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ALPI-PIAVE BEAM TRANSPORT CONTROL SYSTEM UPGRADE AT LEGNARO NATIONAL LABORATORIES

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Abstract

During the last decade, the control system employed for ALPI and PIAVE Accelerators was upgraded to the new EPICS-based framework as part of the new standards adopted in the SPES project in construction in Legnaro. The actual control for beam transport was fully completed in 2015 and it has been in production since that year. Due to the power supply upgrade and to optimize costs and maintenance time, the original controllers based on industrial PCs were substituted with dedicated serial-over-ethernet devices and Virtual Machines (VMs). In this work we will describe the solution designed and implemented for ALPI-PIAVE accelerators.

HARDWARE STATUS AND UPGRADE

In the original control system installation, the entire ALPI and PIAVE Accelerators were controlled by INTEL industrial PCs placed along the lines (Fig. 1) and controlled through dedicated applications based on EPICS control system framework [1-3].

Each industrial PC provided up to 9 serial interfaces to magnet power supplies. This solution used Power Over Ethernet (POE) technology as the power source to minimize the number of cables.

Magnet power supply control cards were controlled through RS232 serial communication protocol and the EPICS control application run directly inside the device: different serial communications were established simultaneously during IOC start-up and are maintained during program execution. In addition to that, other devices such as NRM and gauss meter were added to the line and remotely controlled using the industrial PCs and RS232 communication protocol.

Over the years it has been possible to observe the software part was extremely robust: only a few bugs fixed were required to optimize communications with an older version of power supply control cards and naming convention upgrade for process variables; at the same time, we discovered the hardware part was not as robust as originally designed: several hardware faults focused on POE cards and motherboards required extraordinary maintenances. The instability of these components and their availability on market brought us to force an upgrade for the entire system.

To maintain the backbone infrastructure in terms of cabling and communication protocol as much as possible, the following criteria were followed during design and implementation:

- Power Supply controls must be kept with RS-232 serial communication
- Most of the communication wires must be reused with the new configuration
- Controllers must be moved to the control system hypervisor infrastructure, using a dedicated VM

Figure 1: INTEL industrial PC used as lens controller.

- Serial communications require a dedicated serial-to-ethernet converter to guarantee the proper data exchange between VM and magnets power supplies
- The number of serial-to-ethernet converters must be optimized considering the number of devices to control and their topology

Hardware Upgrade

According to these requirements, the following solutions and tools were used:

- To minimize the number of serial-to-ethernet converters and based on the experience matured in similar challenges, the industrial PCs were substituted with DeviceMaster systems (Fig. 2). This kind of device can be considered a server with device networking capabilities: it provides serial communications with RS-232/422/485 protocols and it supports native COM, TTY, or TCP/IP socket communications. As mentioned in the previous paragraph, all the ports available in each device have been set to work with RS-232 serial protocol.

Figure 2: DeviceMaster (serial-to-ethernet converter) used for beam transport control upgrade.

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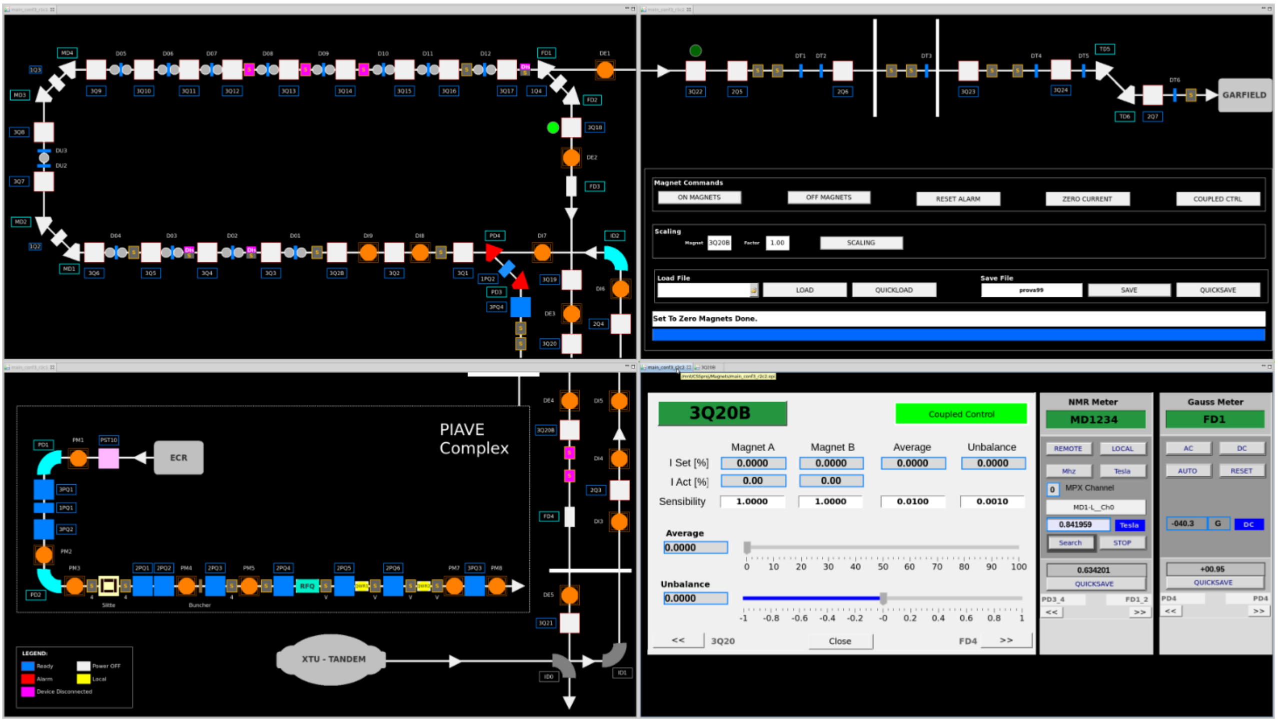

