MEBT AND D-Plate CONTROL SYSTEM STATUS OF THE LINEAR IFMIF PROTOTYPE ACCELERATOR*

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Abstract

Linear IFMIF[1] [1] Prototype Accelerator (LIPAc) [2], Rokkasho, Japan, comprises a succession of devices and systems that accelerate a deuteron beam up to 9 MeV with a current of 125 mA, generating a power of 1.125 MW, and transport it up to a beam dump. The beam power becomes critical from the point of view of losses; even tiny losses must be avoided. This fact, and the complexity of the accelerator operation, requires a coherent strategy when designing, commissioning and optimizing the accelerator control system, specifically focused in the control systems of the Medium Energy Beam Transport (MEBT) and the Diagnostic Plate (DP, a movable set of diagnostics). Both systems are essential to validate the performance of the accelerator and particularly the ion source, Radio Frequency (RF) and Radio Frequency Quadrupole (RFQ) systems. This contribution will describe the recent advances in the control architectures and the EPICS based developments achieved in MEBT for the motion control of bunchers and scrapers, control of the power supplies in quadrupoles and steerers, and refrigeration and vacuum. Besides, control of fluorescence profile monitors (FPMs) in the D-Plate is displayed.

LIPAC CONTROL SYSTEM

LIPAc control system consists of the remote control, monitoring and data acquisition of all devices, systems, subsystems and operations carried out in the accelerator vault with intense radioactive environments. It uses EPICS [3] as the main set of control software tools, providing the control with distribute and real-time features. It is composed of five main elements, namely, accelerator Central Control System (CSS), Local Area Network (LAN), Personal Protection System (PPS) [4], Machine Protection System (MPS) and Timing System (TS). Within each LIPAc subsystem there is a Local Control System (LCS).

LIPAc control system development is an unique and complex work due to the special characteristics of the prototype accelerator and its beam dynamics, that are, the unprecedented high beam intensity inducing the simultaneous combination of high beam power and high space charge. Therefore, MEBT and D-plate control system development is related with general accelerator characteristics in the following way:

- LIPAc is aiming to produce a very powerful CW deuteron beam (1.1 MW @ 9 MeV). The unavoidable beam losses [5] along the accelerator lead to an important rate of neutrons and radiations that must be properly controlled. On the other hand, the power of the beam itself could, in case of accidental or abnormal operation conditions, damage or destroy highly valuable parts of the machine.
- Beam losses must be observed and studied in order to fulfil beam stability in terms of transverse position and shape. To obtain this fundamental information several diagnostics devices have been installed along the accelerator line, these devices require an specific control and a fast data acquisition.

LIPAc Local Control Systems (LCSs)

The main function of the LCSs is, obviously, to control its own subsystem, displaying their own process variables (PVs) for the rest of LCSs and enabling access and modification of these PVs by the CSS. Safety, device protection and optimization activities are also included among its functions. LCSs are composed of different elements but following three layers architecture based on EPICS, Fig. 1. The lower level consists of equipment (power supplies, diagnostics, sensors, motors) connected to the intermediate level via specialized links. The middle layer consists of EPICS front-end systems (so-called input-output controllers (IOCs)). The upper layer, part of the CCS, consists of workstations, which either play dedicated roles, offering a man-machine interface function. These two levels communicate through TCP/IP on Ethernet.

