New Programmable Logic Controller for the CHESS F2 X-Ray Monochromator

Kurt Manrique-Nino, Eric Edwards, CHESS, Cornell University, Ithaca NY 14850, U.S.A.

Abstract

This paper describes the upgrade process of the ladder code that will run on the new programmable logic controller (PLC) at the F2 X-Ray Monochromator. The functionality of the program was preserved, but new improvements were added such as configurable timers, the Modbus protocol has been successfully configured and is ready to be integrated to the Experimental Physics Instrument Control System. The human machine interface (HMI) was updated to match the new improvements added in the controller.

Introduction

The Cornell High Energy Synchrotron Source is in the process of replacing and an existing programmable logic controller (PLC) at the F2 X-Ray Monochromator. This instrument contains a crystal, which is cryogenically cooled using liquid helium to avoid to be damaged by the X-Ray beam. [1] The cryogenic cooling system is controlled by a programmable logic controller (PLC). In turn, this controller is connected to a human machine interface (HMI), by which the operator can monitor the status and control the cooling system. The new programmable logic controller will allow the activity recorded to be transferred to the Experimental Physics Instrument Control System (EPICS) in the form of an activity log.

Programmable Logic Controller

A programmable logic controller (PLC) is a type of computer used in industrial environments such as factories and laboratories. This type of computer is able to run for an indeterminate number of years and are extremely reliable compared to a regular personal computer. At CHESS we are in the process of upgrading the PLC that is in charge of regulating the temperature, retrieving data and controlling the cooling system of the F2 monochromator. The existing PLC will be replaced by the DirectLogic 205 housing with a Do-More H2-DM1E processor [2].The program that will run on the new PLC is divided in one main ladder and three separate programs.

- Main Ladder ($Main): contain the majority of the program that will control the monochromator's temperature and pressure.

  The first 11 rungs are latches for the heat exchanger, helium flow and the level of liquid nitrogen within the cryogenic storage Dewar. The rung 12 will check that all previous latches are ON, if this condition is met it will output C12 ON. Rungs 13 and 14 are to set the monochromator on fault if previous conditions are satisfied. Rungs 15 and 16 will turn on the warning latch if C12 is ON and the reset button is activated. Rungs from 21 to 26 are the jumpers for the helium flow, monochromator's vacuum chamber and heat exchanger vacuum system. The rungs 27 through 30 are dedicated to the heat exchanger and the pumps. Rungs 32 through 34 will run the following programs: Network, Modbus and Timers. Rung 35 will gather the status of the backup battery within the PLC and the rung 36 gathers the PLC's scan time. Rungs 37 and 38 will activate the software and hardware watchdogs. The software watchdog will turn off all the outputs and

force stop the PLC, meanwhile the hardware watchdog will reboot the PLC.

- Timers ($Main@Rung 34): this program has one accumulating timer that will record the time while the cooling system is running. In addition, it has three independent off-delay timers for the helium flow, heat exchanger can vacuum and warm up system. These timers can be adjusted in seconds and minutes through the human machine interface. Lastly it has 14 up-counters for the input trip-counter.
- Network ($Main@Rung 32): this program is in charge of moving the 4 IP octets into 4 memory locations. Those locations will be display the current PLC's IP address on the human machine interface.
- Modbus ($Main@Rung33): this program will transfer the input, output and memory coil status to their respective Modbus memory coil. The Modbus coil data will be stored at the Experimental Physics Instrument Control System (EPICS) to keep track of the monochoromator activity and will ease any further troubleshooting process (Table 1).

Modbus Coil	PLC Address	Nickname (Ladder)
MC1	X0	Cave Dump
MC2	X1	Roof Dump Button
MC3	X2	Dewar Overflow Temp Sensor
MC4	X3	Low O2 Alarm
MC5	X4	Fill Request
MC6	X5	E-Stop
MC7	X6	Cryo Pressure Switch
MC8	X7	HX Can Vac
MC9	X8	Flow OK
MC10	X9	Temp OK
MC11	X10	F2 Mono Vac OK
MC12	X11	Slit In Place
MC13	X12	HX Can Valve Closed
MC14	X13	Drivac @ Speed
MC15	X14	Rough Pump @ Speed Pin 5
MC16	Y0	Helium Valve Relay
MC17	Y1	LN2 Valve Relay
MC18	Y2	ANN Warning Relay
MC19	Y3	ANN Fault Relay
MC20	C0	Cave Dump Latch
MC21	C1	Roof Dump Latch
MC22	C2	Dewar Ovr Latch
MC23	C3	o2 Alarm Latch
MC24	C5	E-Stop Latch
MC25	C10	F2 Mon Vac Latch

Table 1: Modbus memory addresses. All physical inputs and outputs from Y0 through Y3 and memory coils C0 through C3, C5 and C10 are copied to the Modbus memory.

