THE FIRST STAGE OF THE POST MORTEM ANALYSIS SOFTWARE USED FOR THE HARDWARE COMMISSIONING OF THE LHC

A. Rijllart, B. Khomenko, D. Kudriavtsev, A. Raimondo, H. Reymond, N. Trofimov, CERN, Geneva, Switzerland

Abstract

After a failure during the operation of the LHC, leading to a beam abort or a power abort, a coherent set of so called "Post Mortem" information will be collected from the various sub-systems to analyze the causes of failure. To be able to understand the failure before resuming LHC operation, the collected information needs to be analysed within a few minutes and this requires a highly automated analysis system. To develop the Post Mortem Analysis software, we use a staged approach by providing self-contained software modules, first for the individual systems, such as the Quench Protection System, the Power Converter and the Power Interlock Controller, and second for the hardware commissioning when these systems will interact. All of these modules are made using LabVIEW™ and form the building blocks of the final Post Mortem Analysis software. A large part of the code developed over the last years for the quality test of the LHC magnets has been reused, profiting from the similarity of the algorithms. This paper describes the present state and the additional stages needed to build the final system.

INTRODUCTION

Many systems of the LHC, such as the Power Converters, the Quench Protection and the Interlocks, have been designed to acquire data of their most important parameters in circular buffers during operation, for the purpose of Post Mortem analysis in case of a fault [1]. Upon reception of a Post Mortem trigger, these buffers can be frozen and transmitted to the Post Mortem system for storage and analysis [2,3]. During the LHC Hardware Commissioning, each system is first tested individually and in a second step several systems interact together when combined for powering and protecting one superconducting circuit. Our software architecture has been based on satisfying these initial requirements and preparing the way for building Post Mortem events from a coherent data set suitable for global event viewing and analysis.

Using our experience as measurement and analysis systems developers, based on LabVIEW programming and industrial components, we have selected a modular design and a staged approach for the implementation. Our involvement in systems for the measurement and qualification of the LHC magnets, both at CERN for the reception tests and in industry during their assembly, has confirmed this solution as a good compromise between development cycle time, maintainability and expandability [4].

Some of our previous developments also serve in this project, by reusing many analysis modules in LabVIEW, communication techniques and software integration methods. The great number of mathematical and analytical functions proposed by LabVIEW, associated with its easy way in building a graphical user interface, has lead to the development of tools fully in phase with the user requirements.

SYSTEM OVERVIEW

The Post Mortem system is centralised around a server that collects and stores data from client systems that do not have hard disks, converts the data from the binary client format into a standard format (SDDS-Self Describing Data Set [5]) and creates a file system to easily retrieve this data. Post Mortem client computers running the data viewers connect to the server using NFS for Linux and SMB for Windows clients. The applications for the individual systems' analysis also run on client computers connecting to the server. Analysis output is generated in files that can be uploaded into the MTF (Magnet Test Folder) database.
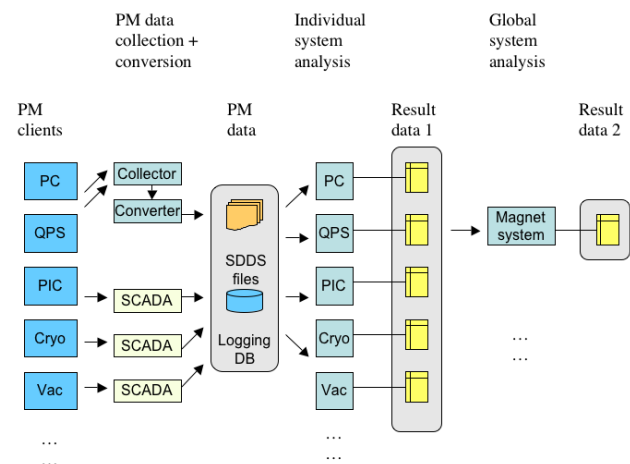

Figure 1. Architecture of the PM system

RAW DATA COLLECTION

Each PM client makes a connection to the PMCollector task on the PM server using a client API written in C++ for this purpose. The data is sent either as a memory dump or as a data object to the PMCollector that stores it in the received format. The PMCollector notifies the PMConverter of the arrival of new data.

DATA CONVERSION TO SDDS

The data conversion is based on a description file per client file format, called PMX. It describes in a simple text format the type and amount of all data stored in the client buffer and allows a generic converter, written in C++, to create the SDDS (Self Describing Data Set) file, in both binary and ASCII format.