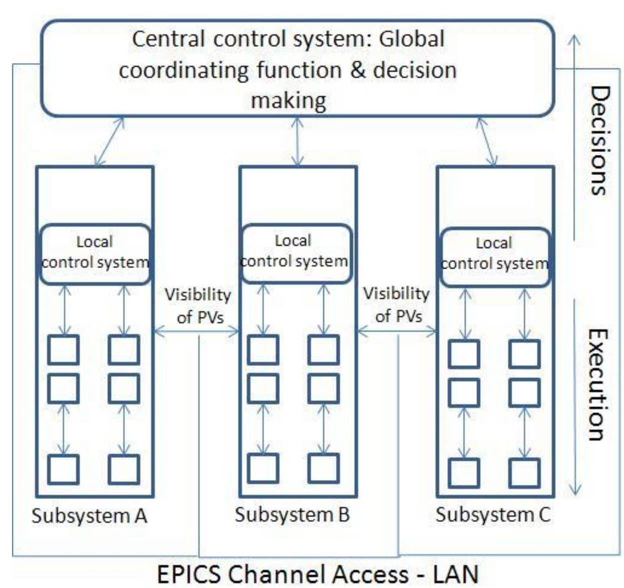

Figure 1: LIPAc general distributed process control.

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[1] IFMIF, the International Fusion Materials Irradiation Facility, is an accelerator-based neutron source that will use Li (d, xn) reactions to generate a flux of neutrons with a broad peak at 14 MeV equivalent to the conditions of the Deuterium-Tritium reactions in a fusion power plant. IFMIF is conceived for fusion materials testing.

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MEBT LOCAL CONTROL SYSTEM

The MEBT subsystem [6] is responsible of the transport and matching of the RFQ beam into the SRF Linac.

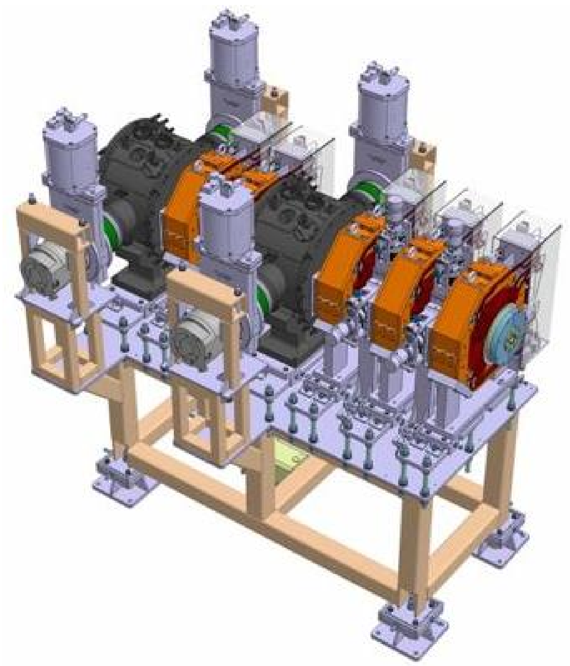

Figure 2: MEBT subsystem 3D scheme.

In order to minimize the beam losses caused by the strong space charge forces affecting the beam in this area, while keeping the sufficient freedom in beam optics optimization, a very compact scheme based in two sets of quadrupole magnets with steerers and two re-buncher cavities has been proposed, Fig. 2.

MEBT Local Control System interfaces the MEBT and the rest of the accelerator control system, the complete MEBT LCS architecture is shown in Fig. 3. Control of the main devices that make the MEBT up is explained in the next sections.

Control of the Bunchers

There are two re-buncher resonant cavities, see Fig. 4, with power couplers to supply the RF to the resonator, and a tuning system. That means temperature measurements for the water cooling and motion controls for the tuners (two stepper motors) including position readbacks (linear potentiometers) and limit switches. The stepper motor shifts a copper plunger in order to keeps resonance frequency constant during operation, potentiometers and limit switches are necessary to manage the motor. Cooling channels at the bunchers are used to keep copper temperature at 20 °C. The whole buncher control is managed by a Siemens [7] PLC S7-300 except the stepper motor control which is externally carried out by the low level RF system [8]. Communication between PLC and EPICS is achieved using S7plc EPICS driver.

