human-readable form in the Control Room or for on or off-line analysis
- Storing data on line in the various databases
- Generate Post Mortem reports after a beam loss

Communication Layer

The Controls Middleware (CMW) [6] communication layer provides the high level software communication for the FESA applications. This software suite provides standardised solutions which are transparent for the end users.

Machine Timing

The central timing system distributes the accelerator timing events and the UTC time to all FECs on the machine control network. The use of a dedicated timing network guarantees fixed latencies and therefore the front-end computers and associated WorldFIP segments can be synchronised to a precision close to the timing signal jitter.

For the application described here, the timing signal is processed with a FESA class. The input parameter for the class refers to the name of an event object that links the logical events to accelerator or hardware interrupts. The WorldFIP fieldbus is a real time field bus and transmits messages at fixed time intervals which are defined in the bus arbiter list. On every cycle, 8 bits of device data can be sent or received via the bus. The device data is stored in a large buffer for each device on the segment. Once every second, the fieldbus manager collects the data from the buffer and constitutes a complete data point for each of the devices on the segments. A data point for one RadMon device consists of 104 bytes.

PostMortem (PM) Library.

Post Mortem [7] is a specific General Machine Timing (GMT) event that is distributed via the timing network when there is a machine failure or a beam loss in the LHC. In this situation, all electronic equipment will provide data from a short period of time but with a very high timely precision. In the case of the RadMon system, the entire data stored in the shared memory from each FEC is made available to the expert with a timely precision of 100 ms. Several cycles after the event the data taking is frozen and data sent to the Post Mortem server and the PM database in ASCII format with self-describing header information.

Logging Databases

During operation, data from the monitors is stored on line in a database, named the measurements database. To store the data, the RadMon class implements an XML scheme which takes care of the parsing and loading process. The data in the measurement database is stored for a period of one week before it is overridden. The timely resolution of the data in the measurement database is 1 s.

A subset of the data from the measurement database is stored on a long term basis. The timely resolution for the long term data storage is regulated and can be either at fixed intervals (e.g. every 10 minutes) or when the data value has changed ('log on change').

Settings Database

The radiation monitoring system is entirely database driven. Every radiation monitor has a unique hardware address and a specific hardware configuration. In the settings database, each hardware address is linked to a hardware setting and the associated sensor calibration. Records in the database can be added, removed, edited and associated through the use of simple webpage based forms.

The sensor calibration data is needed to convert the raw data from the monitors to physics data stored in the logging database. After each hardware modification, a new configuration file for the FECs is generated using a web form application. Upon boot time the FECs upload this file and then scan the complete field bus segment to detect the hardware addresses of all devices that are connected to the segment and operational. The RadMon class then performs the association between hardware address and calibration data so that the raw device data can be interpreted correctly.

The settings database also associates each monitor with a unique junction box in the underground area of the LHC. A RadMon radiation monitor can thus be connected to any WorldFIP TAP box in the LHC which facilitates maintenance and operation.

Equipment Alarms

The LHC alarm system is known as Laser Alarm interface or LASER [8]. This system communicates the operational equipment status to the equipment owners and to the consoles in the LHC control room.

RadMon uses the integrated device class in the FESA framework to collect, store and manage information from the radiation monitors. Alarms generated by the monitors can indicate for example, an abnormal operating temperature, bad communication via the fieldbus, or high current consumption. Once the accelerator is stopped, the device owners can ask to access the underground tunnel to intervene on the hardware.

Each alarm provides the hardware address of the device, a short description of the problem and the name and telephone number of the person in charge.

DATA VIEWERS

The raw radiation data that is stored in the SHM segments in the FECs can be viewed on-line via the radmonfip library. This option is mainly used to verify the monitoring hardware.

Data that is stored in the short or long term logging databases can be accessed via a web-based interface named TIMBER [9]. This interface allows users to select variables of interest within a time range, and then either see a statistical summary of data logged, or visualize the data in an interactive chart, or extract the data to a file. Since September 2006, every CERN user has access to the operational data from every monitoring device installed in the LHC tunnel and experimental caverns from his office.

For expert data analysis a data viewer Java API has been developed. This application also collects the data from the measurements database but it proposes several types of mathematical tools for data filtering and analysis and proposes several scientific formats for the data display.

Finally, the PM Data Viewer and PM Data Browser applications make possible to view the content of the Post Mortem files or browse the Post Mortem data repository and view the content of the selected data files.

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