DEVELOPMENT OF THE VACUUM CONTROL SYSTEM FOR THE LHC

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ABSTRACT

A new vacuum control system is under development for the LHC, it will be used for beam and insulation vacuum. The starting points for the elaboration were: to use PLC's for equipment control and to develop fully data-driven software applicable to other CERN accelerators without software modifications. A SCADA (Supervisory Control And Data Acquisition) approach has been chosen and the PVSS-II product was used as a kernel at the application level. All control aspects of the vacuum equipment are described in a new Oracle database structure. The database contents are used to configure the PLC's, MMI (Man Machine Interface) and the interfaces to the alarm and logging systems. The MMI provides a complete representation of the vacuum system state through synoptic views, pressure profiles and history. The same software is already deployed for the SPS and LEIR machines.

INTRODUCTION

LHC vacuum consists of four vacuum systems (two beams, cryomagnet and helium distribution line insulation vacuum), some of them being almost 27 km long. To maintain and measure the required vacuum, more than 3500 pieces of equipment of 27 different types will be used.

In 1995, a new MMI (Man Machine Interface) for vacuum control has been put into operation for major CERN accelerators (LEP, SPS, PS) based on X-Windows and Motif [1]. The successful operation of this software during the following eight years sets it as a standard in data presentation and control for accelerator vacuum systems at CERN. When we started the development of the new LHC vacuum control system, we were asked to keep the same functionality and "look and feel" as the existing control application.

Meanwhile a guideline for the development of the slow control application had been defined at CERN. It recommends using a PLC based solution for the equipment level controls and a commercial SCADA product, PVSS, for data acquisition and user interface.

To handle the large variety of equipment types, we use a data driven application. Equipment to be controlled is described in the vacuum control database (VCDB), the primary data source for configuring the whole control system. When we developed the control for LHC, we kept in mind the possibility to use all LHC solutions for other accelerators. The latter were used as test benches for prototyping. The challenge was to develop only one application able to be configured for any accelerator described in the VCDB.

SYSTEM ARCHITECTURE

Hardware

The hardware architecture is shown in Fig1. The kernel of the control system is the PVSS server. It communicates with 28 PLCs (Siemens S7/400) via an Ethernet network. Every master PLC communicates with the equipment to control either directly via I/O modules, or via one or more slave PLCs (Siemens S7/300) and I/O modules.

Master PLCs are connected to the PVSS server via Ethernet, slave PLCs are connected to their master via a proprietary network (Profibus). The server, running the core part of the vacuum PVSS system, collects data from the master PLCs. It is also responsible for storing pressure history in the central LHC logging system and for generating alerts to the LASER alarm system. A number of operator console computers running the man machine interface are using the data available from a single PVSS server.

