STATUS OF THE SOLEIL CONTROL SYSTEM

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ABSTRACT

This document presents the status of the Control systems deployed on the SOLEIL synchrotron facility, and explains the main technical choices and the underlying guidelines and project management rules followed to achieve these results.

INTRODUCTION TO THE SOLEIL PROJECT

SOLEIL project presentation

The SOLEIL light source is a 2.75 GeV third generation light source under construction [1] near Paris in France, which will serve an international community in many fields of science. The project was launched in January 2002 and the construction started in August 2003. Now, the 100 MeV Linac injector and the Booster synchrotron are being commissioned. Installation of the Storage Ring elements is in progress and commissionning is scheduled in March 2006. The first beamlines hutches will be delivered within the next couple of weeks. It is planned to start users operation by the end of 2006 on 10 beamlines.

Control groups organisation and missions

Inside the SOLEIL Computing Division, the Control staff has been organized into 2 groups working in very close collaboration: the one in charge of the Software side and the other one in charge of the Hardware side. They have to specify, design, implement and maintain the Machine Controls System as well as the Beamlines ones. During the project, one of their main guidelines has been to use as much as possible standardized components with up-to-date technologies and to minimise home-built products so as to focus efforts on SOLEIL specific needs and user support

INDUSTRIAL APPROACH

The control system of a synchrotron shares many similarities with other large scientific facilities (LHC, W7X, LMJ…), and some elements are not very different to the control system of a factory or a power station. As a consequence, solutions to most of the control needs have already been found in the industry.

High standardisation of components (HW and SW)

We can quickly summarize the control requirements to:

- Analog input or output – fast or slow, with large or small accuracy, synchronous or asynchronous
- Digital input or output - with different levels (TTL, PECL…)
- Data exchange mediums (serial link, GPIB)

In order to meet these requirements, we have divided the electronics of the control system into three categories:

- Programmable Logic Controllers (PLC) for slow and well known processes,
- Compact PCI (CPCI) systems for fast or synchronous control,
- Standalone crates to control motors.

Each piece of hardware control is interconnected via Ethernet so as to exchange data and commands. Locally, a simple, industrial and widespread fieldbus (PROFIBUS) is used to connect equipment to the control system.

In addition to these hardware concepts, our object oriented software framework, the TANGO one [2] [3], allows us to have such a modular approach and to detail software and hardware breakdown.

Nevertheless the standardisation involves specifying the process equipment by taking into account the control. This is a challenge because the control is never the most important equipment specification.

The "LEGO®" model

Small blocks of hardware and software have been identified and made, then assembled to build the Machine and Experiments control systems, like bricks of a LEGO [4] set. Each block or LEGO brick represents a generic project. For instance, to generate a synchronous 16 bits analog signal, a commercial product has been standardized and the software part (a TANGO Device Server) has been developed.

The internal work has been organized in order to obtain blocks that can be easily assembled together.

Large use of subcontractors and commercial products

Because the size of the team is designed for the exploitation and not for the construction of SOLEIL, mass-market technologies and products are currently been used. We do not intend to reinvent the wheel. The goal is to implement an operational control that fits with SOLEIL's needs. Moreover, using the mass market in control allows saving money. Calls for tender have been made to select products that fit our requirements at the best price: PLC, CPU, Axis controllers…

Many subcontractors have been employed to carry out well identified, known and standalone projects which in turn have required additional staff with specific skills: this is the case for PLC integration, PCB design, Software Device Server development, java applications.

To standardize the control, to implement commercial products and to work with subcontractors requires organisation, coordination and planning.

PROJECT MANAGEMENT GUIDELINES

Management vision

The team, which now stands at 17 people and will soon increase to 20, has grown during the project. Some of them have already worked on the controls of other scientific instruments; others had positions in industry before joining SOLEIL. These different experiences proved to be very fruitful. The team has a good knowledge of new and industrial technologies and products, and has been boosted by achieving an operational control that exactly fits SOLEIL's needs (not too much and not too little!).

Definition of our commitment with internal customers

The control system requirements have been agreed with our internal customers (Machine and Experiments) in formal documents (called Objective Contracts), the main guidelines of the development and our commitment. They list the supplies, the workload and the priorities. Therefore, this step is essential and the organisation is based on it.

