CONTROL SYSTEM OF A FFAG COMPLEX FOR THE ADSR PROJECT IN KURRI

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Abstract

An 150 MeV proton FFAG accelerator complex is now under construction as the proton driver for the feasibility study of accelerator driven subcritical reactor (ADSR) in Research Reactor Institute, Kyoto University (KURRI). The control system for this FFAG accelerator complex is based on conventional PCs and programmable logic controllers (PLC) on TCP/IP network. The databases of parameters for connected devices are maintained by PLCs and these can be accessed by any type of equipments or higher integrated applications as long as they can handle the network connection. We report the current status of the controlling system and future upgrades, such as the trial to combine SAD with our control system over the network for the beam commissioning of our FFAG complex.

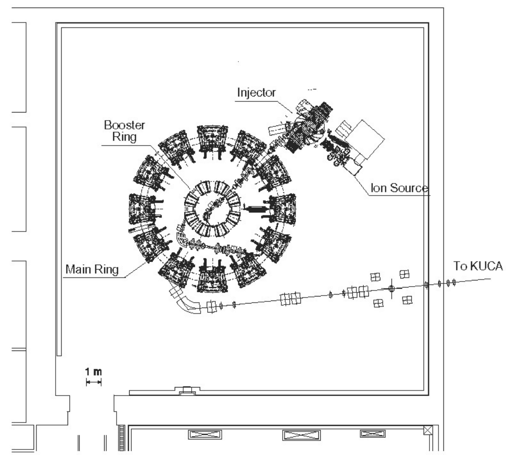

Figure 1: FFAG complex at KURRI.

INTRODUCTION

Kumatori accelerator driven reactor test(KART) project[1, 2] has been approved by the ministry of education, culture, sports, science and technology and started from the fiscal year of 2002. The main purposes of this project is to study the basic feasibility of ADS system and to develop a practical FFAG accelerator as a proton driver for ADS, based on the developments and successes on PoP FFAG accelerators in KEK[3, 4].

In KART project, an accelerator complex which consists of one FFAG with an induction unit for acceleration as the injector and two FFAG with RF as the booster and main accelerators will be constructed(Fig. 1). Basic specifications for this FFAG complex are summarized in Table 1. The layout of these FFAG accelerators in the accelerator room is shown in Fig. 1. In near future, this accelerator complex is expected to be served for multi-purpose usages in various fields, such as physics, chemistry, material science and medical applications.

Since this accelerator complex consists of the first practical FFAG accelerators, many major and minor modifications have been made during the construction. The control system for this accelerator complex is especially required to be flexible to such time-to-time changes in the design and construction of FFAG accelerators. The expectation for multi-purpose usages also requires the flexibility and the good interface to the user's equipments for experiments. Furthermore, the combined operation with a nuclear fuel assembly in the ADSR study requires high reliability and stability towards the control system from the point of nuclear safety. Of course, the requirement for "high cost performance" should not be neglected.

Table 1: Specification of the FFAG complex at KUR

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

In the present control system, we decide to develop a control system which is based on PC and PLC to meet above requirements.

PLC is popular as the low-cost and high-performance controller in the industrial world. PLC modules for a wide variety of devices, such as digital and analog I/O, stepping motors or thermometers, are already available as the commercial base. The main applications of PLC are the factory automation and the built-in controller for the various machines, they keep high performance under a bad environment, e.g., high temperature or high noise level. Recently PLC obtains the capability to handle TCP/IP and UDP/IP, thus it is possible to construct a PC and PLC system without special softwares or interfaces for the communication between them.

We choose LabView for the development of control softwares on PC. LabView is known as its easiness of usage and availability on various operating systems, so those who are not familiar with the software programming can join the development of the control system.

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In the present system, PCs mainly serve the man-machine interface developed on LabView and PLCs govern the low level devices and manage the database of parameters for devices connected to PLC modules. Thanks to PLC's capability of network communication, the database on PLC can be accessed from any type of equipments or higher integrated applications as long as they can handle the communications over the network,

We report the current status of the development and future upgrades, such as the trial to combine SAD with our control system over the network for the beam commissioning of our FFAG complex.

SYSTEM OUTLINE

Framework

The framework of the present control system is shown in Fig. 2. The present system is basically the same control flow in AVF cyclotron at Tohoku University[5], i.e., PLCs are controlled by the remote PCs over the fast network. In this architecture, devices and instruments such as power supplies, motor drivers, inputs and outputs of analog signals and digital logic signals are connected to respective PLC modules. Such PLC modules are on TCP/IP network for the communication with the remote PCs, which are served for the human interface and high level sequences.

