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STATUS OF THE LIPAC MEBT LOCAL CONTROL SYSTEM*

E. Molina Marinas†, A. Guirao[1], L. M. Martínez Fresno,
I. Podadera, V. Villamayor, CIEMAT, Madrid, Spain
A. Marqueta, IFMIF/EVEDA Project Team, Rokkasho, Japan
[1]now at Instituto de Química Física Rocasolano - CSIC, Madrid, Spain

Abstract

The Linear Ifmif Prototype Accelerator (LIPAc), a 125 mA 9 MeV deuteron accelerator, is being commissioned in Rokkasho, Japan. The Medium Energy Beam Transport (MEBT) line [1] has already been installed and connected to the ancillary systems and the adjacent systems, the Radio Frequency Quadrupole (RFQ) and the Diagnostics Plate (DP). The status of the MEBT Local Control System (LCS) was presented in the previous edition of ICALEPCS [2]. Since then, the functional specifications of the MEBT components controls have been completed, the control cabinets have been designed and are now being installed, and the software has been written. In this paper, the final architecture and functionality of the MEBT LCS will be described and the preliminary results of its commissioning will be presented.

INTRODUCTION

The MEBT line of LIPAc transports and matches the beam out of the Radio Frequency Quadrupole (RFQ) into the Superconducting RF linac. The devices have been described in [1]. The LCS is in charge of the supervision and actuation of the MEBT devices and auxiliary systems:

- the vacuum system components: pumps (primary, turbos and ionic) valves, heaters and gauges.
- the instrumentation of the water cooling system.
- the instrumentation of the buncher cavities[3].
- the beam scrapers.
- the instrumentation of the magnets.
- the magnets power supplies.

The control system of LIPAc is based on EPICS. As part of the IFMIF/EVEDA project, CEA-Irfu[1]has designed the Common Software Platform (CSP) [4] with two main goals: providing a common set of programs for the different subsystems and defining the templates for the EPICS top directories and the operator interfaces (OPI).

LCS DESCRIPTION

Physical Layout

The LCS is housed in two seismic EMC 47U cabinets (see Fig. 1), 800 mm(D) × 600 mm(W). The power supplies (PSU) for the quadrupole magnets and the steerer are mounted in an additional two cabinets of the same dimensions. The cabinets are housed in the RF area of the accelerator building. Power and signal cables run from the cabinets to the MEBT devices, with a length of about 50 m. Interlock cables connect the LCS to the Machine Protection System (MPS) and to the Low Level RF system of the buncher cavities. The power for the cabinets is supplied via the MEBT secondary board, which is part of the power distribution system of the accelerator building.

Hardware

The Input Output Controller (IOC) is a fanless computer running CentOS. The IOC is connected to the Control System Network. It is also connected to the MEBT PLC and the power supplies, via a dedicated 16-port switch. Communication between the IOC and the power supplies is performed via the Modbus driver, version 2.7. Communication with the PLC uses the S7plcDriver, version 1.17. A diagram of

Figure 1: MEBT cabinet 2.

the LCS can be seen in Fig. 2. The main PLC consists of a Siemens CPU S7-319, digital and analog input/output modules and a CP340 module for serial communication (ASCII over RS-485). The PLC acts also as Profinet I/O controller and Profibus master. The instrumentation of the rebuncher cavities, the water cooling system and the magnets is directly connected to the input/output modules.

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† eduardo.molina@ciemat.es

[1] Commisariat à l'énergie atomique et aux énergies alternatives, Institute de Recherche sur les lois Fondamentales de l'Universe, Paris-Saclay

