DEVELOPMENT AND CURRENT STATUS OF THE CONTROL SYSTEM FOR 150 MeV FFAG ACCELERATOR COMPLEX

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Abstract

A control system for a 150 MeV FFAG accelerator complex in KURRI has been developed and served for actual commissioning of this accelerator complex with high reliability. This control system has been developed using simple and versatile tools such as PLCs, LabVIEW for MMI/DAQ systems, MySQL and Apache, and this can be a good example for small institutes without specialists on accelerator control. The design and development of our control system are reviewed from the perspective of developers without specialized experience on accelerator control. Also, the current status and applications of this control system are introduced.

INTRODUCTION

Kumatori Accelerator driven Reactor Test (KART) project[1] 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[2, 3] as a proton driver for ADS, based on the successes on PoP FFAG accelerators in KEK[4, 5, 6]. This accelerator complex consists of one FFAG accelerator with an induction acceleration as the injector, and two FFAG accelerators with RF as the booster and main accelerators. Basic specifications for this FFAG complex are summarized in Table 1. Mitsubishi Electric Corporation is responsible for fabrication and installation of accelerator, design and beam commissioning are managed by the collaboration of Kyoto University and Mitsubishi. Kyoto University is responsible for the control system, except the hardware installation along with the accelerator itself.

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 its use and development is crucial for the current control system because the development must be performed by people in our institute, who are little familiar to accelerator itself.

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

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 develope a control system based on LabView, known as its user-friendly GUI environment, and PLC known as one of the most reliable control devices in the field of factory automation.

In this paper, the current status of this control system and the review of our development strategy are introduced.

CURRENT STATUS

Currently, our control system[7] has been served for the beam commissioning of 150 MeV FFAG accelerator complex with concurrent development of itself for more than three years. Recent developments are mainly on the data acquisition(DAQ) system, and some applications to other facilities in our institute are now in progress.

DAQ System

Three different data acquisition systems are now under evaluation for practical use in the FFAG operation. One is an conventional way, i.e., recording every parameter appears on MMI(Man Machine Interface) to a file on MMI PC using VI. The second one is based on MyDAQ developed by Spring-8 group[8]. The details of this DAQ system will be discussed in this conference by Osanai[9]. The third one is originally being developed in our group, consisting of a LabView VI combined with Apache and MySQL. This VI obtains all of the parameters from this memory on PLC, converts and send the data to Apache server by POST method. Then the data is processed by a simple php script for storing on MySQL databases.

Software PLC

Some equipments require special protocols managed by special softwares running on specific platforms such as Windows. Sometimes these special softwares can not easily be eliminated due to the lack of protocol information. We have developed an VI for such special equipments, namely “software PLC.” This VI emulates an ethernet module of PLC towards remote PCs, and the conversion and forwarding of data to special control software is performed with the help of event handler implemented with

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Windows etc. This “software PLC ” has been successfully applied to the control of an old d.c. power supply.

Application to Other Facilities

Our control system has proven its reliability, flexibility and performance through the operation of the FFAG accelerator complex. Based on this success, several applications have been in progress in our institute. One of such typical example is the pneumatic transportation facilities for neutron irradiation at KUR[10]. This facility manages the transfer of samples to the center region of nuclear reactor for neutron activated analysis or radioisotope production. A malfunction of this system can cause undesirable neutron flux disturbance at the core, resulting in serious troubles of the reactor operation. Previous control system was based on hard-wiring and custom circuits, intending to ensure the reliability rather than flexibility or usability. Now the control system has been replaced with the current control system to increase flexibility while maintaining reliability. The cooperation with MySQL and Apache is also realized for the web-based status monitor and the tracing system of radioactivity produced with this facility.

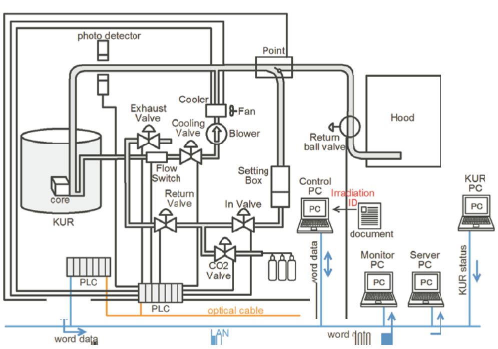

Figure 1: Outline of the pneumatic transportation apparatus and the new control system.

REVIEW OF OUR DEVELOPMENT

Recent developments and successes of PC based control system attract a lot of scientists including those in small institutes like us. In the application to cases in small institutes, some specific problems emerge due to the nature of small institutes, such like limited resources. As previously introduced, our control system has been developed by a group of people in a small institute who are not familiar with accelerator physics. Authors believe its success has been proven by its stable operation in the original accelerator project and its subsequent applications to other cases. So, our development is reviewed as an example for the developers in small institute. Of course, authors are grateful if developers of more general environment for control system, like EPICS, pay attention to our case to serve easier and better environment for small institutes.