Part of the advantages in PLC is that a wide variety of modules for various kinds of devices are available as commercial base. Therefore, one can easily control almost any devices by PLC without special software drivers, while the development of the drivers for devices itself is a kind of important work in EPICS.

Hardware

FA-M3R series by Yokogawa Electric Corporation is used as the PLC in the present control system. This series is well adapted to the network. For example, FA-M3 is the only controller that allows programming to be done from a remote location through the internet, while other PLCs require to prepare a special network for the PLC. Another important feature in this PLC series is the capability of bus extension by optical fibers. All modules connected by optical fibers work as if they are one module block, therefore, the configuration of modules is not affected by the physical limitations, such as the location of devices etc. This feature enables CPU to be kept away from the high noise or radiation environment, which always become problems in the control system of accelerators. The hardware configuration of the current control system is shown in Fig. 3. All the devices are grouped into several groups based on the hardware configuration such as "ion source" or "booster", and one CPU is assigned for each group. All the CPUs are placed in the control room to prevent from the electrical noise and radiation damages. Only the slave module blocks, which consists of several interface modules, are implemented close or inside the devices, then connected to the respective CPUs with the optical fiber. A typical implementation of the slave module block is shown in Fig. 4. Each CPU module has its own program to maintain the database of parameters from/to the connected devices. Lower level sequences, such as the hardware protections, are also implemented in PLC. PLC modules are connected to the 100 Mbps ethernet network for the communication with remote PCs over TCP/IP protocol.

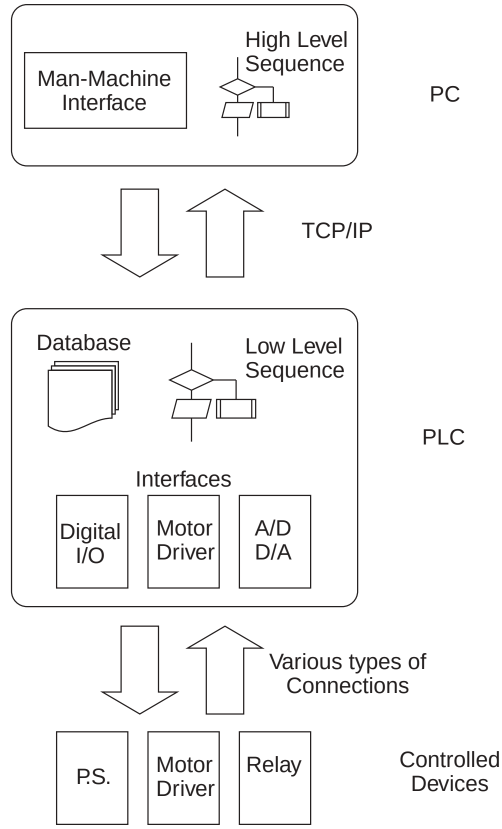

Figure 2: Schematic diagram of the present control system. PLC is responsible for serving the interface between low-level devices and higher PC control software and for maintaining the database of parameters of connected devices.

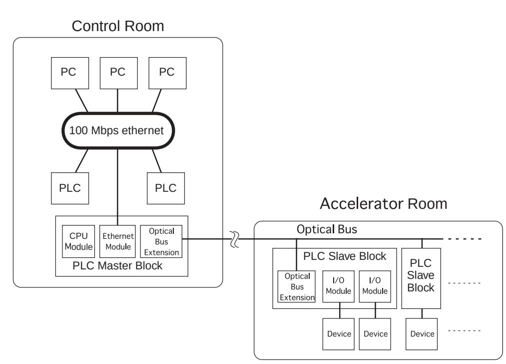

Figure 3: Hardware configuration of the present control system. Each section has one CPU which governs the connected slave modules. All CPUs are placed in the control room and connected over the TCP/IP network.

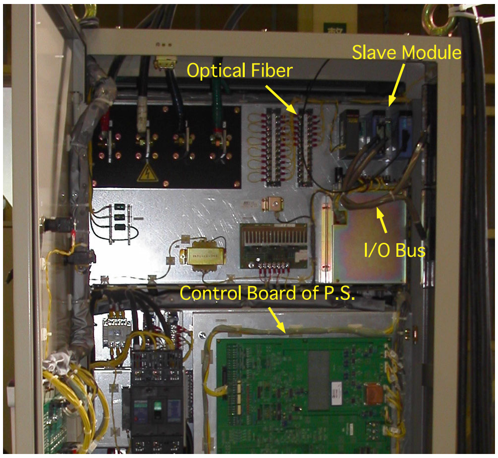

Figure 4: A typical implementation of a slave module in the device. In this case, a slave module block is implemented in the power supply and serves the data communication with the control board of power supply over I/O bus line.