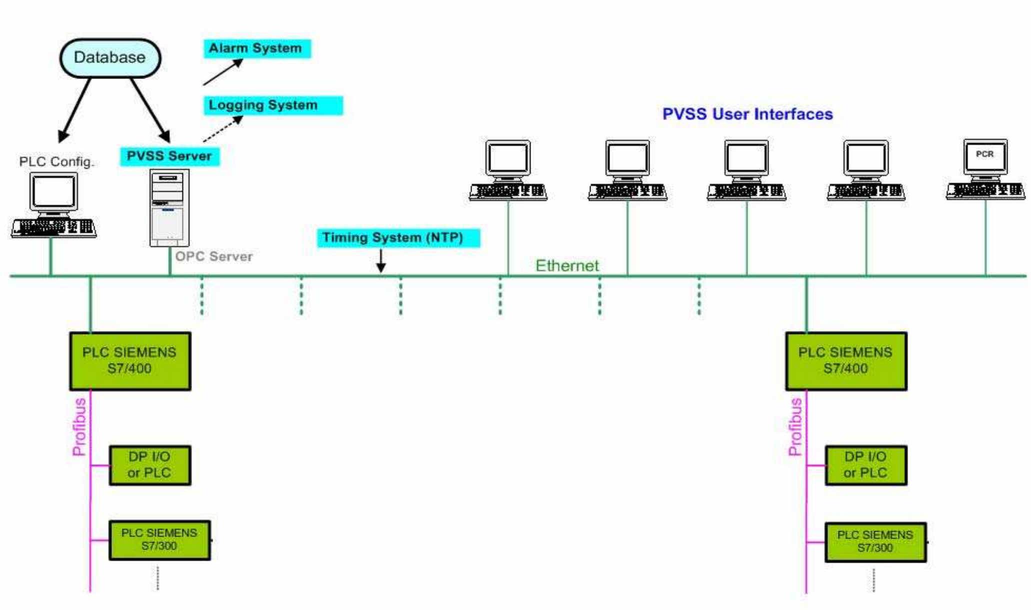

Figure 1 : Hardware configuration of the vacuum control system

Databases

The offline data for configuring the vacuum control application are taken from the following major sources:

- Vacuum control DB: all information about the vacuum equipment to be controlled;
- Survey database: static information concerning accelerator layout;
- Alarm database: configuration parameters for the common LHC alarm system (LASER)

For the LHC machine, the data in the vacuum control DB is synchronised on operator request with the central database of all LHC equipment.
Data from the vacuum control DB is extracted in form of four text files using an “Export Utility”:

- A “PVSS file” which is a major input for the so-called “Equipment Import Utility”. This utility reads the content of the text file and configures all necessary parameters for the vacuum equipment in PVSS (hardware addresses, archiving options, alerts settings, etc.);
- A “PLC file” which is used to configure the PLC software;
- A “logging file” which is used by the central logging manager(s) to transfer data from the internal PVSS archive to the central LHC logging database system;
- An “alarm file” to configure the relationship between the alarm system (LASER) and PVSS.

Data from the survey DB is extracted in the form of a text file by a dedicated script. This text file is later used by PVSS and the MMI to get information on the accelerator layout.
The following picture illustrates the use of different data sources for configuring vacuum control system:

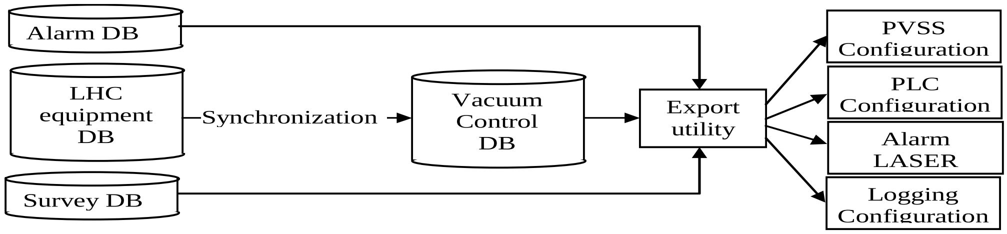

Figure 2 : Data sources for configuring the vacuum control system

VACUUM CONTROL DATABASE

A new design for the database holding vacuum equipment control information has been developed. The basic concepts of the new design are described bellow.

Equipment attributes

Equipment installed into the tunnel or underground zones are grouped into classes according to their type and function (valves, gauges, etc.). Each equipment type has a list of attributes containing all the required information to be accessed and displayed by the control system. The attributes basically only depend on the type of equipment with some exceptions (for example, devices of the same type, connected directly to PLC, or connected via a multiplexer need different hardware address information). Values of attributes include position in the tunnel or hardware addresses.

In the very first version of the equipment database, there was a dedicated table for every distinct equipment type with fields corresponding to specific attributes. This design had one great disadvantage: inserting a new device type or making changes to the list of attributes for an existing device type required changes in the database structure.

In order to overcome these problems a new approach has been proposed. The value of all attributes of all equipment is stored in a single table. Other tables contain the definitions of the attributes for each type of equipment. With this approach, the set of attributes for a given device is not determined by the structure of the database but by the data in that database. When we add new equipment types or modify existing ones, only changes in the data are required. Today, the export utility has still to be changed when new types are added, but a future improvement will allow fully data-driven functionality; the software for editing the database is not changed.

Equipment types and control types

From the controls point of view, the difference between equipment types is not so important, more important is how the equipment is controlled.