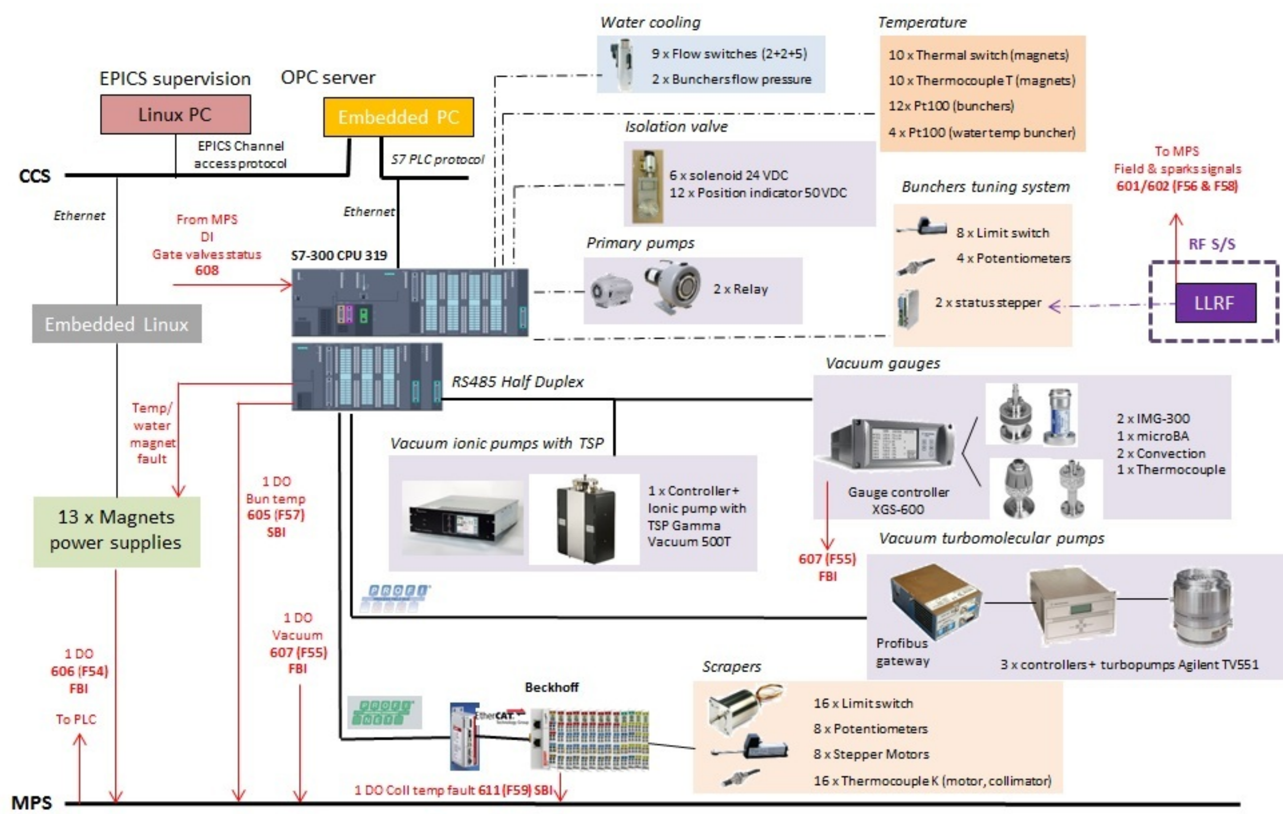

Figure 3: Global MEBT control architecture.