Software

Softwares for PC are developed by LabView, therefore, the software can be easily prepared without the special knowledge on the programming or on the operating system, on contrary to the case in EPICS. The conceptual diagram of the softwares is shown in Fig. 5.

The remote PC has one or more man-machine interface(MMI) VIs and a communication VI, which communicates remote PLCs over TCP/IP. All the communications are initiated by the communication VI, usually every 100 ms. In each communication, the data on the PLC memory allocated for the parameters from devices is transferred to the PC, then the parameters are resolved and stored as global variables in LabView. Each MMI VI asynchronously reads the variables and displays the values or the status on the screen. MMI VIs also serve the manipulation feature for the operation. Any manipulations made by the operator are written into the global variables through MMI VIs, then these values are translated into a set of parameters and transmitted to PLC by the communication VI in each communication cycle.

The parameter set received by the Ethernet module of

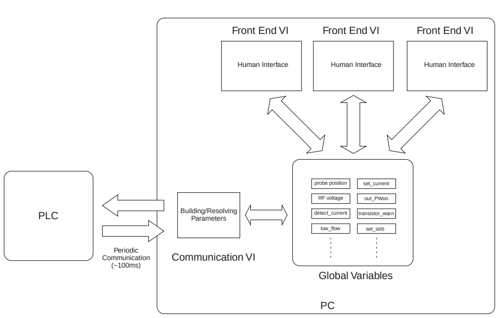

Figure 5: A conceptual diagram of the software on PC.

PLC is expanded to the memory area and CPU in the PLC reads the memory and transfer the parameters to modules in a very high speed (less than 0.1 μs). Then the signals comes out from the respective modules. The status of controlled devices are transferred on the memory by the CPU, then the Ethernet module sends the data on the memory upon requests made by remote PCs.

The important point in the current scheme is that all the communications between PCs and PLCs are limited to read/write the parameter set on the memory in PLC. All the commands the communication VI uses are very simple ones, i.e., "write to the memory" and "read from the memory". For example, any remote devices which would like to know the status of a certain device simply ask the PLC to transfer the data on a certain region of the memory allocated for the objective device. In this manner, any softwares or devices can work together in the present control system, as long as it can handle the basic TCP/IP communication. Therefore, the memory in PLC becomes the database of the parameters of connected devices. The memory protection features in FA-M3R are very strong, e.g., a built-in backup battery which lasts ten years. This because FA-M3R are supposed to be used under a condition that some memory troubles such as power failure, high level noise may be expected while in the operation. This feature makes our database safe without special protection system.

CURRENT STATUS AND FUTURE PROSPECTS

The development of the control system is coincided with the construction of the FFAG accelerator complex. Prototype of PLC programs and the MMI VIs have already been prepared and these control softwares showed good performance in the test operation of devices, such as power supplies, in the factory.

The first acceleration test for the injector will start in May 2005 and several basic commissioning tools are in development for this acceleration test. One of such commissioning tool is shown in Fig. 6.

This tool is now being developed for the closed orbit search of the first turn beam in the injector FFAG. The beam is searched by the beam probe along the radial direction under the control of this VI and the graph of the beam intensity versus radial position is shown on the display. This VI also calls the external beam tracking code and displays the beam tracking result for the parameter set for injection given from the front panel of this VI. The closed orbit position can be investigated by the comparison of both results. Currently, the simulation code which gives the hard edge and thin lens approximation is used. More practical simulation code such as SAD will be called from VI in the advanced stage. We also plan to implement the dynamic link between SAD and the control system with this VI, i.e., the parameter obtained through the control system is automatically transfered to SAD and the appropriate change of

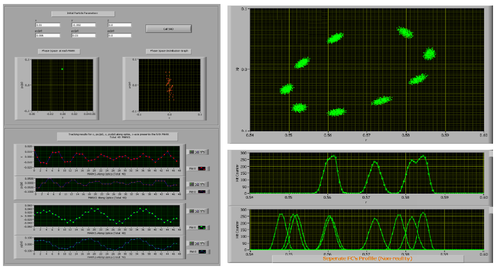

Figure 6: One of the commissioning tool which is now being developed. This tool will be used for the closed orbit search of the FFAG injector. The beam intensity is measured in the radial direction, then the result is compared from the result of simulation code. All manipulations for for the beam commissioning including for the beam tracking code will be performed in one VI.

device parameters are made by VI based on the output from SAD based on the input from the control system.

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