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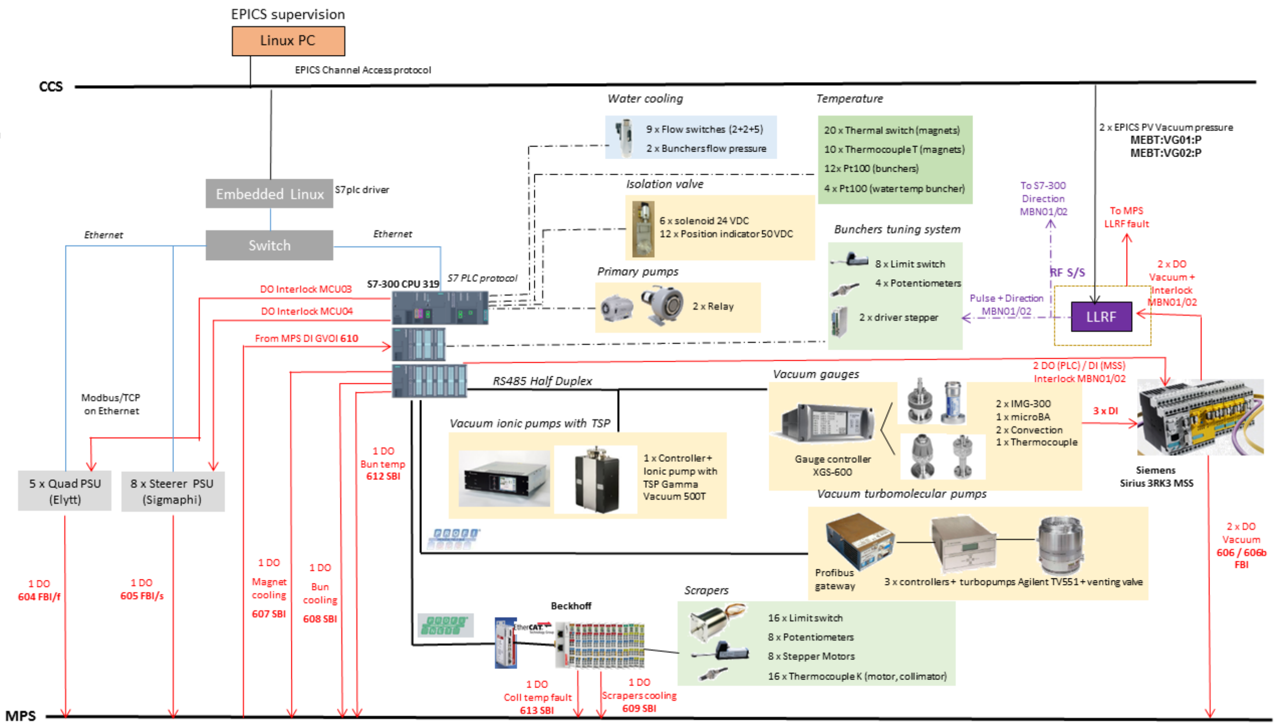

Figure 2: MEBT LCS diagram.

A second PLC, a Beckhoff CX-1020 CPU and input and ouput modules, controls the stepper motors of the beam scrapers. The CPU is configured as a Profinet device and is connected to the Siemens PLC. Beckhoff has already been chosen for previous projects [4] and software can be reused with minor modifications.

The vacuum system devices take up most of the space in the first cabinet (MCU01). There are three turbomolecular pumps , model Agilent TV-551. The three controllers are arranged in a multi-drop RS485 network connected to a TMP ProfiBus Gateway, which in turn is connected, as a DP slave, to the main PLC.

A second RS485 network is connected directly to the PLC CP340 communication module. There are two devices in this network. The first one is a gauge controller, model Agilent XGS-600, and the second one is a Gamma Vacuum Multiple Pump Controller.

Finally, as an interface to the MPS, a SIRIUS 3RK3 modular safety system has been selected. Its fail-safe inputs and outputs comply with the speed requirements of the MPS.

FUNCTIONAL DESCRIPTION

The functional specification of the MEBT LCS has been defined with special emphasis in PLC programming and the interfaces with the rest of the accelerator systems.

Scrapers

A scraper is a beam intercepting device. There are two scrapers in the MEBT. A scraper has four blocks, in a cross-shape configuration, and each one of them is actuated by a stepper motor. The phases of the stepper motors are connected to a power stage that is controlled by the Beckhoff PLC. Data is exchanged between the Siemens and Beckhoff PLCs via Profinet. Motion is controlled with a closed loop, using a linear potentiometer as encoder. The controller is a PI for the two horizontal motors while the vertical motors controller is purely proportional. Concerning the operation of the scrapers, it is important to verify the position of the scrapers prior to start beam operation. The PLC program implements the code developed for the XFEL project [5], adapting it to the characteristics of the scrapers motors. The main difference is the lack of an electromagnetic brake, which simplifies the programming. A fault in the scrapers movement (limit switch interlock, driver error, motor temperature) should send a slow soft alarm via EPICS. It is recommended to stop the beam if any movement error is detected. In case there is any problem with the water cooling or the temperature of the collimators, a slow MPS interlock is triggered. Those interlocks are discussed in the interlocks section.

Rebuncher Cavities

The movement of the automatic tuner is controlled directly by the LLRF which sends two signals: direction and control pulse. However, the limit signal switches and the driver errors are sent to the S7-300 I/O modules. In case of error (limit switch, driver, temperature or cooling) the movement is inhibited by sending a stop signal ,hard-wired to the LLRF. If a limit switch is pressed, the PLC will check the direction input signal from the LLRF in order to avoid any out of range movement. Once the limit switched has been cleared,

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operation can revert to automatic and send the proper signal to the LLRF.

