SACLAY GBAR COMMAND CONTROL

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Abstract

The GBAR experiment will be installed in 2016 at CERN's Antiproton Decelerator, ELENA extension, and will measure the free fall acceleration of neutral antihydrogen atoms. Before construction of GBAR, the CEA/Irfu institute has built a beam line to guide positrons produced by a Linac (linear particle accelerator) through either a materials science line or a Penning trap. The experiment command control is mainly based on Programmable Logical Controllers (PLC). A CEA/Irfu-developed Muscade SCADA (Supervisory Control and Data Acquisition) is installed on a Windows 7 embedded shoebox PC. It manages local and remote display, and is responsible for archiving and alarms. Muscade was used because it is rapidly and easily configurable. The project required Muscade to communicate with three different types of PLCs: Schneider, National Instruments (NI) and Siemens. Communication is based on Modbus/TCP and on an in-house protocol optimized for the Siemens PLC. To share information between fast and slow controls, a LabVIEW PC dedicated to the trap fast control communicates with a PLC dedicated to security via Profinet fieldbus.

INTRODUCTION

The goal of the GBAR experiment [1] is to measure the terrestrial gravitational field effect on antimatter. The method chosen by GBAR is to decelerate anti-hydrogen ions and then remove their charge to measure free fall acceleration. To obtain this anti-hydrogen ion, a few reactions are needed requiring ELENA (at CERN), to decelerate antiprotons and an intense production of positrons. The Saclay GBAR Linac based facility, see Fig.1, has been developed to prove that producing high intensity positrons is possible, without using a radioactive source like sodium.

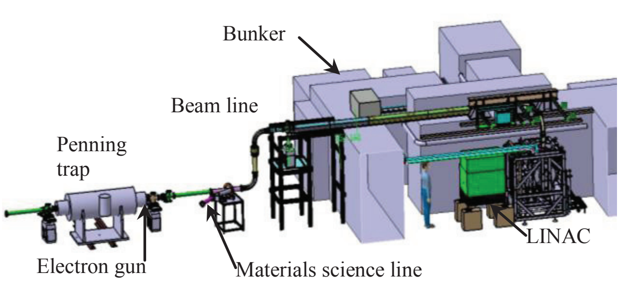

Figure 1: Saclay GBAR.

This project started in 2005 and produced its first positrons in 2009. The GBAR Saclay experiment is composed of one Linac confined in a bunker and a beam line which guides the positrons outside to a Penning trap or a materials science spectrometer. The GBAR experiment was approved by CERN in 2012; the next step will be the installation at CERN in 2016.

LINAC

The Linac was delivered by Getinge Linac Technologies with a Schneider PLC, which is in charge of the security and processing. All information required is accessed via Modbus/TCP and displayed on the SCADA. To control the environment of the Linac, like vacuum, a National Instrument (NI) FieldPoint cFP-2220 PLC was installed. The CEA implemented the code which manages the security aspect and has modified the Modbus/TCP library available on the NI website to be compatible with multiple clients. Communication with the two PLCs is achieved through their input/output (I/O). For example, if the environmental conditions are validated, the NI PLC will authorize the Linac to produce a beam by setting one digital output at 10V.

BEAM LINE

The beam line guides the positrons to the Penning trap, or the materials science line, through a magnetic field generated by coils placed all along the pipes. Several HAMEG HMP4040 electric power supplies generate the current in the coils, see Fig.2. To command them, a specific Ethernet protocol is available, but the SCADA, which centralises information, doesn't understand this protocol. To solve this issue, the CEA developed software which communicates on the one hand with the power supplies and on the other hand with the SCADA with Modbus/TCP. This gateway is a full JAVA software running as a Windows service on the same PC as the SCADA.

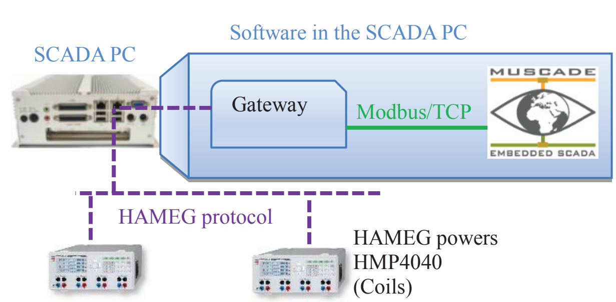

Figure 2: Saclay GBAR.

