INTEGRATION OF PROGRAMMABLE LOGIC CONTROLLERS INTO THE FAIR CONTROL SYSTEM USING FESA

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Abstract

For the upcoming 'Facility for Antiproton and Ion Research' (FAIR) at GSI, the Front End Software Architecture (FESA) framework built by CERN has been chosen to serve as front-end level of the future FAIR control system [1]. All beam diagnostic devices of FAIR will be controlled by FESA classes that are addressable by the new control system. The connectivity to the old control system is retained, since both control systems will be in operation contemporaneously for several years. Commercially available Programmable Logic Controllers (PLCs) have been installed as part of Beam Induced Fluorescence (BIF) monitors to replace outdated network attached devices and to improve the reliability of the BIF systems. The new PLC devices are controlled by FESA classes which are addressed from the existing C++ software via Remote Data Access (RDA) calls. This contribution describes the system setup and the involved software components to access the PLC hardware.

THE BIF SYSTEM

Beam Induced Fluorescence monitors determine the transverse beam profiles with minimum beam disturbance [2]. The measurement principle is based on the excitation of gas molecules by the passing ion beam in the beam pipe. The emitted photons are measured by digital CCD cameras with image intensifiers to ensure single photon detection. Using two cameras installed above and sideways of the beam pipe, the horizontal and vertical beam profiles are measured simultaneously. Currently, there are four BIF monitors installed in GSI accelerators and transfer lines. For the next years, a final number of seven monitors is anticipated.

Hardware

Each camera has a remote controllable iris to adjust the light intensity illuminating the image intensifier. A smaller aperture of the iris also increases the depth of field. This results in a larger properly focused area in the obtained image. The amplification of the image intensifiers can be adjusted by setting two voltages for the different amplification stages.

The aperture of each iris as well as the amplification of the image intensifiers has formerly been controlled with a self-built, Ethernet connected module, containing several digital-to-analogue converters (DACs). During long term runs of the system, these modules crashed non-deterministically after some hours or days of operation. For the FAIR project, a more reliable solution was desired. The setting of voltages is a common task for PLCs, so this commercially available and field-tested solution was selected.

Software

The software controlling all BIF devices, including irises and image intensifiers, is called ProfileView [3]. The communication with the old hardware is performed via a standard TCP connection. New settings are sent to the device, which replies with an acknowledge message. The communication channel is kept open continuously, to detect failures as soon as possible.

After extensive testing of the system, it was decided to replace the faulty devices by PLCs. To control the new hardware, the ProfileView software was adapted to support both hardware variants.

Figure 1: One of the 'satellites' of the BIF installation. It controls two BIF monitors and features two sets of control devices (from left to right): Power Supply, ET 200M controller, SM322 relay element with eight outlets, two SM332 12-bit DACs.

PLC HARDWARE

As PLC hardware, the SIMATIC system from Siemens [4] was selected (see Fig. 1). The PLC is able to set voltages for each iris, the intensifiers and calibration LEDs which had to be controlled manually before. Furthermore, an easy to use remote reset capability for supplemental hardware devices of the BIF system is realized by relay modules. The relays support switching of 230 volt supply voltage. Devices of the BIF system like the cameras or the gas flow control can be restarted remotely in case of errors.

The hardware was installed at different locations along the linear accelerator. A schematic of the system is depicted in Fig. 2. The main controller and the Ethernet communication module are located in an electronics room. The distributed sub-systems with local control units, relays and DAC devices, so-called 'satellites', are located near the BIF hardware in a radiation safe area.

The system consists of the following Siemens SIMATIC components:

- S7-300 - the main controller
- CP343-1 Lean - for Ethernet communication
- ET 200M - the satellite controller
- SM322 - relay with eight outlets
- SM332 - 12-bit DAC with four outlets

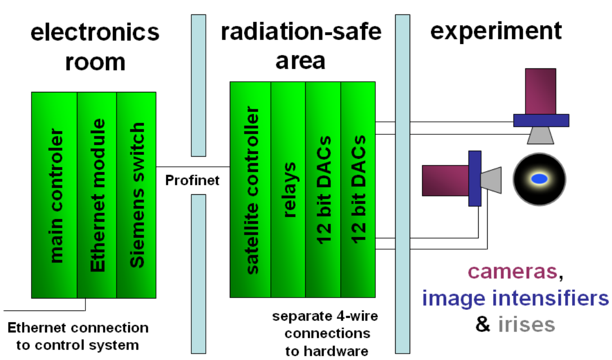

Figure 2: PLC installation.

Communication from the main controller to the satellites takes place via Profinet.

To ensure correct voltages at the BIF hardware, the connections from the DACs to the devices are made in 4-wire technique, to sense the voltage loss over the cable length. In this way, conduction losses are compensated and the applied voltage at the hardware matches the desired voltage in the software.

FESA CLASS AND PLC SOFTWARE

The FESA framework developed by CERN [5] will be the front-end level of the FAIR control system. A FESA class is typically developed by the hardware specialist of a device and provides read/write access on the device's registers. FESA runs on PowerPC or Intel based VME CPUs and on standard Linux PCs. The connection from the control system to the FESA class is established via RDA calls defined in the CERN Middleware (CMW) library. A FESA class allows incoming connections from multiple applications. If an application subscribes to data changes in the device, the FESA class will notify the application in case of new values.