Human Machine Interface

The human machine interface (HMI) is a touch screen used to control and check the current state of the inputs and outputs of the programmable logic controller. Both instruments are connected via Ethernet. The display used is an AutomationDirect EA9-T10CL [3] and C-More programming software was used to configure the new software for the HMI. The upgrade consisted of changing the addresses for the light indicators and buttons to match the addresses on the ladder code, rearranging the layout for the main, aux and inputs-outputs screen, adding a new information screen and removing the clean air system screen. The new software has 6 screens, four of which secured by password:

- Main Screen (Figure 2): displays a schematic of the monochromator's cooling system along with 13 indicator lights.

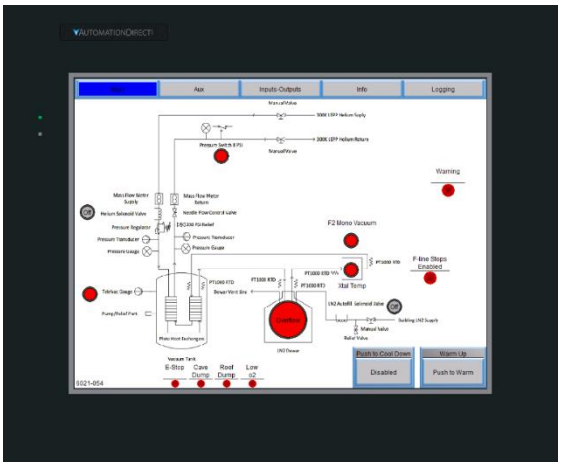

Figure 1: Main screen.

Inputs (ranging from X0 to X14), outputs (ranging from Y0 to Y3) and memory coils displayed on the main screen are copied to the Modbus memory, the activity log will be recorded at the Experimental Physics Instrument Control System (EPICS).

- Aux Screen: in this screen were added 3 off delay timers that can be set up by the operator. Its time values are stored within the retentive memory of the PLC. The first timer will delay the helium flow shutdown and the second the heat exchanger shutdown; both have to be set up in seconds and initialized by pressing the reset button. The third timer is for the Can Vacuum Jumper and is set up in minutes.
- Inputs-Outputs screen: on this screen there are light indicators for all the inputs and outputs, along with memory coils ranging from C0 to C10. On the bottom of the screen, there are two jumper buttons for the LEPP Cryo and Helium Flow; and five jumper buttons for the heat exchanger.
- Info screen (Figure 3): this screen was added with the upgrade and its main purpose is to monitor the current state of the PLC and its inputs. This screen is layered in three columns, on left column there is the current IP address of the PLC which is updated every 5 seconds along with the scan time in microseconds.

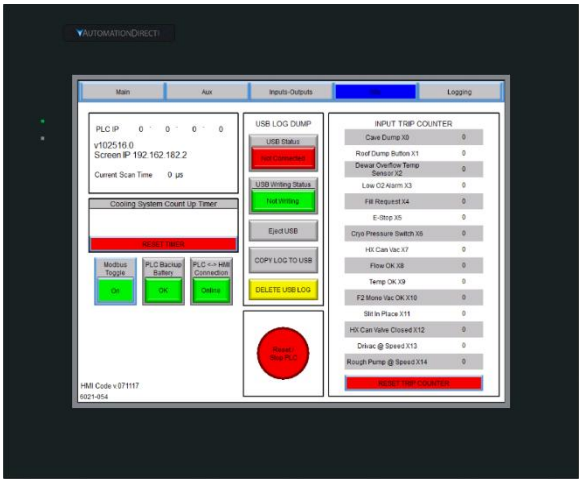

Figure 2: Info screen

Below there is a resettable accumulating timer which will count the time of the cooling system on. At the bottom is located the Modbus toggle button and two indicator lights, one for the status of the PLC backup battery and the Network connection between the HMI and the controller. In the middle column are the controls to copy the activity log recoded by the HMI of all the inputs and outputs to an USB drive as a .txt file. On the right column is located a resettable input trip counter. Every time one of the 15 physical inputs turns on, it will increase the corresponding counter by 1.