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PENNING TRAP

At the end of the beam line, a Penning trap provided by RIKEN Institute is accumulating short bunches of positrons in order to create a large plasma. The trap is composed of a superconductor magnet and electrodes inside which create a potential difference that will trap electrons and positrons. Software has been developed by the Irfu with LabVIEW on a PC to control the electrodes with a sequence described in a text file easily editable by the user. The security and slow environment parameters such as the temperature of the trap are managed by another Siemens PLC (CPU319-3 PN/DP) system. As with the other PLCs, this PLC is monitored by the experiment's SCADA, the communication between both is specific and has been developed by the CEA to optimize the data size and frequency.

Electron Injection

In a typical sequence controlled by the PC, the trap is first filled with electrons. They are generated by an electron gun mounted [3] on a push-pull which is placed at the entrance of the trap. The Siemens PLC is in charge of security to avoid the electron gun smashing the beam monitor. To share information between both systems, a Profinet communication has been established using a Hilscher Profinet PCI card (CIFX-50-RE). The Hilscher driver is provided in C language, so as to make it possible to use with LabVIEW. The CEA has developed a dynamic link library (dll) and added an abstraction level to make the configuration simpler.

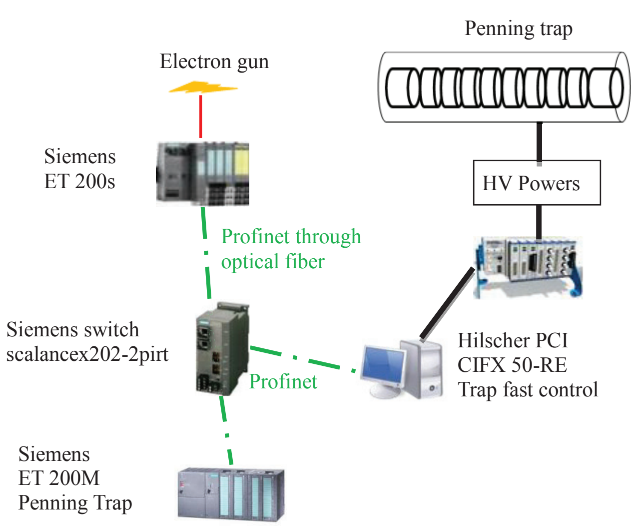

Figure 3: Electron gun control.

Temperature Acquisition

As the Penning trap is composed of a superconductor magnet, the system is monitoring the temperature. Temperature sensors are connected to a CABTF acquisition module [2]. This module has been developed by the CEA and is now manufactured by MII. It measures temperatures between 1.5°K and 300°K with any resistive sensor types with a 0.1% precision. To minimize the dissipated power, the sensors are excited by a continual current (100µA) between 0 and 150 Ohm and by a continual voltage between 150 and 40 kohm. The CABTF communicates with the Siemens PLC on Profibus fieldbus (other protocols available: WorldFIP, Modbus RS485 or RS232 or TCP), which will transmit the information to the SCADA, see Fig. 4.

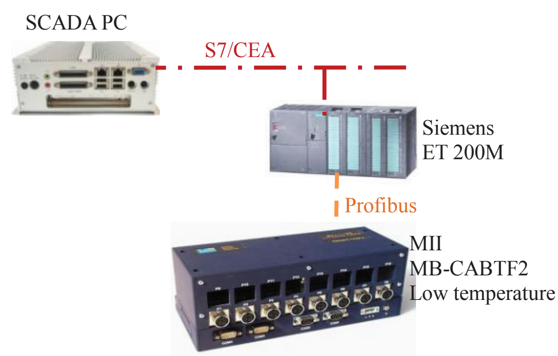

Figure 4: Acquisition module (CABTF) manufactured by MII under CEA license.

SUPERVISION WITH MUSCADE

All information collected by the PLCs is sent to a SCADA , see Fig.5, developed by the CEA/Irfu called Muscade (µS.C.A.D.A for Embedded or Centralized System) |3].