Development Team

Our development group mainly consists of two scientific staffs, one graduate student and three technical staffs. Additional members temporarily join this group for special developments such as radiation protection which must comply with laws and regulations. Our development team are mainly served for the accelerator construction itself, not specialized only for the development of control system. Hardware installations are sometimes helped by Mitsubishi Electric Corp. or other related companies. Technical staffs are from reactor-related groups and expected to be operators of this accelerator complex after the construction.

Problems in Our Case

Limited Human Resource In any small institutes like us, the development team has to be organized from limited number of people with varied skills other than in their own speciality. In our case, sufficient abilities on English or on coding with C/C++ should not be expected while these are unspoken requirements of open-source based system. Furthermore, most of members have their original duties other than accelerator construction. Some kind of “ready-to-go” recipes are definitely required to minimize the effort.

Limited Budget Restrictions on the budget is always much stricter in small institutes. Open source environments, which are usually cheap on licensing, tends to require rather high level skills on computing, or some restrictions on the environments like supported OSes or hardwares. Furthermore, the evaluation of an environment itself becomes difficult and expensive because available resources such like hardwares or software licenses are usually less in small institutes than larger institute. These kind of “hidden costs” sometimes become too huge to be paid by a small institute. For example, having a VME crate, some modules and a license of VxWorks for evaluation purpose itself could not be afforded by our limited budget.

Time Deficit Time-poor schedule is usually set in this kind of project, thus the development should minimize the delays resulting from itself. Especially in our case, accelerators themselves should require a lot of time and reliable operations of equipments in their commissioning stages because three accelerators in experimental stage were to be constructed as the practical machines within three years as a part of our five-year project. In this limited time, we also had to train technical staffs for the routine accelerator operation and maintenance.

Our Solution

To overcome problems arising in our case, the strategy of the development was well examined and prepared. We perform our development with following policies.

Open Interface Based on Commercial Environment It is inevitable for small institutes to introduce commercial based environments properly because the "hidden cost" is rather clear on commercial based environment. The most important point of open source should be transparency in the architecture. Therefore, we have designed our system to comply with de-facto standard as much as possible, not with environments (OSes, LabView etc.) specific features, and to clarify the interface scheme defined by ourselves. The costs in future, such as changes of platform etc., are expected to be minimized in this policy.

Least Training for Development Minimizing the efforts paid for the training of development is important for the speedy and reliable development. The GUI-based environment of LabView drastically reduces the amount of training for members in our development team with little experience on C/C++, or Unix-based system. Additionally, core parts of the programming, like the communication with PLC, are served as the standardized sub VI and global variables. What ordinary developers should do is to prepare proper parameters and develop their own MMI by simply making buttons and displays and by referring corresponding global variables. In the programming of PLC, special programming for the communication is totally eliminated by limiting the memory-block transfer initiated by casting a command from communication sub VI to the ethernet module of PLC. This command is processed by the ethernet module independently from CPU process. All developers have to do is to read/write the data on the memory just like referring physical terminals of PLC modules in ordinary developments.

Cheap, Common Hardware FA-M3R[11] from Yokogawa is the primary hardware in our control system. This PLC is so popular in Japan, especially in accelerator facilities like KEK etc. because of Yokogawa's continuing support to accelerator controls. Therefore, we expect competitive price and accumulated know-hows with this PLC. In fact, a lot of actual ladder sequences used in the control system at CYRIC[12] were introduced as example codes in the early stage of our development. Based on its common use in Japan, Yokogawa guarantees the compatibility of ladder sequences and hardwares towards future. This policy can reduce the prospective "hidden cost" on the compatibility issues. Common hardwares have advantages in maintenance as well. Yokogawa guarantees the alternative module within one business day in the case of module failures.

Scalability and Simplicity Our system introduces clear separations between developments in LabView part and in PLC part. PLCs are treated as database servers without programming by using simple memory transfer command over TCP/IP. These data are decoded by referring a parameter table given as a simple excel file for each CPU. What developers should do is to manage the relations to data on the PLC memories. This simple scheme is kept through the development, thus the softwares developed on the test bench works fine in the actual system without modification.

NEEDS IN SMALL INSTITUTES

Usual developments of control system environments tend to pursue higher performance, more generalities and higher flexibility by relying on user's abilities and performances of forefront devices. But these kind of directions in the development progress can raise problems we faced during the development. Some kind of consistent and continuing efforts on the development on handy environments of control system should be made by intending the transfer of successes in PC-based control systems for small institutes. We have developed such handy control system by ourselves. Another possibility is the continuing development of a subset environments of forefront environments specialized for most common hardwares and commercial based environments.

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