Definition of internal responsibilities

Once we have clarified our commitment, we have been able to organize a realistic breakdown structure and work distribution. Because the team is working towards a single goal (the control of SOLEIL), it is important to define who is in charge of each supply in the team.

Share developments with other groups

Moreover, because we have faced a lot of work, it was agreed with others groups (Experiment groups or Machine groups) to share the workload. The tasks they have in charge are close to their experience and knowledge: PLC programming, high level synoptics. Of course, this work is done in close collaboration with our teams and if necessary we provide support and training.

Straight communication

To conclude as regards management, communication is essential. It is a large part of the job. If tasks are too numerous or not clearly prioritised, we risk forgetting something or missing a deadline. Two levels of communication have been set up: on the one hand, internal communication is essential to explain goals, organization and priority, and to ensure that there is no repetition of completed tasks. On the other hand, external communication ensures that our work fits with the requirements and the schedule of the project.

HARDWARE TECHNICAL CHOICES

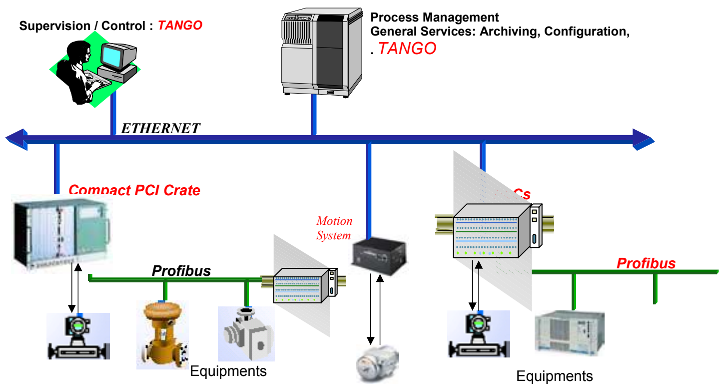

Figure 1: Hardware synoptic

Industrial hardware components for SOLEIL Control systems

The standard hardware components, selected for the Machine and the Experiments, are industrial products adapted to the SOLEIL's needs. There are 3 groups of independent hardware devices:

- PLC's are dedicated to slow and safe applications like vacuum, temperature, interlock… More than 100 PLC will be used. The PLCs are Siemens S7-300 family products. Digital and analog inputs/outputs can be connected directly or via Profibus fieldbus to the PLC CPU .The machine and beamlines groups have developed their own PLC applications: after a training period, and with help from the team and from Siemens support. In addition, they can call for a subcontractor for PLC integration and cabling folder.
- A ready to use solution is available to control 1000 motors in accordance with the SOLEIL control standard: 4-phase bipolar stepper motor, absolute SSI or incremental TTL encoder. SOLEIL developed 3 crates called ControlBox, DriverBox and VacuumBox to supply standard packaging and connectors to industrial products: multiaxis Galil DMC-2182 controller, Midi-Ingénierie and Phytron power board. A kit of software utility and Device Server has been provided. Nevertheless, the non standard motors, (like brushless or ceramic ones) can be controlled by adapting the standard solution if necessary. We support non standard motors only when they are justified.
- Compact PCI are dedicated for fast, communication bus, and high performance applications. A 6U crate customized contains 2 distinct CPCI buses which can receive 3U or 6U boards: Inova CPU with Pentium-M processor, I/O boards provided by ADLink and National Instruments and the software components associated. External patch panels developed by SOLEIL give standard connectors for standardized boards.

Timing system

To bring electrons from the LINAC to the storage ring, many equipment must be triggered synchronously to the beam. The timing system provides the time base needed for this purpose. More than a simple clocks distribution system, it is a real network, broadcasting clocks and data all over SOLEIL. Data are used to send events to equipment : for example, injection of electrons inside the booster, extraction of electrons from the booster to the storage ring, or even triggering diagnostic equipment.

The timing system is made up of a central system and several local systems. The central system provides clocks and data and broadcast them to the local systems through an optical fiber network. Local systems are placed close to the equipments and they provide delayed signals to trigger them. These delays can be precisely adjusted by the user, making the equipment synchronous with the electrons beam moving inside accelerators and the storage ring.

