CERN ALARMS DATA MANAGEMENT: STATE AND IMPROVEMENTS

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Abstract

The CERN Alarms System - LASER is a centralized service ensuring the capturing, storing and notification of anomalies for the whole accelerator chain, including the technical infrastructure at CERN. The underlying database holds the pre-defined configuration data for the alarm definitions, for the Operators alarms consoles as well as the time-stamped, run-time alarm events, propagated through the Alarms Systems.

The article will discuss the current state of the Alarms database and recent improvements that have been introduced. It will look into the data management challenges related to the alarms configuration data that is taken from numerous sources. Specially developed Extract-Transform-Load (ETL) processes must be applied to this data in order to transform it into an appropriate format and load it into the Alarms database.

The recorded alarms events together with some additional data, necessary for providing events statistics to users, are transferred to the long-term alarms archive.

The article will cover as well the data management challenges related to the recently developed suite of data management interfaces in respect of keeping data consistency between the alarms configuration data coming from external data sources and the data modifications introduced by the end-users.

INTRODUCTION

The Alarms Service, LASER, is a critical system, used during the Operation of CERN's accelerators.

The existing service was developed for handling the abnormal situations for all accelerators and with the Large Hadron Collider in particular [1]. Previous implementations of the system were done for the PS complex [2] and for the SPS complex [3].

The alarms data management is an important part of the Alarms service. Already since the beginning of the 1980s there was an idea to implement a data driven alarms system for the PS Complex Controls.

Since 1986 a relational database and in particular the Oracle® RDBMS was chosen as the basis for the alarms data management.

SCOPE

At present the data stored in the Alarms Database covers the needs for an alarms service for all accelerators at CERN. The database contains data for the Fault States (abnormal situations) of the accelerators' devices controlled by the Controls System, e.g. magnets, beam monitoring devices, etc. The data stored in the LASER DB is used for the Technical infrastructure alarms, e.g. alarms for the areas of electricity, cooling, etc. It covers also the safety systems, the radiation monitoring system, the computer network alarms as well as alarms data for abnormal situations in the Controls software itself.

All of the above listed domains of alarms data are called providers and there are 31 in total. This accounts for more than 3,000,000 data elements stored in the LASER DB.

AREAS OF THE ALARMS DATA MANAGEMENT

There are three distinct areas of data, which are part of the Alarms data management.

Configuration Data for the Alarm Definitions

The main pieces of data that build-up the alarm definitions are the fault family, fault member within a family and the fault code of a given family. The combination of those three pieces of data uniquely identifies an alarm at CERN and represents the fault state. Additional attributes, provided by the configuration data, are the priority of the alarm, the action to be taken, etc.

The alarm definitions configuration data is extremely important due to the principle of LASER that all fault states must be defined in the LASER DB prior to their use. The LASER service will not accept and propagated events, whose definitions are not in the Alarms database.

Configuration Data for the Users Consoles

As the name suggest the data in this area is used for configuring the displays on the Operators Alarms Consoles. It includes the operators' category structures, which help the users to group the alarm events on their screens, preferences of displayed categories on the consoles, filters for the events, etc.

Run-time Alarms Data

The run-time alarms data is the time-stamped alarm events, which are coming from more than 220 sources. An alarm event is the activation, termination or update of the fault state. The LASER server processes the events data and stores it into the LASER DB. The run-time events are distributed to approximately 50 client consoles so that the users will be notified of fault states.

OVERVIEW OF THE ALARMS DATABASE ENVIRONMENT

For the purposes of the Alarms data management several db accounts are used. The main accounts are depicted in Fig. 1 as well as the ETL processes, which are used for LASER data configuration and archiving.

Alarms Configuration Data Collection Account

The Alarms Configuration Data Collection db account is used in order to collect all alarms configuration data

from the different providers. The data could be provided in the form of different db objects, e.g. views, materialized views or tables. There are 31 starting objects, which correspond to the 31 data providers. All of those objects have a standardized structure and contain the same type of configuration data. This is done in order to solve the problem of unifying the data from so many diverse providers as well as to ease the data import process.