Some client data is already in the form of a structured data object and its conversion into SDDS does not need the PMX descriptor.

The converter uses subscription to a property of the collector to be informed of the arrival of new files for conversion. The average conversion time of a 1.5 MB file is about 50 ms.

THE PM BROWSER

In parallel with the development of the data collection and conversion system, a viewing tool has been designed and proposed to the experts of the post-mortem data clients. The GUI is made of three specific areas, which give a set of functionalities. The first one, based on the PM server folder tree allows selecting an event. For this, the user has to choose the system, the equipment type, and the event itself according to its creating date. A basket feature can be used to accumulate a set of events, from which a selection can be made which signals to plot. Here the possibility is given to save and load a set of signals. This allows the experts to define "fixed views" (pre-selected lists of signals), which is useful for repetitive analysis. The data can also be shown in tabular form. Many plots and tables can be shown simultaneously. A third area is reserved to specify a search, which can be by date, type of equipment or location, but also by type of fault, string pattern of the circuit name or trigger source.

ANALYSIS PER SYSTEM

The analysis per system is done with a specialised application per system, where the expert can select, view and apply analysis functions to specific data sets.

For the power converters the analysis is first focused on eventual fault states. Then the expert can select and view analogue signals in a graph and apply first and second order derivative calculation, FFT and special scales to verify the proper functioning of his converter. He can also view state changes in tabular form to check the internal functioning of the converter.

The Quench Protection System PM analysis application has a similar set of viewing functions, but the analysis is based on a predefined set of verifications that are shown in tabular form and can be saved in XML format.

The Power Interlock Controller analysis is based on pattern recognition of seven different sequences produced by a set of digital signals. The data is displayed in three simultaneous graphs and the output is shown in tabular form.

Each individual system analysis has common requirements, such as selecting a data set, selecting signals and performing certain checks. A signal selection and analysis template has been made to describe the analysis in a uniform way across systems.

EVENT BUILDING AND VIEWING

Each system time stamps its own data set at the time of recognition of the event and with its own accuracy. This makes that a trigger generated by a power converter, received by the interlock controller and subsequently retransmitted to the quench protection system will have all slightly different time stamps. The event builder identifies data sets with closely spaced time stamps and checks if they belong to the same circuit. The data of such an event can be loaded for viewing and an automatic zoom and delay time calculations are performed by the application to help the operator decide if the delays were within limits. The view is composed of an analogue and digital plot synchronised in time. Information relative to the event itself is presented on the top of the view (circuit name, test type, timestamp of the event). A screen shot of the final signal display is being saved and uploaded to MTF, together with the decision of the expert if the test passed or failed.

CONCLUSIONS

The first stage of the post mortem analysis system has been used during the hardware commissioning of the LHC sector 7-8. It has been built bottom up from four different individual systems' analysis modules and one combining the results from the others to perform the circuit analysis. Because of its ability to show signals from different systems into two time synchronised plots, one for analogue signals and one for digital, it has been an important help for all the teams involved in the test and validation of the several sub-systems, such as power converters, power interlock controllers, quench protection systems and cryogenic.

In the chosen architecture, new client systems can be integrated easily, because of the modular approach of the building blocks, first per system and second per event. A total of 20 clients are foreseen for the final PM system.

A test of the general emergency stop has been provoked in July 2007, which caused 143 equipment data sets to be transmitted simultaneously to the Post Mortem system. This allowed us to perform a scalability test, to verify the efficiency of the data collection and the conversion of the data.

REFERENCES

[1] R.J. Lauckner, "What Data is needed to Understand Failures during LHC Operation?", Proc. Chamonix XII, CERN-SL-2001-003-DI, January 2001.

[2] J. Wenninger, The LHC Post-mortem System, LHC-project-note-303; Geneva : CERN, 15 Oct 2002.

[3] R.J. Lauckner, "What do we see in the control room", Proc. Chamonix XII, CERN-AB-2003-008, March 2003.

[4] A. Rijllart, Industrial Controls for Test Systems from Superconducting Stands till Magnet Fiducialisation in the tunnel for the LHC project, ICALEPCS'05, Proceedings, PO2.005-2, 2005.

[5] A Brief Introduction to the SDDS Toolkit, M. Borland, Argonne National Laboratory, USA, 1998, http://www.aps.anl.gov/asd/oag/SDDSIntroTalk/slides.html