CONTROL SYSTEM BASED ON PCS AND PLCS FOR THE L-BAND LINAC AT OSAKA UNIVERSITY

Ryukou Kato, Shigeru Kashiwagi, Tamotsu Yamamoto, Shoji Suemine, Goro Isoyama
ISIR, Osaka University, 8-1 Mihogaoka, Ibaraki, Osaka 567-0047, Japan

Abstract

A control system comprising of only personal computers and programmable logic controllers has been developed for the L-band electron linac at the Institute of Scientific and Industrial Research, Osaka University. The system has a simple structure consisting of a few PCs connected with Ethernet and PLCs with FL-net.

INTRODUCTION

The L-band electron linac at the Radiation Laboratory of the Nanoscience and Nanotechnology Center attached to the Institute of Scientific and Industrial Research (ISIR), Osaka University, was constructed in 1975-1978 [1] and has been used for radiation chemistry studies by pulse radiolysis technique. Recently, the linac has been extensively used for studies pertaining to nanotechnology, beam science as well as for basic studies in their related fields. In the advanced studies with the linac [2,3], stability of the electron beam and reproducibility of the linac operation are extremely important. The linac has been upgraded for higher stability and reproducibility of operation for advanced studies in beam science. A computer control system has been newly introduced for the linac not only to realize precise reproducibility of operation but also to make routine operation possible by even an unskilled operator.

In this paper, we present details of the control system and operational experiences.

HARDWARE IMPLEMENTATION

Configuration

The new control system is based on personal computers (PCs) and programmable logic controllers (PLCs). The PCs are used for operator consoles as human machine interfaces (HMIs), while the PLCs control various devices directly. The PLCs and their wiring terminals are installed in device control stations (DCSs). The DCS is the basic unit of the control hardware and all the devices of the linac except for those connected with GPIB are wired to the DCSs. The DCSs are placed at various places to form a distributed control system; three DCSs are in the control room and four in the linac room. In addition to these DCSs, the klystron modulator and the three SHB amplifiers, have their own PLCs for internal control. Network boards are added to each PLC, so that they can directly link to the control network. The schematic layout of the L-band linac and the present configuration of the control system are shown in Figures 1 and 2 respectively.

Networks

The PCs and the PLCs are connected to the networks using two different communication protocols. For the network connecting the PLCs, we have chosen FL-net, which is an open PLC network for factory automation. Protocol of FL-net is a vendor-independent open standard, and it works on compatible devices with Ethernet standard. Each PLC can share data through a common

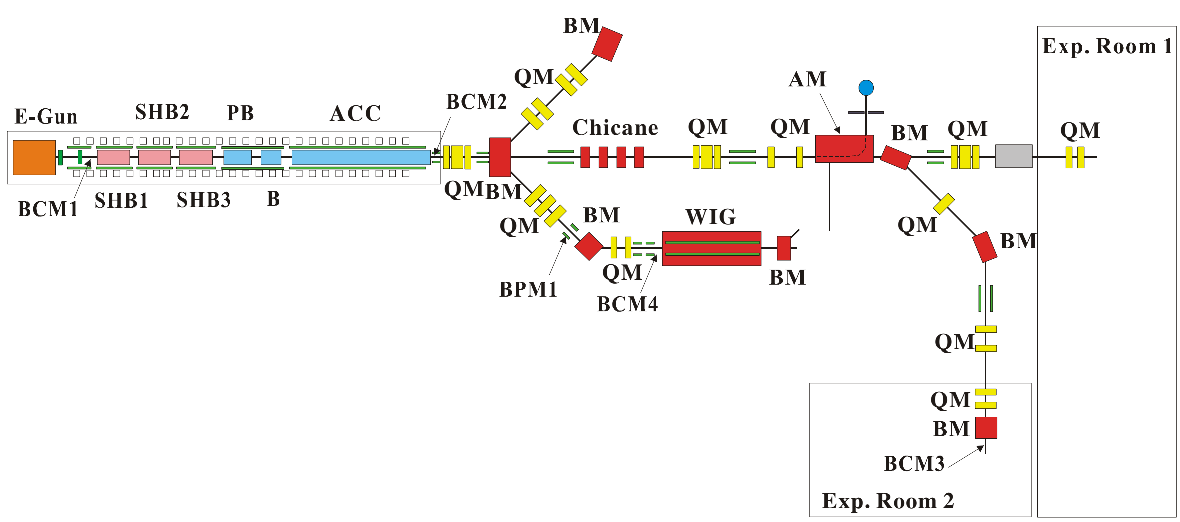

Figure 1: Schematic layout of the L-band linac. E-GUN: Electron gun, SHB1: 108MHz SHB cavity #1, SHB2: 108MHz SHB cavity #2, SHB3: 216MHz SHB cavity, PB: Prebuncher, B: Buncher, ACC: 1.3 GHz accelerating tube, BM: Bending magnet, QM: Q-magnet, AM: Analyser magnet, WIG: Wiggler, BCM1-4: beam current monitors, BPM1: beam position monitor.