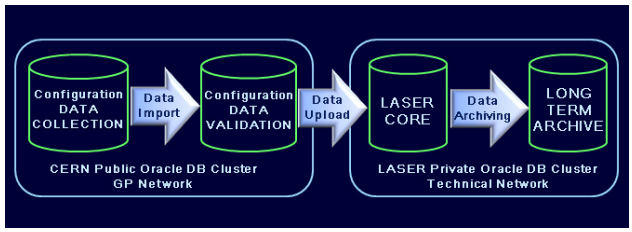

Fig. 1: Overview of the LASER data management environment – main database accounts and ETL processes.

Alarms Data Validation Account

The configuration data for the alarms definitions is not directly imported from the Data Collection into the LASER Core account. Due to the complexity of the process to validate the data and to transform it into the final destination format the loading of the alarms data passes through an intermediate stage.

LASER Core Account

The Core database account holds all the configuration alarms data, which is used directly by the LASER server. The account contains the user preferences and consoles configuration, which are extracted via a set of views and provided to the LASER consoles. The same account also stores the on-line alarm events in the form of a short term alarms archive, which contains data for the last six months. There are 200,000 time-stamped events recorded on average per day, however at peak times there could be up to 1000 events per second send to the LASER DB.

Alarms Long-term Archive Account

The long-term alarms archive has a completely denormalized schema and the structure is more like a data warehouse.

There is a PL/SQL procedure for transferring the on-line data into the long-term archive, which is executed as a db job once per day.

The long-term archive has been in operation since 2005. At the beginning of each year archiving of the previous year's data is done and between 4 to 10GB of data is added to the long-term archive. PL/SQL procedures, dedicated to this process, are used. During the long-term archiving a factor of 10 reduction of the data volume is achieved. Only the alarm record at activation time and at deactivation time for the alarm events are kept, thus all records between those two are removed.

Alarms Data Management ETL Processes

There are two main types of ETL processes, which are used for the Alarms data management.

The first type is related to the loading of the configuration data into the LASER Core account. The data needs to be validated carefully against the business rules, established for the alarms definitions and transformed into the required format. This is done in two stages due to the complexity of the data manipulations. The first process in the chain is called 'Data Import'. It takes the data from the Data Collection account and moves it to the Data Validation account. The Data Import process mainly verifies the validity of the provided data, while the second process, called 'Data Upload' has as a primary goal to transform the data into the required final format while still performing checks.

The second type of ETL processes are related to the archiving of the alarms data. There is a process that runs every day, which transfers data older than 6 months from the LASER Core to the Archiving account. Another process runs once per year in order to establish the long term archive for the previous year.

Complexity of the Database Schemas

Table 1 provides the exact figures showing the complexity of the alarms-related database schemas. The alarms database model is not a very complex one – altogether there are 207 tables and 241 constraints throughout the four main accounts. On the other hand due to the numerous validations, checks and transfers of data, part of the intensive ETL processes, there is a big PL/SQL code base.

Table 1: Alarms Database Accounts Statistics

Tables	207
Constraints	241
Lines PL/SQL code	32,000
Volume	195 GB

SERVICE QUALITY ASSURANCE

Database High Availability

One of the challenges in front of LASER DB is to provide high availability service - 24 hours a day, 365 days a year, as the Accelerators complex at CERN cannot function reliably without the Alarms system.

The high availability of the database is achieved through the use of Oracle cluster technology (RAC) which guarantees not only the hardware but also database software redundancy. The solution ensures no down time even during routine software patching of the database.

Another point in the strategy for high availability is to have a special db cluster dedicated only to LASER (private). This approach guarantees that no problem could be encountered due to other db clients on the same cluster.

