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UPGRADE OF CONTROL SYSTEM OF ALBA MAIN BOOSTER POWER SUPPLIES

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Abstract

This article introduce a project for upgrading the control system of the main booster power supplies of ALBA synchrotron. A brief description of the booster power supplies and the motivation for this upgrade is given. The several options for the upgrade that are being evaluated are discussed. Different possible architectures are also presented. Finally, conclusions about how to face this kind of project are given.

INTRODUCTION

ALBA is a 3 GeV third generation synchrotron light source operating with users since 2012. The injection system is composed of a 100 MeV Linac as pre-injector followed by a full energy booster synchrotron. The booster requires AC power converters (PC) operating at 3.125 Hz with a sinusoidal-like current waveform.

Main Booster Power Supplies

The Main booster power supplies are power supplies that feed the main magnets of the booster accelerator. The main magnets perform the tasks of bending and focusing the electron beam in the booster accelerator. The correction magnets are excluded from this group. Five different groups of magnets are supplied by the main booster power supplies. One group is formed by the bending magnets and the other four group are formed by quadrupole magnets [1]. All the magnets within a group are in series connection. Some of the specification and loads of the main booster power supplies are summarized in Table 1.

Table 1: Summary of Main Booster Power Supplies Specifications and Loads

PS type	Bend	QS180	QS340	QC340
# ps	2	2	1	1
I_{peak} [A]	750	180	180	180
V_{peak} [V]	1000	120	200	750
R_{Load} [$m\Omega$]	710	440	610	2360
L_{Load} [mHy]	200	27.2	48	216
Resolution [ppm]	5	5	5	5
Stability [ppm]	15	15	15	15
Reproducibility [ppm]	50	50	50	50

UPGRADE MOTIVATION

The main reason for the upgrade of the control system for the main booster power supplies is the obsolescence of some components. This makes very expensive the maintenance of them. The control system is a full-custom development from a specific manufacturer and is not longer used for new developments.

Other reason for the upgrade is the lack of flexibility to implement new features in the present control systems. After some year of operation, there are new requirements to the main booster power supplies. This new requirements cannot be satisfied by the present control system. The new requirements are related to the increment of the reliability of the power supplies and with the ramp to ramp repeatability of the output current.

SYSTEM DESCRIPTION

A brief description of the control system is given in this section. Firstly a description of the power supply control key features is given. Then, some of the new requested features of the new control system are listed.

Key Features

Ramping Main Booster power supplies work in what is called ramping mode. The output current of the power supplies is a raised co-sinusoidal waveform which follow the energy increment of the electrons in the booster accelerator.

Tracking Between Power Supplies The tracking between different power supplies is the ratio between the difference on the output currents and the value of one output.

$$NTE = \frac{I_{ps_1}(t) - I_{ps_2}(t)}{I_{ps_1}(t)} \quad (1)$$

When the tracking is between power supplies with different output peak values, the tracking error is defined as:

$$NTE = \frac{I_{ps_1}(t) - K \quad I_{ps_2}(t)}{I_{ps_1}(t)} \quad (2)$$

Figure 1: Main Booster Power Supplies during commissioning

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Where K is a factor to normalize the output values. The specification for the main booster power supply is a tracking error better than 0.1 %. This is quite demanding at low currents (tens of amps).

Integration with Timing System The output of the main booster power supplies must be synchronized with rest of the synchrotron systems. For this reason a trigger input is required. The trigger signal starts the output current ramp.

Resolution The resolution required for the main booster power supplies is 5ppm.

Whished Features

Non-Proprietary System The use of non-proprietary components is one of the main goal for the new control system. This feature is wished in the hardware and software components. In terms of hardware the use of standard buses and components is needed in order to avoid obsolescence in the near future. In the case of the software, ALBA found necessary to have right of modifying the software in order to fix bugs that can appear after years of operation, to make upgrades and to add new features.

Upgradable and Updateable System The extended lifetime of ALBA accelerators makes very likely upgrades and updates of the different system. The main booster power supplies are no the exception. The new control system has to allow future upgrades and the addition of new features in order to avoid future obsolescence of components.

Increased Diagnostic Capability The actual control system has very small diagnostic capabilities. This limits the capacity of performing online diagnostics of the power supplies. A better diagnostic system is needed for a condition based maintenance

Key Components

This section briefly describes the key components of the control system.

High Precision Acquisition The output of any feedback control system cannot be better than the measurement of it. In the case of the main booster power supplies the high requirement of resolution (5ppm FS) and tracking errors (0.1 %) make the acquisition system one of the key components of the system.