To describe the way equipments are controlled, the databases contain another classification in addition to the equipment types: control types. Every control type describes a set of attributes required to control the equipment. Every equipment type may have a reference to a control type, meaning that all equipment of this type is by default controlled in the same way. However, in case of rare exceptions it is possible to override the reference to the control type for single device if, for example, this device is controlled in a specific way.

Inheritance

It was found useful to introduce a mechanism for data inheritance for equipment types and control types. The database structure allows the definition of a tree hierarchy for types. Parent-child relations allow in many cases to avoid data duplication and to simplify database content editing as the common attributes may be defined at the parent level and inherited by all child types.

Master and machine data separation

The database structure is split into two major parts:

- Master data, defining parameters common to all the accelerators. This includes the definition of equipment types, control types, the definition of all attributes, etc.
- Machine-specific data containing information specific to one machine (LHC, SPS, etc.). This includes the definition of vacuum sectors, individual equipment with their attributes, etc.

This approach is illustrated by the following figure:

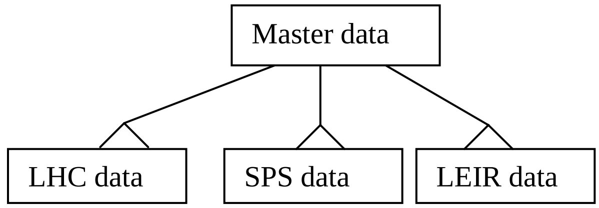

Figure 3 : Relation between master and machine databases

When we define the database for a new machine, we only need to create a new account and enter machine-specific information into database. For safety reasons, master data and data for every machine are stored under different ORACLE accounts.
The main disadvantage of the new database design is that content of the database becomes less "human-readable", i.e. it is more difficult to interpret data stored in the DB. To solve the problem, a specialised DB editor has been developed to handle data. It is implemented on a Java platform (ORACLE JDeveloper).

PVSS Man Machine Interface

The MMI has been built using the PVSS tools. PVSS has been selected at CERN after a long evaluation procedure among different SCADA products. The system comes with a powerful MMI interface builder, a database, an equipment interface, alarm and logging facilities.
In some cases, where the functionality provided by PVSS does not fit our requirements, specialised ActiveX controls have been developed using Microsoft Visual Studio. Dedicated ActiveX controls and Dynamic Link Libraries (DLLs) are mainly used to read and interpret the configuration data coming from the survey DB, and to represent them on screen in appropriate form. However, as it uses a proprietary library, all the ActiveX graphical part will need to be re-implemented with proper tools if the operator consoles need to be moved to Linux platforms.
The MMI starts with the main view representing the global status of the vacuum equipment (the SPS in this example). This view allows selecting parts of the accelerator and opening other views for these selected parts. The vacuum status in different systems is represented by colours according to predefined rules. The machine layout is drawn using data from Survey DB. It is possible to introduce configurable "distortions" to the survey data in order to see a less realistic but clearer machine layout.
From the main view, it is possible to execute "global" actions for many devices (for example, open all valves in the whole machine or in a selected part of machine). It is also possible to see a logbook of all actions executed from any operator console.

