A CONTROL SYSTEM DEVELOPED FOR A 150 MEV FFAG ACCELERATOR COMPLEX AND ITS APPLICATION

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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 designed and developed by a limited number of non-specialists on accelerators and control systems in a small institute. The way how we manage the design and development of the current control system will be reviewed as well as the current status and its extending applications to facilities and instruments other than our FFAG accelerator complex.

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.

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 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.

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. The first beam extraction from the main ring succeeded in October, 2008, and the experiments combined with the fuel assembly started in March, 2009. No serious interferences to the commissioning and the operations arising from the control system have occurred up to now. As planned in the beginning, the development of the control system was successfully performed by a small group consisting of two scientists, three technical staff and a graduate student, who are also main members of the construction and the commissioning group. Additionally, many of them had no experience in accelerator operation or construction prior to this project. Specific training was not performed for developing the control system, but just for the conventional usage of LabVIEW and basic knowledge on PLC. The total cost of the control system was also minimized to be as low as 1/10 of a typical control system for a cyclotron of 100 MeV-class developed by typical accelerator manufacturers.

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[8]. 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 con-

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trol system has been replaced with the current control system to increase flexibility while maintaining reliability (see Figure 1). 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.

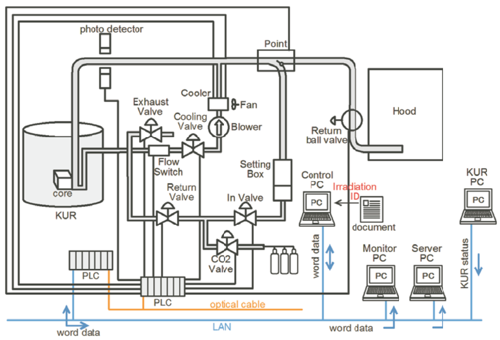

Figure 1: Outline of the pneumatic transportation apparatus and the new control system.

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 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 implicit requirements of open-source based system. Most of members can only join the accelerator construction as their additional duties to the main one, thus the time spent for the construction is limited. Some kind of "ready-to-go" recipes are definitely required to minimize the efforts of the members.

Limited Budget Restrictions on the budget is always much severer in small institutes. Open source environments, which are usually cheap on licensing, tends to require rather high level skills on computing, or not a few restrictions on the environments like supported OSes or hardwares. The evaluation of an environment also becomes difficult and expensive because available resources such like hardwares or software licenses are usually less in small institutes than in larger institutes. 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 of a control system should minimize the delays arising from itself. Especially in our case, accelerators themselves 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 which are expected 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 proper commercial based environments because the "hidden cost" is rather clearly shown in the case of commercial based environments. The most important advantage in open-source environment should be the 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. With this policy, the costs in future, such as changes of platform etc., are expected to be minimized.

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[9] 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[10] 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, i.e, lack on human resources, time and budget. 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 one of such handy control system by ourselves. Another possibility is the continuing development of subset of forefront environments specialized for most common hardwares and commercial based environments.

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