Figure 3: The new control system setup utilizes the original Human-Machine Interface, which has been integrated into the design of the panels using the Control System Studio framework.

- Using DeviceMaster servers, the entire control topology was redesigned trying to maintain the communications wires used between Industrial PCs and Power Supply communication boards. In Table 1 the new topology is described: it is possible to observe how several industrial PC connections were remapped with a single device converter. In this new design, only 4 wires had to be re-cabled.

Table 1: Industrial PC to DeviceMaster Upgrade: Remapping and Number of Connections Managed Per Device

Serial-to-Eth converter	Original Industrial PC	Conn.
DeviceMaster 1	PC1 + PC2	11
DeviceMaster 2	PC3	9
DeviceMaster 3	PC4 + PC5	16
DeviceMaster 4	PC6	6
DeviceMaster 5	PC7	8
DeviceMaster 6	PC8 + PC9 + PC10	10
DeviceMaster 7	PC12	6
DeviceMaster 8	PC13 + PC14	11

- All the DeviceMaster server provides a dedicated web socket for each physical port. Control applications use these sockets to communicate with the field.
- The serial wires had to be re-wired to be compatible with the new devices. As a consequence, the older DB-25 connectors (industrial PC compliant) were substituted with new RJ45 (DeviceMaster compliant).
- Because the serial protocol did not change, no modifications were required to the magnet power supply boards.

SOFTWARE SETUP AND UPGRADE

Originally the EPICS control application run inside every device system directly connected to magnet power supplies: dedicated Driver Support was developed to interface the hardware to the EPICS environment accordingly to fit the requirements of our site.

The software porting from industrial PC to virtual machines required several upgrades to the software, and in particular, the re-design of the code, upgrading serial communication protocol from standard configuration (physical ports on the Operative System) to web socket. Due to the modular implementation of EPICS controllers, it was possible to reuse the original EPICS Driver Support without major modifications. In this process, it was upgraded also the EPICS framework and the new applications run with EPICS V7 and use the new PVAccess communication protocol to exchange data. The old EPICS Channel Access is still used to guarantee retro-compatibility with the other EPICS servers and clients available on the distributed control network.

The new size of this system can be analysed through the numbers indicated in Table 2: the heterogeneous set of devices is managed by about 5000 EPICS variables, covering all the devices controlled via DeviceMaster servers. In this estimation, it is not counted all the devices (magnets power supplies, steerers, etc.) with a native ethernet communication protocol. If also consider all the set of power supplies,

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despite the kind of control (DeviceMaster versus native ethernet), the total number of EPICS process variables is about 7050 parameters (Table 3).

Table 2: Composition of the DeviceMaster-Based Beam Transport Control System

Parameters	**Beam Transport System**
EPICS IOCs	**10**
Devices	Magnets: **70** NMR: **3** Gauss Meters: **3**
EPICS Variables	about **5000** PVs

Table 3: Composition of the Entire Beam Transport Control System, Including the DeviceMaster-Based Part

Parameters	**Beam Transport System**
EPICS IOCs	**39**
Devices	Magnets: **81** NMR: **3** Gauss Meters: **3** Steerers: **26**
EPICS Variables	about **7050** PVs

The original Human-Machine Interface developed for the beam transport control system was developed using the old Eclipse-based Control System Studio [4] and it was not modified (in terms of tools and code) because the lower EPICS control servers guaranteed compatibility through the Channel Access protocol (Fig. 3). In a further stage, the entire Graphical User Interface will be migrated to the new Phoebus framework in order to be aligned to the last stable product maintained by the community.

In addition to the work done, no modification to the naming convention was required and, as consequence, the archiving service did not require any new setup.

CONCLUSION

The beam transport system received a full upgrade from a hardware and software point of view: the usage of virtualization technology and dedicated serial-to-ethernet converters let us increment the robustness of the system, minimizing the weak points (hardware faults) seen in the previous configuration. In addition to that, maintenance was optimized and the operation downtime should be decremented.

The minimum modification to the code and the absence of further bug fixes during this upgrade stage confirm how the EPICS software layer provided the stability and robustness in the distributed control system designed in the last decade.

While the first migration to an EPICS-based control system was realized between 2013 and 2015, this new upgrade has been in use for the experimental campaign since the last part of 2022 and no critical faults and downtime have been registered.

REFERENCES

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