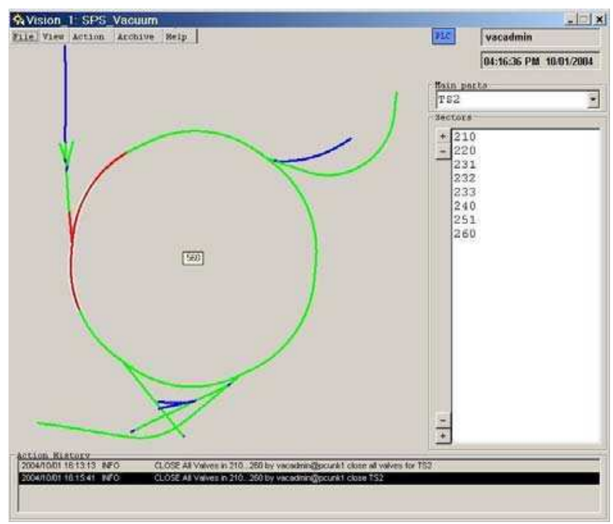

Figure 4 : SPS Main window of application

SIEMENS PLC EQUIPMENT LEVEL CONTROLS

Data collected from the equipment is stored in data blocks in the PLC. PVSS data is stored in data point elements. The PVSS driver transfers the data blocks from the PLC to the computer running the PVSS server and then decodes their content and puts values into corresponding data point elements. The hardware address configuration is stored in each data point element.
The equipment database must contain all data which allows to configure both the PLC code and the address of all data point elements in PVSS.
Data point types describes the size and content of a memory block for all the devices of the same type. Physical address information for a particular device is generated by combining together these two types of data.
For the moment, the Applicom hardware and OPC software is used in each PVSS server machine. It contains an Applicom card, where 8 Master PLCs can be connected and an Applicom library which transfers data from the PLCs to the PVSS Server. An internal PVSS driver (under development) will be used soon to allow PVSS to communicate directly to PLCs.

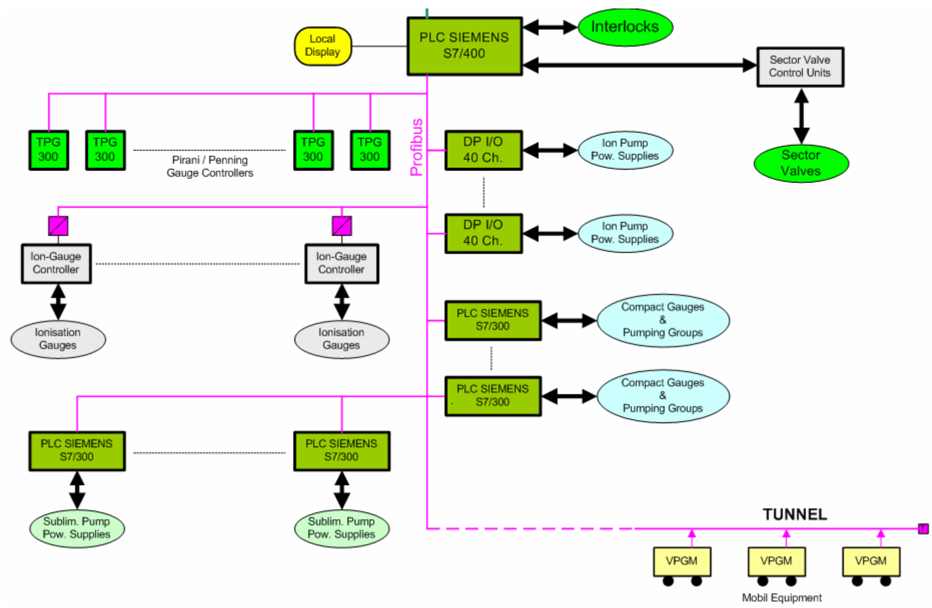

Figure 5 : Architecture of PLC level

IMPLEMENTATION FOR SPS AND LEIR

The solutions designed for LHC were used to renovate the vacuum control for SPS and build a new one for the LEIR machine, serving as a prototype for the LHC vacuum controls.

A computer with Intel architecture running Windows Server software is used for the PVSS server. It is planned to move the PVSS server platform to LINUX for performance reasons as soon as the Siemens-PVSS driver will be available.

The equipment level controls were implemented with a SIEMENS PLC of type S7-400 and SIEMENS analogue and digital I/O modules. The modules and the CPU are connected through a SIEMENS proprietary bus. The PLCs are connected to the PVSS server via Ethernet using an Applicom interface card.

To control the SPS equipment, 8 PLC are connected to a single PVSS server trough one Applicom interface card. All PLCs are running in master mode. For the LEIR machine, only one PLC is connected to one server using one Applicom card.

The SPS application is in operation since 2003 and the LEIR application has been deployed recently.

STATUS OF DEVELOPMENT FOR THE LHC

The main specificity of the LHC application is the requirement to show the equipment of the four separate vacuum systems in parallel. To handle this, we have extended the MMI functionality to show all vacuum systems in one synoptic or profile window. On the main view, different vacuum systems will be shown as rings with different colours. The status of the equipment will be represented by the border colour. As for the other machines the main view is used to navigate between vacuum systems and to see detailed information.