In case if the operator needs to force stop or reset the PLC, on the bottom of the screen is located the “Reset/Force Stop” button. It will take the operator to a different screen secured by password. Within this screen, the PLC can run the software or hardware watchdogs. The software watchdog will force stop the controller and turn off all the physical outputs. However, it is necessary to connect the PLC via USB in order to start it up again. The hardware watchdog will reboot the PLC, this process may take between 3- to 5

seconds, and up to 10 seconds to restore the connection with the human machine interface (HMI).

- Logging screen: the HMI keeps track of the activity of all the physical inputs and outputs and memory coils in the internal memory. As part of the upgrade process, the event manager database (Figure 3) had to be updated with the new PLC addresses in order to match the ones in the ladder code.

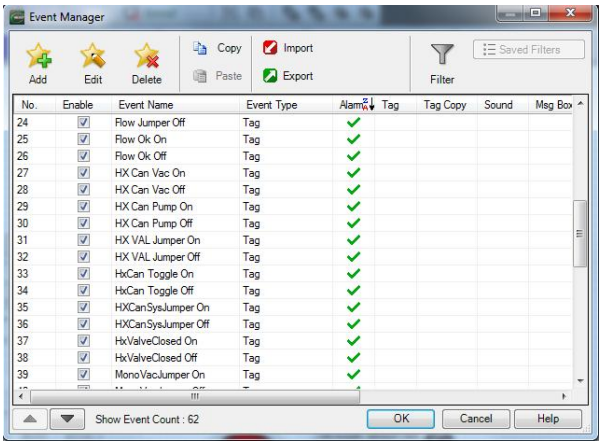

Figure 3: Event manager. The activity log records the activity of 62 inputs, outputs and memory coils

Conclusion

The new ladder code that has been rewritten for the new programmable logic controller preserves the functionality of the previous code, but includes new improvements and enhancements. The old addresses of the previous code were changed, in order to match the addresses available in the new PLC (Table 2). As well, three new configurable timers were added to keep the helium flow, heat exchanger can vacuum and warm up system to keep activated for an adjustable period of time. The Modbus protocol was successfully configured and it is ready to be integrated into the Experimental Physics Instrument Control System.

	Old Addresses	New Addresses
X0	Cave Dump	Cave Dump
X1	Roof Dump Button	Roof Dump Button
X2	Dewar Overflow Temp Sensor	Dewar Overflow Temp Sensor
X3	Low O2 Alarm	Low O2 Alarm
X4	Fill Request	Fill Request
X5	E-Stop	E-Stop
X6	Cryo Pressure Switch	Cryo Pressure Switch
X7	HX Can Vac	HX Can Vac
X8		Flow OK
X9		Temp OK
X10	Flow OK	F2 Mono Vac OK
X11	Temp OK	Slit In Place
X12	F2 Mono Vac OK	HX Can Valve Closed
X13	Slit In Place	Drivac @ Speed
X14	HX Can Valve Closed	Rough Pump @ Speed
X15	Drivac @ Speed	
X16	Rough Pump @ Speed	

Table 2: The addresses X8 and X9 were not available on the previous PLC, therefore the addresses ranging from X10 to X16 were displaced 2 spots in the new ladder code.

In regard to the human machine interface, the tag name list was updated in order to match the addresses of the PLC and those in the HMI program. Additionally, a new information screen was added to the HMI program, where the operator will be able to keep track of the input trip counter, enable or disable the Modbus and reboot or force stop the PLC if is needed.

Acknowledgements

I would like to thank my mentor Eric Edwards for his help, guidance and extensive knowledge on the subject; which was crucial for the project's success. I also want to thank Aimee Kellicutt and Chris Whiting for their assistance and help, and the great opportunity to participate in the Summer Research for Community College Students at Cornell University.

This work is based upon research conducted at the Cornell High Energy Synchrotron Source (CHESS) which is supported by the National Science Foundation under award DMR-1332208.

References

[1] Edwards, Eric. "F2 Cryo System." 2014. MS 2. Cornell High Energy Synchrotron Source, Ithaca.

[2] AutomationDirect. "Do-more H2 Series PLC System Specifications.": 1-7. Print.

[3] AutomationDirect. "C-more Operator Panels Overview.": 1-13. Print.