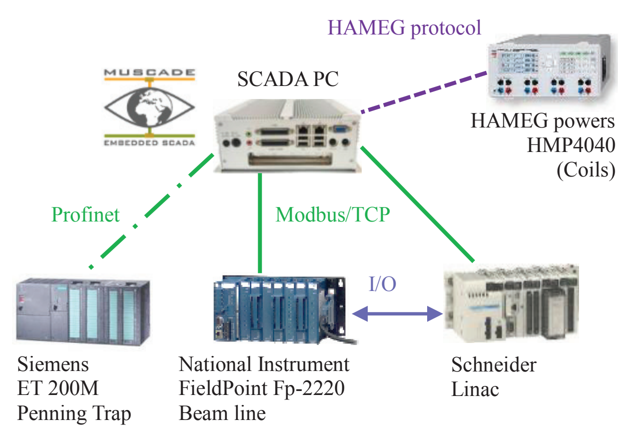

Figure 5: Saclay GBAR.

Muscade is full JAVA software based on client/server architecture easily accessible by distance, which helps with process diagnostics in case of failure.

Needs and Solutions

Muscade responds to several needs specific to the research projects:

- Understanding the behaviour of the PLC process and the machine: Around an alarm (few seconds before and after), Muscade archiving, see Fig. 6, is at the PLC frequency, which helps to understand the PLC process since we know the state of its I/O. In

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addition, it's also possible to add an archiving point on a trigger (threshold, rising/falling edge on a parameter)

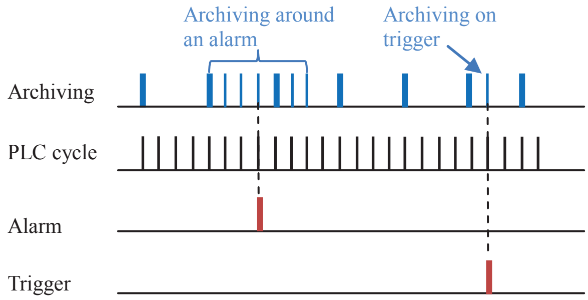

Figure 6: Archiving.

- Debugging with a replay mode by moving step-by-step in the archiving on one or several views.
- Remote maintenance: Muscade client provides graphical user interfaces (GUI), see Fig.7, which can be downloaded from anywhere through a web browser since it is a JAVA applet. The user can view live or historic information and therefore easily discuss with the local user.

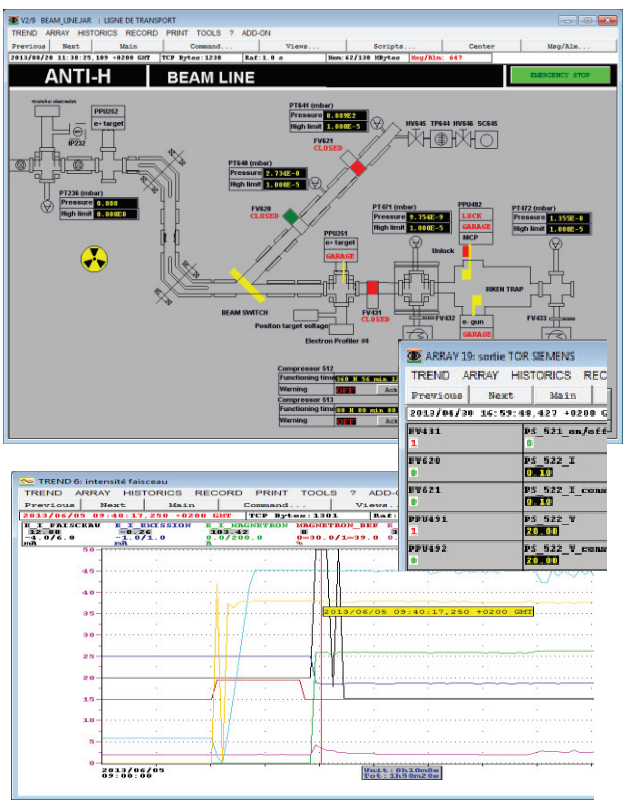

Figure 7: Muscade client GUI.