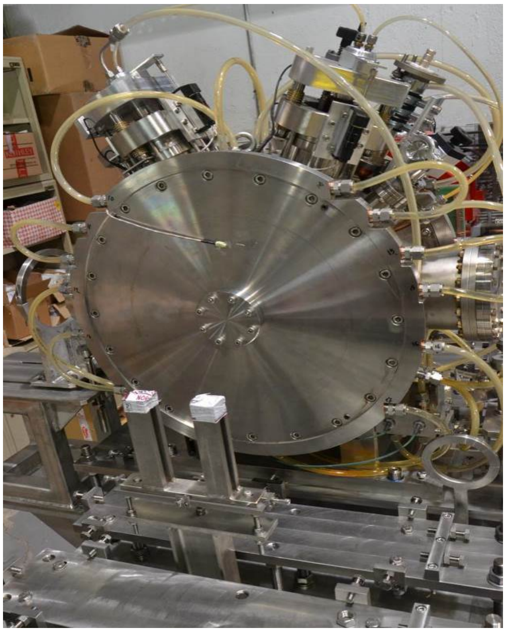

Figure 4: MEBT buncher cavity.

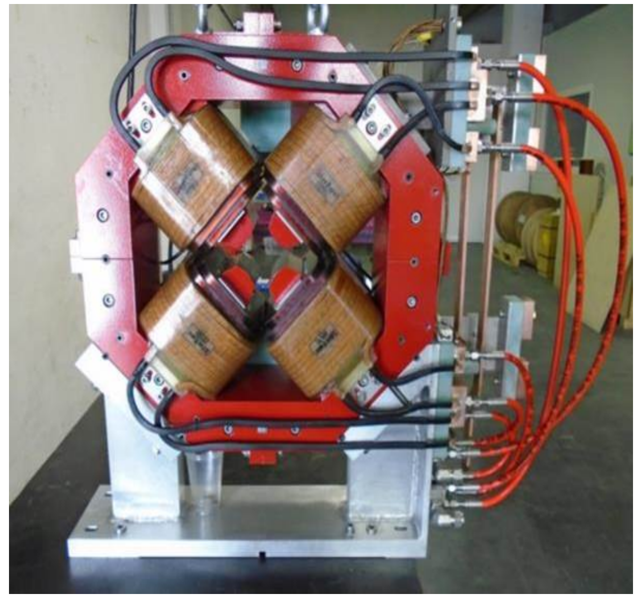

Figure 5: MEBT quadrupole magnet.

Control of the Scrapers

The two scrapers must stop the out-of-emittance beam particles before injection into the SRF Linac. Thus, they are movable items so they need motion control (eight stepper motors) including position readbacks (linear potentiometers) and limit switches. The scrapers motion control is managed by a Beckhoff [9] system. This solution system is based on CPU CX1020 model with digital input/output modules for limit switches. The communication from the Beckhoff system to EPICS is carried out using S7plc EPICS driver.

Control of the Quadrupoles

Transverse and longitudinal focusing for the beam is carried out using quadrupoles and steerers, as shown in Fig. 2. Therefore, the LCS controls settings and monitorage of the five quadrupoles power supplies and the eight steerers bipolar power supplies and temperature measurements for the water cooling. The beam size in the RFQ is small (phase advance 90 deg/m) while in the HWR-Linac the phase advance is comparatively lower (20 deg/m) where the distance is much longer between focusing sections. Consequently, the MEBT must have a very compact structure to limit the beam emittance growth. Thus, four quadrupoles, see Fig. 5, are used for transverse focusing and one more is needed to limit the beam size in the MEBT itself. The control of the five quadrupole power supplies and the eight steerers bipolar power supplies is being carried out with EPICS over Modbus protocol.

Refrigeration and Vacuum

Four pumping units and four valves are used to maintain the vacuum level, ten gauges are utilized to read it. A PLC is in charge of the control of these devices; its communication with EPICS is carried out using S7plc EPICS driver.

