CONTROL SYSTEM FOR A 150 MeV FFAG COMPLEX IN KURRI

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Abstract

A simple, convenient control system has been developed for a 150 MeV proton FFAG accelerator complex at Research Reactor Institute, Kyoto University (KURRI). This control system is based on conventional PCs and programmable logic controllers (PLC) and these are connected over TCP/IP network. Each PLC is responsible for autonomous control of connected devices such as motors or power supplies, and also responsible for maintaining a parameter database periodically read/written by remote PCs over TCP/IP network. Man-machine interfaces (MMI) and integrated sequences are developed using LabView on these PCs. This control system has been successfully served for the actual operation of this FFAG complex, including the radiation protection control. Further developments in DAQ or interfaces are on the way.

INTRODUCTION

Kumatori Accelerator driven Reactor Test (KART) project[1, 2] has been started from the fiscal year of 2002. The main purposes of this project are to study the feasibility of accelerator driven subcritical system (ADS) and to develop an FFAG accelerator complex as a proton driver for ADS, based on the successes on PoP FFAG accelerators in KEK[3, 4]. This accelerator complex consists of one FFAG with an induction acceleration as the injector, and two FFAG with RF as the booster and main accelerators. Basic specifications for this FFAG complex are summarized in Table 1.

Table 1: Specification of the FFAG complex at KUR.

Beam Energy	25 - 150 MeV
Maximum Average Beam Current	1 μA
Repetition Rate	up to 120 Hz

Since this is the first practical FFAG accelerators, the control system for this complex is required to accept many major and minor modifications in the design and equipments during the construction. Furthermore, easiness on the use and development is crucial for the current control system because we have to develop the system with limited number of technical staffs with limited skills other than their own specialties. While we have to keep such flexibility and easiness, the combined operation with a nuclear fuel assembly requires high reliability and stability from the points of nuclear safety and radiation protection.

To meet such requirements for the present control system, we decide to develop a control system based on LabView, which is widely known as its user-friendly GUI environment, and PLC well known as one of the most reliable control devices in the field of factory automation.

In this paper, the outline and current status of this control system are introduced with some plans for future upgrades.

SYSTEM OUTLINE

Architecture

The architecture of the present control system is shown in Fig. 1. This is basically the same as that for the AVF cyclotron in Tohoku University[5]. In this architecture, devices and instruments such as power supplies, motor drivers, inputs and outputs of analog and digital signals are governed by respective PLC modules. Such PLC modules are on a local IP network for communications with remote PCs which manage MMIs and high level control sequences.

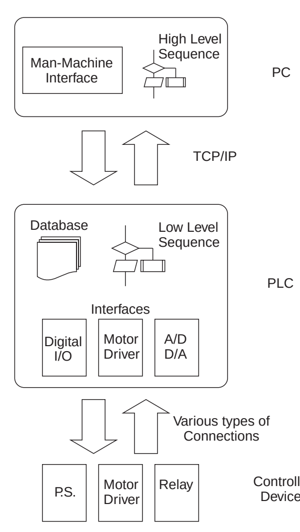

Figure 1: Schematic diagram of the present control system.

There are two major difference in our control system compared to that in Tohoku University.

One difference is that we positively use the memory of PLC as the database of this control system, just like CA server in EPICS. Ethernet modules of PLC accepts various types of commands for memory operation of PLC over network as a default function, thus we have already possessed

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a kind of database server in operation without any setup, on contrary to the case of EPICS in which a series of setup is required for starting up a CA server.

The other difference is that the data transfer protocol is standardized and abstracted, and developers eventually do not care for data transfer between PCs and PLCs. This kind of abstraction drastically reduces the difficulty for technical staffs to start a development on the actual control system.

Hardware

FA-M3R series by Yokogawa Electric Corporation is chosen as the PLC in the present control system. This series is well adapted to IP-based network, e.g., FA-M3R allows all maintenances except hardware troubles over IP-based network.

FA-M3R also has a bus extension capability by optical fibers. Up to 32 module blocks in remote places connected by optical fibers can work as if they are one large module block, enabling CPU to be kept away from the high noise or radiation environment. FA-M3R series also has another advantage on its backup system. All ladder sequences are stored with the complete copy of these ladder sequences on the RAM. FA-M3R automatically restores error blocks from the normal copy as soon as check-sum error is found in either of these ladder sequences. The built-in backup battery can maintain the data on the memory for ten years without external power supply. With these features, FA-M3R obtains the durability for the memory lost without losing the flexibility to the modification of codes.

The hardware configuration of the current control system is shown in Fig. 2. All the devices are arranged to several groups based on the hardware configuration of accelerator such as “ion source” or “booster”, and one CPU is assigned for each group. In the current configuration, more than 10 CPUs are used and placed in the control room to prevent them from the electrical noise and radiation damages. Only the slave module blocks, which consists of several interface modules, are usually placed close or inside the devices with the help of bus extension capability. A typical implementation of the slave module block is shown in Fig. 3. Each CPU module has its own ladder sequences to maintain the database of parameters from/to connected devices, lower level sequences such as the interlock sequence for hardware protections. PLC modules are connected to 100 Mbps ethernet network for the communication with remote PCs over TCP/IP protocol.

There is no special requirement for PCs other than the network capability and compatibility to LabView, therefore conventional Windows laptop PCs are often used as MMI PCs, especially for on-site controls. Wi-Fi access points prepared at most of places in the accelerator building for such laptop PCs.

Software

All MMIs and higher control sequences are developed on LabView. LabView is known as its easy programming process and support of various operating systems.