- Optimizing the bandwidth between the Muscade client and server to be compatible with low bandwidth conditions: for example, the CEA team from Saclay (France) can view the status of a Concordia telescope station (Antarctica) through satellite communication.
- Working in standalone mode, the Muscade client software can be installed on a computer and the user can visualize the archiving locally, without an Ethernet connection.

Security

The security aspect has been taken into account:

- Integrity of the software: code signing with VeriSign/Symantec.
- Client station: at each download, the software signature is checked by certificates installed in the client keys shop.
- Connection: Secured connection to the server with SSL.
- Authentication: e-token on a USB key with client certificate.

Software Architecture

The software architecture of Muscade is client/server, the server is in charge of retrieving information from the devices, archiving and alarms. The clients display the information with synoptic, trends, tables, and messages (alarms). The client and the server communicate with a specific protocol called Muscade client API, but the Muscade sever is open to other communications: Modbus/TCP and EPICS channel access. To reach devices, Muscade can communicate currently with devices through Modbus/TCP, EPICS Channel Access, OPC-UA client, S7/CEA which is an in-house protocol for Siemens S7 PLC. Users can add another protocol to Muscade by implementing a new plug-in.

The Muscade server is composed of 3 elements which are running as Windows services and communicate via Ethernet:

- Muscade communicates with the devices, Muscade archiving and Muscade client directly in local mode, or through servlet mechanism from a distance.
- Muscade archiving gets data from Muscade core and sends data to the Muscade client directly in local mode or through servlet from a distance.
- The Muscade alarm handler will detect a default, send this information to the Muscade server, and if necessary automatically send an email and an SMS if the operator has not validated the alarm.

In remote client mode, the user requests a download of the client software with an address in a web browser, see Fig.8. The IIS server transfers the latest version of the client application using Applet Java technology, then the Muscade client application will start the communication and the servlet will authorize or refuse the communication and transmit the data. The Muscade client can communicate with the Muscade server to get on line information and configuration, or with the Muscade archive to get old data.

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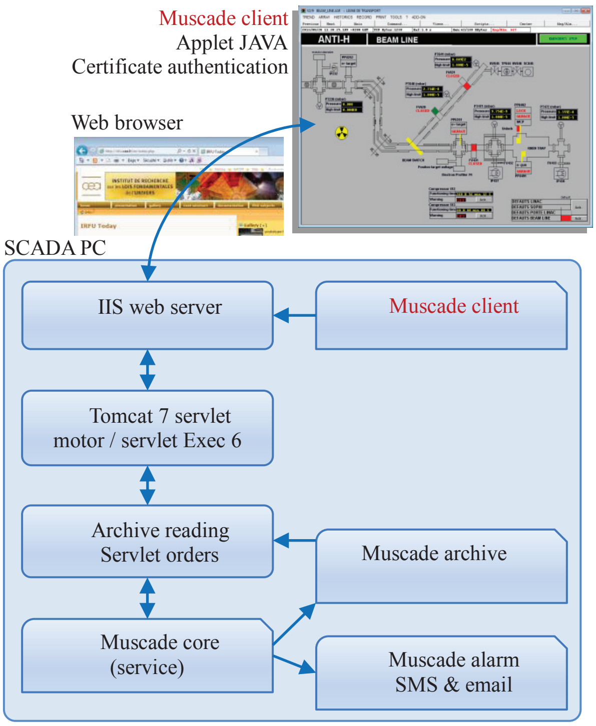

Figure 8: Remote client Muscade architecture.

PC Server

The reliability of the supervising PC is an important aspect to reduce the maintenance and to ensure it runs 24h/7. The criteria to choose the PC were: long life, which means no mechanical movement; resistance to dust, vibrations and bad transportation. The Nise 3xxx from Nexcom PC was chosen because there is no fan and no classical hard disk (SSD disk). The OS installed is Windows 7 embedded because it allows creation of clones, regular system updates with a security patch and compatibility with most industrial products. Windows 7 embedded has been configured to limit Ethernet access and disk access by setting the OS part on read only, so at the next reboot, the system will always restart in the same conditions.

REFERENCES

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[3] Muscade, http://muscade.cea.fr/

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