Magnets

There are five magnets in the MEBT. Each magnet is composed of one quadrupole and two steerers, one horizontal and one vertical. Each magnet has a thermal switch that trips if water temperature rises above 60 °C. In addition, two type-T thermocouples are mounted on the steerers. A warning should be sent above 50 °C and a alarm above 60 °C. The PSUs should be stopped in that case.

There is also a flow switch at the outlet of the water circuit of each magnet. In case there is any problem with the temperature of the magnets the corresponding PSU should be stopped. If there is a problem with the water cooling, the PSUs should be stopped via EPICS, as well as the HEBT cooling skid to minimize water leakage in the vault.

Vacuum System

An operator will control the MEBT vacuum system although there will be a certain number of protections to avoid damaging the machine. Sector valves can only be opened when the corresponding interlock is set to 1. In operation, two vacuum levels are defined: high vacuum (pressure less than 5×10^{-5} Pa) and ultra-high vacuum. The state diagram can be seen in Fig. 3.

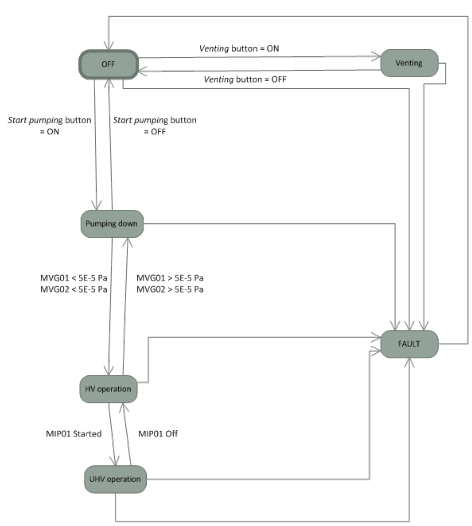

Figure 3: Vacuum system state diagram.

Interlocks

Several signals are sent to the MPS: buncher temperature fault, magnets power supplies fault, vacuum fault, magnets water cooling fault, bunchers water cooling fault, scrapers water cooling fault, collimator temperature fault, cooling skid fault and HEBT cooling skid fault. The MPS sends a signal to authorize the opening of the section gate valves. There are also two interlock signals to the LLRF, one per rebuncher cavity. These signals combine temperatures, driver error, limit switch error, vacuum and water cooling faults to prevent the LLRF from actuating the tuner. Finally, another interlock stops the power supplies when the magnets are overheated.

CONCLUSION

The MEBT local control system is currently being tested in Rokkasho. The functional specification has been written and software has been developed following this specification. Some work remains to be done, mainly concerning the OPI screens, but the hardware, communications and operation are being tested and so far we have not had any major problem. Even for a relatively small system such as this one, the workload is very high for the team in charge, as most of the control system design and development has been done in-house and the parts that have been outsourced (e.g. Modbus communication for the power supplies) still require a careful specification and follow-up.

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REFERENCES

[1] I. Podadera *et al.*, “The medium energy beam transport line (MEBT) of IFMIF/EVEDA LIPAC”, in *Proc. 2nd Int. Particle Accelerator Conf. (IPAC’11)*, San Sebastian, Spain, Sep. 2011, paper WEPS058, pp. 2628–2630.

[2] J. Calvo *et al.*, “MEBT and D-Plate control system status of the Linear IFMIF Prototype Accelerator”, in *Proc. 15th Int. Conf. on Accelerator and Large Experimental Physics Control Systems (ICALEPCS’15)*, Melbourne, Australia, Oct. 2015, paper MOPGF045, pp. 197–200.

[3] D. Gavela *et al.*, “Fabrication and tests of the re-buncher cavities for the LIPAC deuteron accelerator”, in *Proc. 5th Int. Particle Accelerator Conf. (IPAC’14)*, Dresden, Germany, Jun. 2014, paper THPRI051, pp. 3884–3886.

[4] Y.Lussignol *et al.*, "IFMIF/EVEDA common software platform installation manual”, IFMIF/EVEDA, Rokkasho, Japan, Rep.BA-D-23VSVP , Jul. 2017.

[5] E. Molina Marinas *et al.*, “European XFEL Phase Shifter: PC-based control system”, in *Proc. 13th Int. Conf. on Accelerator and Large Experimental Physics Control Systems (ICALEPCS’11)*, Grenoble, France, Oct. 2011, paper WEPKN010, pp. 731–734.