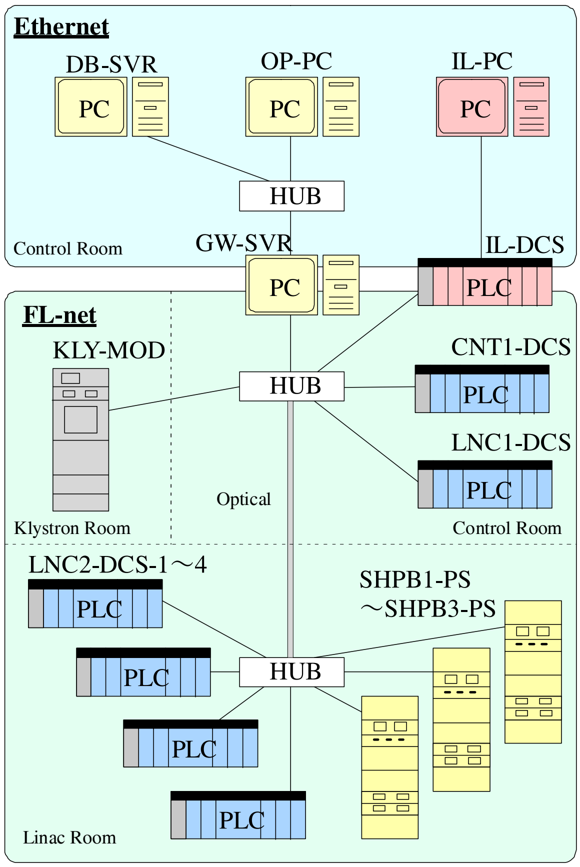

Figure 2: Schematic configuration of the hardware of the control system.

memory (also called link register) in the FL-net module. Data in the link register is sent at certain intervals (typically 10 ms/node) with cyclic transfer. On the other hand, the PCs communicate with each other by Ethernet. In order to transfer control information between these two networks with different protocols, one of the PCs is equipped with both FL-net and Ethernet and works as a gateway server. The PC converts data in the common memory in FL-net to the formats accessible to the other PCs and vice versa.

PLCs and Modules

A Programmable Logic Controller (PLC) is a device that was invented to replace the necessary sequential relay circuits for machine control. PLCs are widely used for factory automation (FA) such as control of machinery on assembly lines. They are recently also being used for control systems of accelerators, because they are more reliable and less expensive as compared to CAMAC, VME, VXI, etc. Since the PLCs are widely used in FA, stable supply of modules and spares over a long period of time can be expected.

Since PLC used in DCS is a key part of the control system, it is the important to select the model which has the maximum capability to be upgrade in future. Considerating the scale of the linac, the number of the control points, the processing speed, the extendability, easiness of the programming and so on, we selected the FA-M3 series maufactured by Yokogawa Electric.

Since the seven DCSs performed different roles, the number of desired modules and the requirement of the CPU abilities are not the same. However, taking maintenance and spare parts into account, we decided to use the same base module, power module, and the same CPU module in these DCSs. The list of the modules which were used is shown in table 1.

Devices and Interfaces

The most difficult part of the upgradation to the computer control system was that the old power supplies and devices had no computer interfaces. New and modified devices, such as the klystron modulator and the DC power supplies, were equipped with computer interfaces. Some of the old components without computer interfaces are still being used, and they would be upgraded in due corse.

The devices are connected to the PLCs with analog I/O, digital I/O, RS-232C, and RS-485 interface modules.The RS-485 serial interface is used for the computer interface of the power supplies. Since the Ladder language has no flexibility to control the serial devices, the BASIC CPU modules and language are used. Since up to 32 devices can be controlled with an RS-485 multipoint serial connection, much wiring is not necessary to introduce a digital control system with PCs and PLCs. The 58 new power supplies are installed in 6 racks and each rack is connected with a single line to an RS-485 controller in a PLC.