Many modern facilities like CEA's Mega Joule Laser or SLS synchrotron have a similar timing system. SOLEIL will use the CEA's solution. To meet our needs, a redesign of this system is in progress.

SOFTWARE TECHNICAL CHOICES

TANGO: The core control system software technology

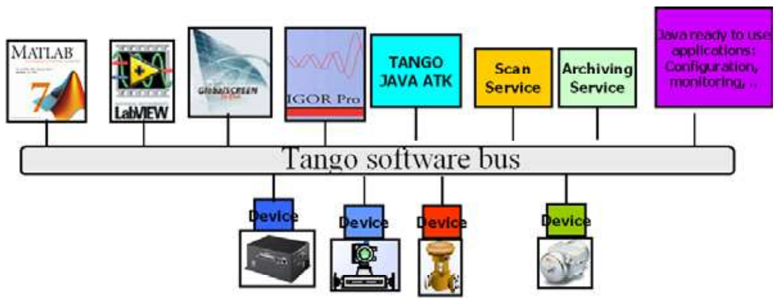

Figure 2: The Tango software bus

Which software technologies use to build a modern control system? This is the critical question the SOLEIL project faced in 2001. In order to answer, it was decided to first describe an "ideal and purely abstract" control system – in terms of features and concepts – then, to look for an implementation that could fit with the model.

The main request applied to the ubiquity of the OO technologies at any control system level. Everything should be an object – from the hardware abstraction running on a crate to its graphical representation in the control room. This sole constraint imposed CORBA [5] and its distributed object model as lowest layer of the control system architecture. However, ease of use was also a major demand and CORBA was known to be a powerful but "heavy" development platform. Moreover, CORBA is a generic tool without any control system oriented features or services. A control system framework that hides CORBA details and provides the developer with an easy to use control system toolbox was required.

The TANGO framework – that was under development at the ESRF [6] – was very close to our expectations. The collaboration contract signed on March 2002 between the ESRF and SOLEIL definitively boosted the TANGO development. ELETTRA [7] and ALBA [8] – two other European synchrotron institutes – joined the collaboration in 2004 and 2005 respectively. After 3 years of collaborative effort, TANGO has reached the required level of maturity and has proved to be a good performances and easy to use framework for software developers.

High level applications

In the framework of control systems environments, what is intended by the expression "high level applications" encompasses all software solutions provided to users with user friendly environments to develop and exploit their client applications [9]. These high level applications can be classified as followed:

- Services provided on top of the Tango control software bus,
- Client environments for handling data processing functionalities,
- Batch processing and task sequencing,
- Supervisory and control graphics applications.

Archiving system

The major functionality delivered as a Tango service is the archiving service. The goal of this service is to maintain the archive history of about 6000 main accelerators control parameters, in order to be able to correlate signals or to get snapshots of the system at different times and to compare them. For this aim, 3 database services have been developed and fully integrated in Tango: an historical database with an archiving frequency up to 0.1 Hz, a short term database providing a few hours retention but with higher archiving frequency (up to 10 HZ), and finally a snapshoting database. These services are available to end users through 2 graphical user interfaces: Mambo (for data extraction/visualisation from database) and Bensikin (for snapshots management).

Bindings with user's development tools

To give users of LABVIEW, MATLAB and IGOR PRO data processing tools, the ability to access data acquired of the Tango control system, SOLEIL developed for each of these environments what is called a dedicated binding, that is, a tango shared library acting as a dynamic wrapper for tango requests (command executing, attribute reading and writing) written in the given environment language syntax to the underlying C/C++ tango core method calls.

Sequencing and batch processing

To address batch processing and sequencing needs, two kinds of environments are available: the Python scripting environment for which a dedicated Tango binding have been developed and Passerelle [10], a graphical environment in which sequences can be modelled by drag dropping component actors (representing elementary tasks) and to use a graphical language syntax to "program" data flow between successive tasks to achieve the wanted process execution.

Supervisory applications

Supervisory and control applications are all Java applications using the Java beans technology and made up on top of the Application Tango Toolkit[11]. This toolkit serves as a base to develop generic graphical application to handle basic issues: configuration, commissioning, etc.