Data Security

Data security is of utmost importance in the domain of alarms data management. A major improvement in this domain since 2009 was the deployment in the LASER Core account of several custom-developed diagnostics frameworks, allowing monitoring and traceability of *who* changed *what* and *when*. This is extremely important especially in the light of providing new applications to the end-users (accelerators operators) to be able to change some of the configuration data themselves.

The first framework audits every session opened in the LASER DB, while the second framework, the History one, records all data modifications and keeps them on-line, available to be accessed through a web-deployed LASER History Browser application.

Development and Testing Environments

The Alarms service is a critical one for the Operation of the Accelerators. The database part of the Alarms service is equally important and every piece of new code should be thoroughly tested.

Three environments have been provided, in order to ensure bug-free alarms data management. The ***Development*** environment is used for developing database functionality as well as developing the related Data Editing and Data Browsing applications and database APIs. The ***Test*** environment (created in 2010) is used for functional testing within the database tier as well as an integration testing environment of the vertical slice of the Alarms service – database tier and LASER server. The ***Production*** environment is the one used for the on-line Alarms data management.

ALARMS DATA MANAGEMENT CHALLENGES

Multiple Data Providers - Eliminating Scattered Sources of Alarms Configuration Data

The data management for the Controls and Operation of CERN's accelerators is implemented as a distributed database environment [9]. Previously the alarms configuration data was gathered from a significant number of databases, e.g. the Accelerators Entities and Signals Naming DB, etc. as well as some scattered db accounts.

During the last two years efforts have been put in place to eliminate dispersed sources of alarms definitions and to streamline them through the main databases, providing data to LASER DB. As a result of those efforts several db sources have been eliminated leaving only the databases shown in Fig. 2 to deliver the alarms configuration data.

An example of this strategy is the migration of the power converter alarms configuration data into the CCDB and its integration into the Hardware Controls devices framework [4]. This solution resolved the issue of synchronization between the devices data in the CCDB and the alarm definitions for the very same devices, which were previously kept in a separate db account. At present the data provided by CCDB accounts for almost 70% of the alarms definitions configuration data imported into LASER [6].

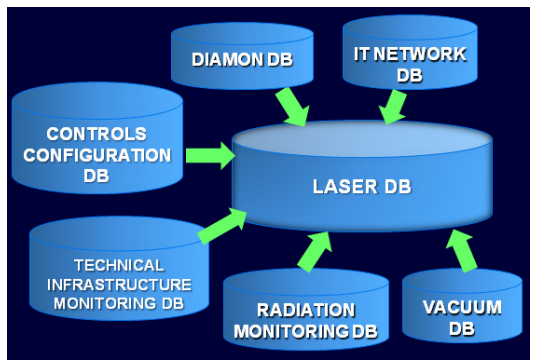

Fig. 2: Databases, providing alarms configuration data to the LASER DB.

The approach of unification of the sources of alarms configuration data guarantees not only a better maintenance of the alarms configuration data by the equipment experts, but it simplifies the process of initial import of the alarms configuration data.

Separation of Alarms Definitions Configuration Data from Users Consoles Configuration Data

An alarm system is supposed to give its users a better insight of the status of the different systems and particularly when problems arise. A badly configured alarms system (due to bad configuration data) will not achieve this goal. Typical problems, which arise in the CERN Controls Centre, are an alarm event not being seen by an operator, due to the alarm definition not being correctly configured in respect to the display category, or an alarm event appearing on the console of an operator of a given accelerator when it should not be there.

In order to solve the above mentioned issues, a clear separation needs to be achieved between the alarms definitions configuration data and the users' consoles configuration data. This means that the equipment experts should be responsible only for the alarm definitions while the operators take complete responsibility for the alarms consoles configurations data, including the assignment of alarm definitions to the operational alarms categories, which they monitor.

First steps in this direction were taken during the last year by providing some basic data editing applications through which the operators could set-up their own configurations of alarm definitions to categories assignments. One must however be extremely cautious with the data changes introduced directly into the LASER Core db as the current database model does not provide a clear split between the two alarms configuration data areas.