Table 1: Used modules

No	Module Name	Model	Qty
1	Base	F3BU13-0N/D2	7
2	Power Supply	F3PU30-0N	7
3	Sequence CPU	F3SP53-4S	7
4	BASIC CPU	F3BP20-0N	3
5	FL-net I/F	F3LX01-0N	7
6	Ethernet I/F	F3LE11-0T	1
7	DI	F3XD64-3F	5
8	DI	F3DX32-5F	3
9	DO	F3YD64-1F	3
10	AI	F3AD08-1N	7
11	AO	F3DA04-1N	3
12	Positioning	F3NC11-0N	14
13	RS232C	F3RS22-0N	4
14	RS422/485	F3RS41-0N	12

SOFTWARE

Hierarchical Structure and Data Flow

Figure 3 shows schematic diagram of the data flow in the hierarchical structure of the control system. DCSs capture the status or the response of the devices through the digital I/O, the analog I/O. As for the serial communication device, the program on the BASIC module does the sequence. The Ladder sequence of DCS transfers the data in the I/O register to the common memory in the FL-net module. Between the FL-net modules, communication is cyclic according to the given node number. The data on the common memory is updated at constant time intervals. GW-SVR updates the data on the shared memory based on the data which was written in the common memory by the FL-net communication and the data which was collected through GP-IB. OP-PC reads the latest data of the devices by accessing the shared memory and displays it on the operation screen. The operation which the user executed on the OP-PC is reflected in the devices by opposite flow.

Human Machine Interfaces

A virtual console panel on an operator PC is composed of : 1) the main control panel which was equipped with file menu and panel menu becomes the base operational panel, and does typical operation sequences such as the start-up, the shut-down, HV ON/OFF of the linac, etc, 2) the integrated operation panel which carries out individual operation sequences such as the LV ON/OFF, HV ON/OFF of the gun, the SHPB amplifiers and the klystron modulator, etc, 3) individual device panels to control each equipment connected to the PLC, 4) the trend monitor which graphically displays time-series analog values of the vacuum degree, the beam current, etc.

The linac can be started up or shut down by a few mouse clicks on the main control panel on the computer screen.

SUMMARY

We developed the distributed control system for the L-band electron linac using the networked PCs and PLCs. The PLCs are used as the device controller and FL-net was selected as the network connecting the PLCs. Since RS-485 serial interface is used for the computer interface of the power supplies, much wiring is not necessary. A graphical user interface on the PC screen is employed as the operator interaction. Distributed computer control system, which has precise reproducibility of operation and user-friendly operation for an unskilled operator, has been realized.

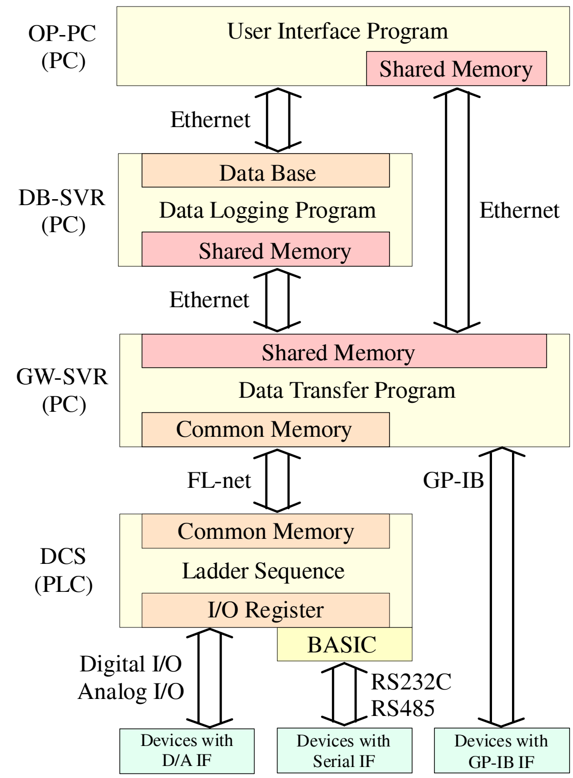

Figure 3: Schematic diagram of the data flow in the hierarchical structure of the control system.

REFERENCES

[1] S. Takeda, K. Tsumori, N. Kimura, T. Yamamoto, T. Hori, T. Sawai, J. Ohkuma, S. Takamuku, T. Okada, K. Hayashi and M. Kawanishi, IEEE Trans. Nucl. Sci. NS-32 (1985) 3219.

[2] T. Kozawa, Y. Mizutani, K. Yokoyama, S. Okuda, Y. Yoshida, S. Tagawa, Nucl. Instr. and Meth. in Phys. Res. A 429 (1999) 471.

[3] R. Kato, R. A. V. Kumar, M. Kuwahara, M. Fujimoto, Y. Nakamura, T. Igo, T. Konishi, S. Isaka, S. Mitani, S. Okuda, S. Suemine, G. Isoyama, Nucl. Instr. and Meth. in Phys. Res. A483 (2002) 46.