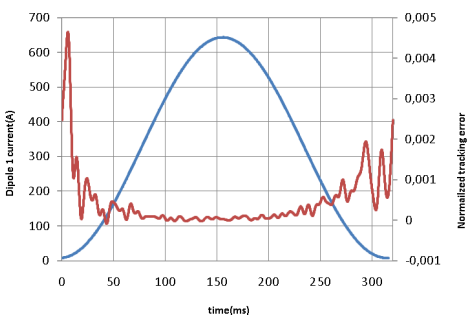

Figure 2: Power supply output current and tracking error

High Precision PWM Other key component of the control/regulation system is the precision pulse width modulator (PWM). A full-digital PWM modulator has great advantages in terms of thermal drift, aging and repeatability. On the other hand, to achieve high resolution when a digital modulator operates at tens of kilohertz is a challenging task.

Synchronization System The output current of the main booster power supplies must follow the increment in energy of the electrons in the booster accelerator. The synchronization in the entire synchrotron is ruled by the timing system which provides signals to trigger events in the rest of systems. The power supplies must be able to receive these signals and produce the output current with the required precision and tracking error.

UPGRADE OPTIONS

Different approaches to the upgrade the control system are being evaluated. All the approaches has advantages and disadvantages. It is worth to mention that all the planned tasks have to fit in the tight operation calendar of the synchrotron producing a minimum disturbance to the users. The evaluated approaches are the following:

New Power Supply by External Company

The option of purchasing complete units to replace the existing power supplies is being evaluated. The main advantage of this option is to transfer the risks of this project to an external company. The disadvantages are the elevated cost and the issues evaluated in the following issue.

Replacemnt of the Control by an External Company

This option will reduce the cost of the upgrade. The challenge in this option is how to assure the non-proprietary and upgradable features that were aforementioned. A possible solution is a licensing agreement to be signed with the external company including know-how and training. There is another issue to take into account to transfer this project to an external company. Power supplies like the main booster power supplies are custom projects for the manufactures and not COTS (commercial-off-the-shelf) products. Our experience is that manufacturers do not expend resources to solve “bugs” after the warranty period or adding new features or upgrades. This makes difficult the maintenance of the power supplies in the long term.

In-House Project

The main advantage of this option is to have full command of all aspect of the control system. It will also facilitate the compatibility between the operation calendar and the test and commissioning tasks.

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PROPOSED CONTROL ARCHITECTURES

Several architecture are being evaluated for the upgrade of the control system for the main booster power supplies.

Full Custom

A full custom development is one option for the upgrade of the control system. The main disadvantage of this option is that upgrades or update may imply the redesign of the complete system.

Integration of COTS Product plus Custom Design when the Component is not in the Market

This approach try to solve the disadvantages of the full custom design. The use of COTS (commercially of the shelf) products allow to replace the obsolete components by new components with the same function. The interconnection between the different components will be done by standards buses and protocols. ALBA-CELLS has used this approach for the development of an state of the art electrometer (reference). The acquired experience will be used to develop a general purpose instrumentation platform. This is a solid background to develop in-house the new control system for the main booster power supplies [2, 3].

CONCLUSIONS

The upgrade of the control system of the main booster power supplies will be addressed in the near future. The main and wished features have been defined. The key components have been identified and different approaches to address these upgrades has been analyzed.

During the analysis of this project, some lessons learn have been identified. These lessons were for a power supply system but it could be applied to any expensive critical full-custom equipment.

- The specification of complex systems should include defined interfaces between the different components. The existence of these interfaces will help to create a hierarchical structure with clear software and hardware boundaries. This hierarchical structure simplifies future upgrades or replacement of obsolete components and also allows to independently test each component of the system.
  It is also advisable to define interfaces compatible with COTS components. This may increase the initial cost of the product but it will make cheaper the updates or upgrades.
- Purchasing process should include a comprehensive design review. The acceptance of the product should be done only after full revision of the *as built* documentation.
- A turn-key full custom product may have hidden cost for maintenance. Although the initial role is to be an end-user, there are possible scenarios were the design role has to be taken.
- Initial requirement for large systems like the main booster power supplies may change after years of operation.
- Full-custom product may not have full support from the manufacturers in the long term or this support could be very expensive.
- Modification of large system could be very difficult without interfering with the operation of facilities. Commissioning time for the upgrade is very difficult to fit in the operation calendar.

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