TANGO BASED CONTROL SYSTEM AT SOLARIS SYNCHROTRON

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Abstract

A National Synchrotron Radiation Centre SOLARIS has been recently built in Krakow, Poland. The accelerator is in commissioning phase. The control system is in operation and provides all functionalities required for the commissioning process. The system is based on Tango Controls and has been developed with strong collaboration with MAX-IV, Lund Sweden and the Tango Community. Protections systems uses Rockwell and Siemens PLC hardware. Synchronization system is based on the MRF hardware. Status, technologies and performance experience will be presented.

THE ACCELERATOR AND BEAMLINES

The Solaris machine is 1.5GeV storage ring the same as one of the MAX-IV supplied with a linear accelerator providing electron beam up to 600 MeV. Since the linac is not providing full energy beam there is need of energy ramping in the storage ring. This is a difference to MAX-IV setup. The Solaris project includes also two beamlines. One is using bending magnet radiation with XAS and PEEM end-stations and the other is basing on undulator source with an UARPES end-station [1].

The accelerators and beamlines are installed except few components of PEEM beamline. There is on-going commissioning of the accelerator and UARPES beamline [2]. The latest result is accumulation of 511 mA current in the storage ring which then has been ramped to full energy of 1.5 GeV at 200 mA [2]. After couple of weeks of the beamline commissioning the photons have been delivered to its end-station.

TECHNOLOGIES

Most of technologies used at Solaris was chosen together with MAX-IV. During procurement and development phase it allowed for sharing of the resources. Having similar technologies simplify cooperation in process of commissioning, too. It also minimizes effort of debugging. There are few differences, too. Some are due to different local legal requirements (like for radiation protection), some due to different project scales or schedule [3].

Tango Controls

The Tango Controls [4] has been chosen as software plat-form for the control system. It has proven its stability and performance. It is responsible for acquisition of more than 5000 signals, at Solaris. More than 1800 attributes (process variables) are stored in historical database (HDB archiving, historian).

There are three so called Tango instances deployed at Solaris. One instance for a linear accelerator and a storage ring and two for two beamlines. Each instance consists of a Tango Host server, HDB and TDB archiving systems, low- and high- level software.

Physical (hardware) devices are connected to Tango System by so called Device Servers which are software translating specific communication protocol to a common Tango protocol based on the CORBA and the ZeroMQ. Each hardware device is represented in the Tango CS as an object (tango device) with attributes and commands representing respectively process variables and actions provided by a hardware. Wherever possible, similar equipment is used for accelerators and beamlines. Thus, number of different kind of device servers are limited. However, there are 61 different device servers used at Solaris. Device servers are divided into several categories corresponding to the machine's subsystem: CTL, DIA, MAG, RF, VAC and WAT. MAX-IV and Solaris are developing [5,6] device servers written with the Python programming language and the PyTango package. However, a few device servers, mostly delivered by commercial company Cosylab (Ljubljana, Slovenia), are written in the C++ programming language.

The main entry point to control system for operators is an open source application called ControlProgram [7], created and delivered by Cosylab. It allows for browsing the Tango database and monitoring all devices. Also, it is used for running GUIs and Tango tools, like Astor or Jive. GUIs in Solaris are developed with the Python programming language and Taurus package from ALBA.

Dedicated and generic Tango GUI applications gives operators access to all necessary signals allowing them for monitoring and act on all the systems. As a tool of choice the Matlab Midlayer library is used for accelerator physics control and measurements.

PLC systems

There are two separate PLC systems in synchrotron Solaris. MPS (Machine Protection Systems) is integrated with subsystems like vacuum, magnets, cooling and RF and it prevents components of the machine against damaged during work in undesired condition. Second one is

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PSS (Personnel Safety System) which prevents people from getting a radiation dose higher than the limits forced by the law.

MPS is based on ControlLogix controllers provided by Rockwell Automation. Today there are seven PLC controllers in “Solaris” placed in server room. Five controllers are integrated with machine subsystems mentioned above and two of them protects existing beamlines: PEEM and UARPES.

MPS is built as a distributed system, it means that all sensors, switches, contacts, relays, actuators etc. are served by PLC nodes placed in various locations of the facility. MPS contains 43 PLC nodes with almost 400 Point I/O modules and communication cards. Communication between PLC controllers and PLC nodes is provided by EtherNet/IP network separated from other Ethernet subnets.

PSS is also distributed system but it’s based on one Siemens S7-300 fail-safe controller. 9 PLC nodes with ET-200S I/O modules are installed in electrical cabinets placed in klystron tunnel, ring service gallery and experimental hall. Communication between PLC nodes and PLC controller is provided via PROFIBUS protocol.

To perform all control tasks needed in “Solaris” some data must be exchanged between two PLC systems. Using PLCs with different communication protocols forced automation engineers to implement additional element in the system: EtherNet/IP – PROFIBUS gateway provided by Anybus.

The MPS system is integrated with Tango Controls through Ethernet/IP Device Server written by MAX-IV based on original libraries used by EPICS driver. This device server exports internal PLC tags as Tango attributes. Various other device servers and GUI applications uses these attributes and group them into logical devices.

The PSS system is connected to Tango CS with dedicated device servers. These device servers process communication initiated by the Siemens CPU which sends datablocks. The GUI for the PSS is provided using QTango library. The PSS software has been provided by Elettra (Bassoviza, Italy).