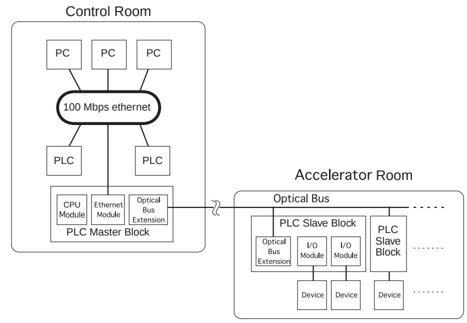

Figure 2: Hardware configuration of the present control system.

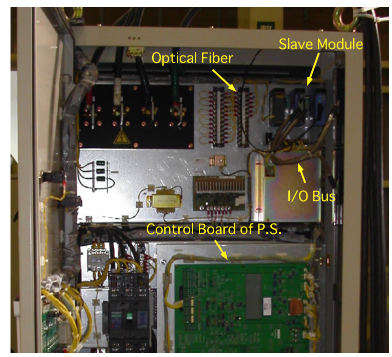

Figure 3: A typical implementation of a slave module. A slave module block is implemented in the power supply and connected with the control board over I/O bus line.

The conceptual diagram of softwares is shown in Fig. 4. Each remote PC has one or more MMIs, and communication VIs responsible for the communication with remote PLCs over TCP/IP. All the communications are initiated by communication VIs, usually every 100 ms. In each communication, all the data on the PLC memory allocated for the parameters from devices is transferred to the PC, then the communication VI translates and stores them as global variables in LabView. Any manipulations made by the operator are written from MMI VIs into the global variables, then these values are translated into a set of parameters and transmitted to PLC by the communication VI in each communication cycle. Translations between sent/received data and global variables are made by referring allocation tables described later.

MMIs on PCs can be easily prepared without the special knowledge on the programming or on the network communication because communication VIs have already managed the communications with PLCs and prepared the parameters as global variables. For conventional developers, placing items like buttons and meters on the window and wiring them with respective global variables are sufficient to develop an MMI for a device. One can also develop more complicated control sequences exactly in the same way as developing a conventional VI in LabView.

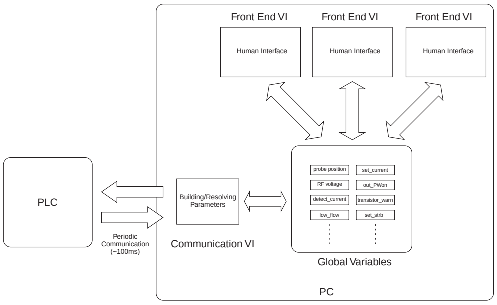

Figure 4: A conceptual diagram of the software on PC.

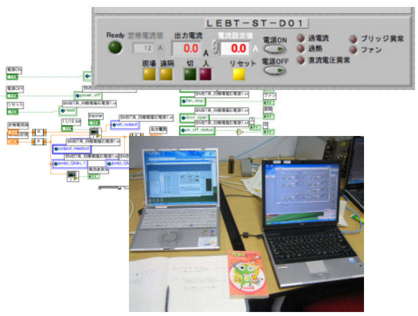

Figure 5: MMI developed on LabView environment.

PLC as Database Server

The parameter set from a remote PC is written on the memory in PLC using a simple memory handling command to the ethernet module. Also, the status of controlled devices written on the memory by ladder sequences is read by a remote PC in the same manner. In this way, we eventually obtain and maintain a database server by just turning on the PLC, on contrary to the case of EPICS in which a series of setup is required for starting up a CA server. Any users, including communication VIs, in remote places can access all the parameters over network by just using simple memory handling commands, just like accessing an SQL server. Of course, all the parameters are available for ladder sequences in PLC as the data on its memory. With this scheme, the developers working with PLC are able to handle data communications with MMIs by just preparing ladder sequences which refers/sets data at the specified address on the memory of PLC.

An allocation table of the parameters on each PLC memory is given as a text file for each CPU and referred by communication VIs. This file contains all necessary information for the translation of data on PLC and VI, such as the name of global variables the assigned address on PLC memory. These allocation tables are continuously maintained as Excel files by technical staffs who directly treat PLCs and hardware devices, and referred by all developers working on this control system. Every time technical staffs update the original Excel files, these files are exported as text files from Excel and served to communication VIs.

CURRENT STATUS AND FUTURE PROSPECTS

Currently, all of permanent devices are already controlled by the current control system, and devices temporarily required for accelerator commissioning are being added and controlled basically within the current control scheme. The interlock system, such as door open/close or emergency stop for this FFAG complex has been also developed and served with the same architecture as the current control system.

Some equipments require special protocols which are not well disclosed by its manufacturers. These protocols are usually managed by special softwares of which information is not well disclosed. We have developed an VI for such special equipments, namely “software PLC”. In this VI, an ethernet module of PLC are emulated towards remote PCs, and the conversion of data to special control software is performed. This “software PLC” has been successfully applied to the control of a d.c. power supply with GPIB interface.

A logging system for parameters of accelerators is very important in the commissioning. As a candidate for our logging system, LabView version of MyDAQ[6] is recently implemented to our ion source part for evaluation. Another DAQ system combined with MySQL and apache is individually under development in our group.

Small handy devices are sometimes very convenient during the test operation or the routine maintenance on site. So, MMIs and communication VIs are now being ported to PDAs with wi-fi capability. Thanks to the multi-platform support of LabView, only minor modifications such as the rearrangement of user interfaces to its screen size and performance optimization are required for this porting.

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