D-PLATE LOCAL CONTROL SYSTEM

Beam Instrumentation (BI) subsystem must warranty the successful operation of the accelerator from commissioning phases of RFQ, MEBT, Superconducting Radio Frequency (SRF) Linac and High Energy Beam Transport (HEBT), to the full power operation. Hence, its main objective is to provide all necessary information to properly transport and accelerate the beam from the source to the beam dump, then, to fully understand and measure all beam characteristics and operation optimization. Most of the diagnostics are concentrated inside of the Diagnostics Plate (DP or D-plate). DP is a movable set of diagnostics, see Fig. 6, that is placed downstream from the SRF Linac, in the HEBT. Main parameters of the beam will be measured in the DP, e.g. current, phase, beam position, transverse profiles, mean energy, emittance measurements, micro losses, energy spread, etc. Beam measurements play a critical role in LIPAc due to its uncommonly high beam current and high beam power. A global control strategy is thus necessary to clearly decide between the different measurements categories. The scope of this paper includes only the recent advance in the control of the fluorescence profile monitors (FPMs).

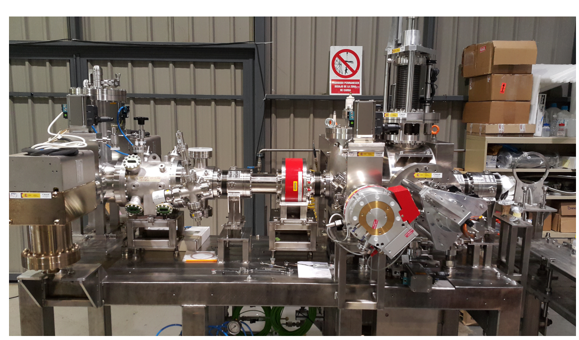

Figure 6: D-Plate support integration at Ciemat.

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Control of the Fluorescence Profile Monitors (FPMs)

The objective of these devices is to develop a non-interceptive beam transverse profiler (in X and Y axis) based on the residual gas fluorescence originated by the beam-gas interaction. FPMs (two in HEBT, two in D-plate) could be used as well for the emittance measurements with quadrupole scans.

The control of the FPMs is based on a Vertilon [10] data acquisition system (PhotoniQ Model IQSP482). High voltage control for the PMT is required; therefore the acquisition system delivers 64 data points for both FPMs of the D-plate.

Control software is based on client-server architecture, see Fig. 7. Vertilon device is accessed from an EPICS IOC (client) using TCP/IP protocol, connecting with a LabVIEW application (server), which is the one that gets direct access to the device.

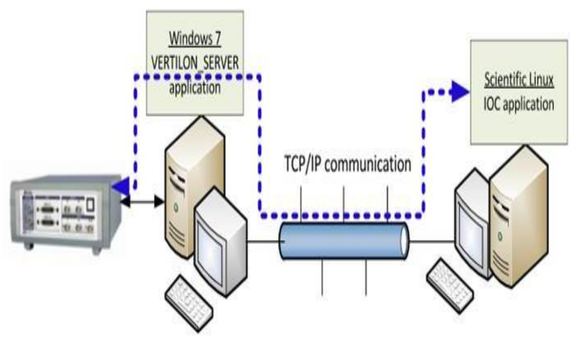

Figure 7: FPMs client-server support architecture.

CONCLUSIONS AND OUTLOOK

The objectives and requirements of LIPAc have been partially explained being the rationale for the design and development for each of the local control systems. The ability to make EPICS run in each of the devices and subsystems presented is not trivial, but the benefits provided against other centralized solutions are absolutely overwhelming. A large and complex facility like LIPAc, whose operation opens unstudied ways, cannot be conceived with independent subsystems, centralized at a single point or unable to understand each other.

LIPAc beam power provides unique characteristics that make the control system an unique and heterogeneous elaboration. For MEBT and D-Plate subsystems, theirs local control systems design has been revealed, explaining the main features and showing its architecture. Local control systems fit in a mostly distributed architecture and properly respond to the specific function for which they are designed, however, they are not isolated entities, they communicate with each other and follow the same multilayer structure.

Since there is no previous experience in operating a machine like LIPAc, all EPICS PVs are available for the central control system, which is the one and only that can manage the whole accelerator and can take decisions based on the information given from every subsystem. Making all the PVs visible for the central control system becomes the next step in order to finish the integration of the whole LIPAc control system.

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