The main task for the moment is filling the LHC vacuum control database with equipment data. Implemented as a part of the project utility to copy data from the LHC database, an user friendly database editor should simplified this task.

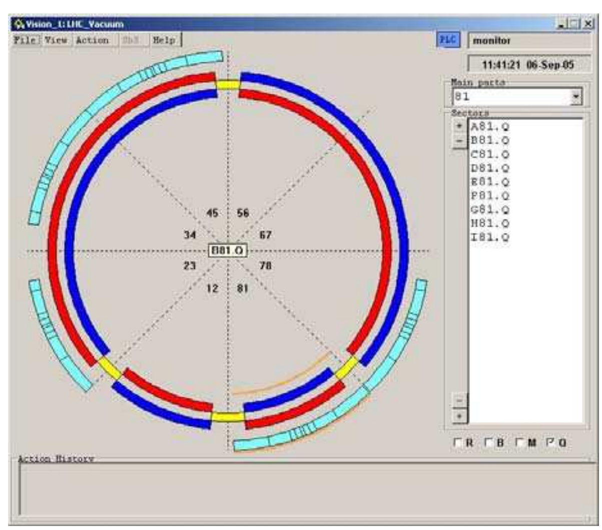

Fig 6 : LHC vacuum system

Figure 6 and 7 show some aspects of the vacuum systems for the helium distribution line and the cryomagnets.

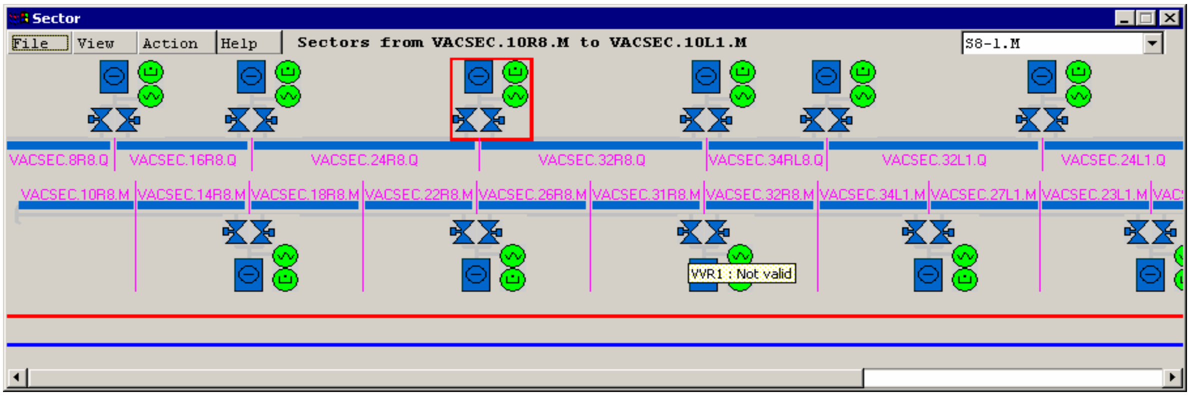

Fig 7 : Sectorisation of QRL and CRYO vacuum systems

CONCLUSION

First experience with the vacuum control system designed for the LHC and tested in operating accelerators has shown that:

- Using PLCs at the equipment control level provides a robust industrial platform with machine-independent communication interface.
- The PVSS system has proved to be an adequate basis for implementing a complex control project like the LHC vacuum control system. But the needed extended graphical capability has required in our case to develop additional facilities to meet the users requirements in data presentation. One advantage of PVSS is the facility to extend its functionality with user made modules.
- Using the vacuum control database as the central source of configuration data allows creating a uniform description of all the vacuum equipments for different accelerators.

The three above mentioned points allowed for meeting our goal to build a unified, machine independent, vacuum control application configured from databases. The successful deployment of the control system for SPS and LEIR has shown that we are on the right track for the large and complex LHC vacuum control system.

REFERRENCE

[1] L.Kopylov et all. “A Data Driven Graphical User Interface for Vacuum Control Applications”, ICALEPCS’1995, Chicago, USA, October 2003.