Timing and Synchronization

A timing system is used to precisely synchronize actions in a number of devices distributed over larger area. Timing system of the Solaris synchrotron radiation source is designed on a timing platform from Micro Research Finland (MRF).

Basic layout of MRF timing system in Solaris is depicted in Fig. 1. The MRF timing system is an event based timing system. The main devices are event generator (EVG) and event receivers (EVR). The EVG and multiple EVRs are connected to an optical network using optical Fan-Outs. The EVGs major function is to generate a stream of timing events on a high speed optical link and broadcast them to the EVRs. Every event has its own event code and the EVR only performs an action if it receives the pre-configured event code. This action is normally a pulse on a Trigger line output of the EVR which is directly connected to a particular Solaris device.

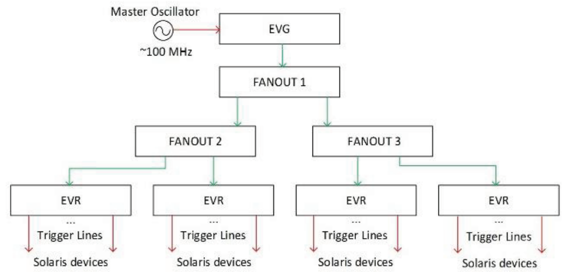

Figure 1: Basic structure of Solaris MRF timing system.

The event network is synchronized to a Master Oscillator clock reference (~99.93 MHz). This clock reference is also directly linked to an event clock.

The EVG (MRF card cPCI-EVG-300) has the following functions (only functions relevant to Solaris are listed):

- Trigger sequences of events. In an event sequence the events are arranged in an order and are generated with relative times between them,
- Trigger the event sequences with an adjustable repetition rate,
- Distribute an event with a revolution period.

The EVRs (cards cPCI-EVR-300) perform several event triggered actions (only actions relevant to Solaris are listed):

- Output a pulse on a Trigger line output with adjustable delay and width,
- Output an event clock or a waveform derived from a divided event clock (waveforms can be synchronized to an event),
- Make a SW interrupt on a specific timing event.

The integration of the EVR/EVG in the control system is composed of 3 components: Tango device servers written in C++, GUIs in Python and a driver wrapper in Python.

Motion Control

As in any physics research facility, especially as advanced as a synchrotron, there is a need for high-precision movement control with resolutions of several micrometers or miliradians. At Solaris, the pieces of equipment responsible for those tasks are IcePAP drivers, which are developed at ESRF, Grenoble, France. The IcePAP is a system composed of controller boards for various kinds of motors aggregated into so-called “crates”. They can be integrated into the Tango control system but most of the configuration is handled on a lower level – the software utilised to configure each controller board that is used at Solaris is IcePAPCMS, which was created at Alba, Barcelona, Spain [8].

PERFORMANCE

The control system has provided all necessary means for successful commission and proved its usability.

Most of the attributes can be read within less than few milliseconds. However, some hardware devices (like ion pump controllers) have interface with response time exceeding 1 second in some circumstances. For such a devices the Tango polling mechanism is used. This mechanism makes device server itself periodically query the hardware and provides cached data to other applications. Additionally, the Tango event system is used by most of client applications.

Challenges

As it is typical for such a complicated setups there were issues and bugs to be solved. Unfortunately due to lack of resources and project schedule limitations not all subsystems software were tested and properly debugged before commissioning start. The issues had not direct impact on commissioning performance nor provided serious delays. However, some of them made machine operation less convenient for operators.

The most important performance issue was related to the computer network bandwidth which was at the beginning limited to 1GB/s due to budget limitations. The most affected systems were YAG screen diagnostic cameras and MPS PLC system. However, budget issues have been solved and during winter shutdown the network equipment has been upgraded. Also separated PLC subnet has been deployed. This allows for convenient operation and prevent from MPS communication incidents.

It has been decided to upgrade Tango Controls from version 8.1.2c to 9.1 during the winter shutdown as well. This was done together with operating systems change from Centos 6.5 to Centos 7. The decision was taken to keep systems as much up to date having still time (before the facility will be open to users) to solve issues which will appear after upgrade. Other reason was to gain detail knowledge about deployment which was outsourced [6]. Few libraries compatibility issues has been solved. There is still a bug under investigation. It appears as increase of resources consumption by the ControlProgram. The root cause has not been yet found. However, the problem has been recently overcame by changing internal logic of window management in the application.

Management Considerations

Lot of work for the control system has been outsourced [6]. This minimized risks related to lack of in-house expertise and tide schedule. Outsourcing allowed Solaris to deploy the control system with only 2 local Tango Controls engineers FTEs, 2 network and systems administrators and 2 PLC systems engineers and one coordinator. This has moved the risk to commissioning and operation phase. It has been minimized with students involvement from the beginning of the project. Students who had practiced at Solaris are natural candidates for open positions. Now, a team building plan for control and IT systems group (CSiIT) has been prepared according to Solaris development plan.

Additionally, no one at Solaris had extensive experience in accelerator operation and commissioning. This led to difficulty in judgement of importance of issues and needs, at early stage of the commissioning. For this, the Solaris has been supported by, among others, MAX-IV, Elettra, ALBA, Soleil and ESRF. After one and a half year of commissioning, experience has been gained.

CONCLUSIONS

The control system based on Tango Controls has been successfully prepared and deployed. Most of early stage difficulties has been solved. The experience has been gained which allows for system further development and maintenance. Currently, simplified applications for machine operation are upon development. The machine control system is heading towards ‘on-button’ machine. There is recruitment process to supplement lack of manpower.

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