For more high level applications, SOLEIL adopted GlobalSCREEN [12], a professional Java SCADA. This environment enables end users to quickly build user-friendly GUIs without writing any java code and by drag-dropping reusable graphical components developed for them by the software control team. A SoleilLibrary of such components has already been developed to this end. This way, SOLEIL can guarantee for users to lay out their supervisory applications with a homogenous look and feel and benefit (as they are natively included in GlobalSCREEN) from many functionalities as access right management, web access and remote administration.

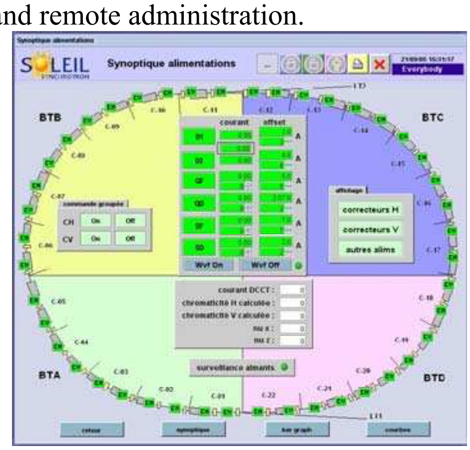

Figure 3: General supervisory application for Booster Control

System and network infrastructures

As we have already explained, Ethernet is the backbone of communication used to interconnect the various systems:

- PLC, CPCI crates, Motion Controllers at the low level
- Linux and Windows servers and X terminals at the "supervision" level

For accelerator control, the Ethernet architecture is based on a "network heart"(composed of a CISCO 6500 switch with redundant critical components), on which are connected about 30 "secondary" switches through redundant fiber optic cables . A WIFI network will be available during Machine shutdowns in the technical gallery around the storage ring to ease maintenance operations on accelerator equipment.

Regarding operating systems, the following choices have been made:

- All CPCI crates run Win2000, which allows us to use mass market products (National Instrument for instance) with widely used and debugged drivers. The REMBO [13] software has been selected to manage the software images deployment and automate installation of these "remote" computers.

- On the server side, Linux is our preferred platform and more that 30 rack mounted bi processor will be used for all general control services (archiving, configuration databases, general purpose Device Servers , supervision applications, beam dynamics applications, X terminals support, ..).
- For operator displays, X terminals will be used as much as possible to minimize installation and support workload.

STATUS OF DEPLOYMENT

The first Control system of SOLEIL has been installed on the Swiss Light Source (SLS [14]) for the control and operation of the LUCIA beamline. Since the end of 2003, this system has been in operation with about 100 Tango Devices, driving SOLEIL standard electronics (Motion systems, I/O boards), SLS EPICS driven and specific beamline equipments. This first integration experience proved to be very fruitful as it has allowed us very early to verify "on the field", that our technical choices were coherent with our user's needs, and to discover minor technical weaknesses of our "standard solutions" (or "LEGO bricks").

At the end of 2004, we installed on the SOLEIL site, the control system for Transfer Line 1 section (between the LINAC and the BOOSTER). Since then, this initial Control system has been widely extended and has successfully allowed Machine physicists to inject beam in the booster ring in July 2005. Electrons energy ramping up to the 2.75 GeV nominal energy of SOLEIL beam, should be done during the first days of October 2005. The booster commissioning will then start till end of year.

At this stage of installation, a significant number of systems have been installed:

- on the hardware side, 7 CPCI crates, 6 Motion Systems and 11 PLC are now in production,
- on the software side, 1000 Tango Devices based on 75 classes are used from 4 main GlobalScreen applications, Tango generic java applications and MATLAB beam dynamics applications.

All major families of accelerator equipments are now controlled by our standard components: beam diagnostics, BPM, power supplies, vacuum systems, RF, safety systems, pulsed magnets.

These good results (in quality and quantity) make us very confident on the scalability of our Control system and the validity of our technical choices. Moreover, the clear definition of our commitments made upstream, proved to be useful, as it has minimized last minute surprises during booster installation.

Of course, the next steps of installation of the Storage ring and the first 10 beamlines in the next couple of months will be intense. Nevertheless, we are all convinced that this period will also be full of exciting possibilities.

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