This problem is addressed in the new LASER Core database model, which is currently implemented in development environment and will be the basis for the renovated LASER service.

EXTENDING THE DATA MANAGEMENT FUNCTIONALITY

A lot of improvements and extensions of the alarms data management services were done during the last two years. Some of the new functionalities are related to extending the database model and some are related to providing new user applications for browsing and editing the alarms data.

Introducing Alarm Instructions

A new area of the Core LASER DB is the one of alarm instructions. This data is related to the configuration data of the alarm definitions and gives directions of what measures should be taken in case an alarm is activated.

Introducing Filtering of Alarm Events, Based on Accelerator's Beam Modes

The filtering of alarm events on the alarms consoles is an example of new functionality provided in the area of the user consoles configuration data. The alarm events that are usually displayed on the operators' consoles now could be filtered based on the beam mode of a given accelerator. This feature is extremely useful as it prevents the operators' consoles to be flooded with alarm events, which are not relevant under certain beam modes. At present the new functionality is used by the LHC Operation.

Development of a Suite of Data Management Applications

A major improvement in the Alarms Data management was the development of a suite of data management tools during the last two years. These applications give users the possibility to explore all alarms data and to maintain the configuration part of it. The choice of development technology both for the Data Browsing and for the Data Editing tools was Oracle Application Express [6].

The LASER *Data Browser* (Fig. 3) is the main reporting application. It comprise of more than 40 different reports and simple graphs with statistics, covering all areas of alarms data.

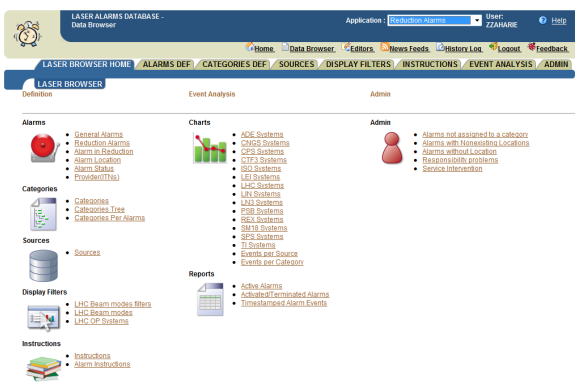

Fig. 3: LASER Data Browser.

The *Help Alarm* is a special report, which is integrated into the Data Browser. It presents all related data for a given alarm definition, which is available in the LASER DB, as well as data coming from other databases e.g. Network DB, TIMDB, DIAMONDB, CCDB, etc. The Help Alarm page is used as a reference report for any alarm by the LASER end-users.

A number of *Data Editors* were developed, targeting specific problems that the operators need to deal with. The editors are related either to giving the users the possibility to manage the Console Configurations, e.g. the *Power Converters Categories* Editor and the *TI Network Alarms Categories Editor*, or to giving the option to edit data related to the newly provided functionality in the LASER model, e.g. *Alarms Instructions Editor* and the *Beam Modes Filters Editor*. Another application, which was developed, is the *Reduction Alarms Editor*. In order to avoid an avalanche of correlated alarms on operators' consoles, special filters are declared by the users called Display or Reduction alarms. This helps to achieve a cleaner console display and to more easily spot the real cause of a problem.

CONCLUSION

The Alarms Service is a critical element, which is indispensible to the Operation of CERN's accelerators complex. The database tier plays a pivotal role and has proven to be a stable and reliable component. Continuous effort is put into its improvement through rationalization, data federation and development of new functionality at the database and interfaces level.

A new LASER Core database model is in the process of being developed catering for additional data elements for the alarms quality management and a workflow for the operators to approve the alarms configuration data.

A significant challenge in the future of the Alarms data management will be the smooth transition between the existing database model and ETL processes and the new ones to support the renovated LASER service.

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