FESA classes

To access the PLC via the control system, two FESA classes are in operation: One very simple class ('BIFPLC') for basic communication with the PLC and a more complex class to perform calculations and monitor the PLC status ('BIFControl'). The BIFControl class uses the communication functionality via an FESA equipment link. It performs the transformation of values from the graphical user interface (GUI) into the bitwise register representation needed for the DACs in the PLC. Furthermore, the instantiation of BIFControl defines failsafe values for each DAC. To protect the image intensifier system, all voltages are limited within BIFControl between defined thresholds. The relay contacts for 230 volt switching are controlled by BIFControl, too.

Communication with the PLC

The BIFControl class has full read/write access to the memory of the PLC controller via the network. Write cycles are usually initiated whenever the class gets new settings from the GUI. Read cycles can be initiated by the GUI or periodically by the class itself.

From the PLC controller's point of view, the data transfer consists of reading from or writing to the same memory space. This is typically done from within the periodically executed organization block 'OB1'. This memory access is completely asynchronous to the access by the BIFControl class. To facilitate the access to complex data structures from within the PLC, scripts and a web interface exist [6]. These tools analyse the design of the BIFPLC class and create short function blocks to access the data structures in the PLC's memory. The scripts are able to generate Step 7 code for the Siemens PLC used at GSI as well as code for Schneider PLCs.

SOFTWARE INTEGRATION

The ProfileView software for BIF monitors is entirely written in C++. To access the BIFControl class for PLC control, a directory server is asked via CMW for a device handle. The returned handle offers access to get, set and subscribe methods. CMW exists as a static library and is linked into the ProfileView executable. It contains the RDA functions and data access methods to connect to FESA classes and to extract user data from RDA telegrams. RDA itself is based on CORBA.

It is possible to set single values as well as multiple data fields at once. The BIFControl class can be accessed from different applications or expert programs at the same time. Therefore, a notification on any value change is desirable. For this purpose a subscription handler is installed, listening to value changes of BIFControl. By invoking the monitorOn() function on the device handle, a user defined callback function can be declared. Every change of any value in the class leads to a call of the specified callback function, containing the new values. This way, ProfileView gets notified, if PLC values are changed by any other application.

The subscription handler is programmed as a separate thread to avoid blocking the application when it is waiting for new data. Once an updated data set arrives at the handler, the new data is processed inside ProfileView and shown in the GUI (see Fig. 3).

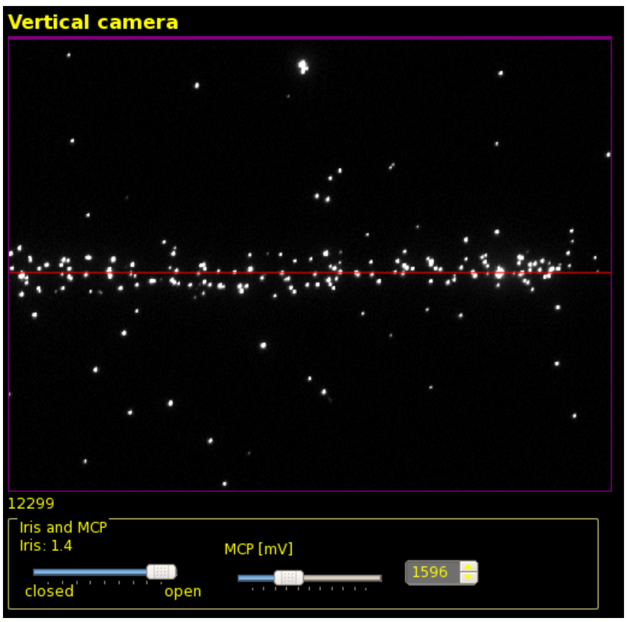

Figure 3: Original BIF image with GUI elements for iris and image intensifier control.

The values of the image intensifier amplification are directly passed to the GUI and shown in millivolt units. Iris values are treated specially: since there are small differences between the remote controllable iris devices, each iris has to be calibrated separately before it is built into a BIF monitor. The calibration provides a millivolt value for each aperture of a particular iris. These settings are stored in the initialization file of the BIF monitor. If a new iris value is set, ProfileView sends the appropriate millivolt value to the FESA class, which in turn sends the bitwise representation to the PLC. The chain is executed in reverse when the FESA class pushes a new iris value to subscribed client applications.

The relays are implemented as a bit array inside ProfileView and the FESA class. If a relay should be toggled, the others have to keep their state. If the user wants to set a new relay value, it is matched with the stored state of the bit array and sent to the hardware.

The integration of the PLC functionality into ProfileView hides the hardware specific part from the user. The GUI looks the same, no matter if the old hardware or a PLC is used for iris and image intensifier control. The relays are only available when a PLC is used.

CONCLUSION AND OUTLOOK

Since there are several applications for PLC controllers planned for the future FAIR facility, this prototype is a good test of the system reliability and the integration into the existing control system.

The PLC hardware turned out to be very stable and reliable in operation. Using the 4-wire technique, the voltages at the hardware are accurate to ± 0,01 volt. During commissioning and several weeks of tests, the PLC did not crash and never lost its connection to the FESA class.

Currently (2010) one BIF monitor is equipped with a PLC system and one more is prepared for the hardware exchange. During 2011, the existing and any additional BIF monitors will be updated with PLCs. One PLC system will be installed in a radiation exposed area in the transfer line from the linear accelerator to the synchrotron. The dose will be measured directly at the PLC to gather information about the system's radiation hardness.

In 2011 a new version of FESA (3.0) will be finalized by CERN in collaboration with GSI. It will simplify the development of PLC FESA classes. Instead of having two FESA classes for PLC control, the complete PLC functionality will be a static library which can be linked to any FESA class.

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