**WEAP025**
**physics/0112037**

# INTRODUCTION OF MODERN SUBSYSTEMS AT THE KEK INJECTOR-LINAC

N.Kamikubota, K.Furukawa, KEK, Tsukuba, Japan
S.Kusano, T.Obata, Mitsubishi Electric System and Service Co. Ltd., Tsukuba, Japan

*Abstract*

As an accelerator control system survives over several years, it is often the case that new subsystems are introduced into the original control system. The control system for the KEK electron/positron injector-linac has been using Unix workstations and VME computers since 1993. During the eight-year operation, we extended the system by introducing a) Windows PCs, b) PLC controllers with a network interface, and c) web servers based on modern information technology. Although such new subsystems are essential to improve control functionalities, they often cause communication problems with the original control system. We discuss the experienced problems, and present our solutions for them.

## 1 INTRODUCTION

The KEK linac was constructed as an injector of the Photon Factory storage ring about 20 years ago [1]. The first beam of 2.5-GeV electrons was provided in 1982. This linac now provides electron/positron beams to several rings [2]: a) 3.5-GeV positrons to the KEKB LER (KEK B-factory Low-energy ring), b) 8-GeV electrons to the KEKB HER (High-energy ring), c) 2.5-GeV electrons to the PF ring, and d) 2.5-GeV electrons to the PF-AR ring. The first control system, which consisted of mini-computers and CAMAC interfaces [3], was replaced by the present control system in 1993 [4]. The present system comprises Unix workstations and VME computers. It has been upgraded occasionally [5] and used over the past eight years.

In this article, we discuss newly introduced subsystems in recent years. They were introduced in order to improve the control functionalities, and/or to enable better maintenance capabilities. Three subsystems are described in detail in Section 2. The experienced problems between the subsystems and the original control system, and their solutions are discussed in Section 3.

## 2 NEW SUBSYSTEMS

### 2.1 Control System Overview

The present control system comprises 4–6 UNIX workstations, 27 VME computers with the OS-9 operating system, 140 PLC (Programmable logic controller) controllers, and 11 CAMAC interfaces with a network port. A home-made RPC (remote procedure call), based on TCP/UDP protocols, are used for communication between them. A simplified view of the control system is shown in Fig. 1.

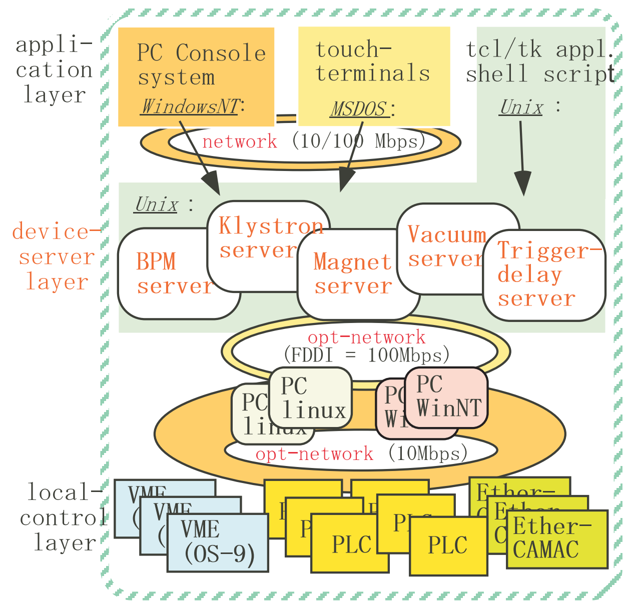


Figure 1: Simplified view of the control system.

The total number of control signals is about 6000 (in 2-byte unit). Since 1998, when the CP violation study started with the KEKB rings, the operation of the linac exceeded 7000 hours per year. The number of control transactions handled by the control system increased every year, and reached 350 transactions per sec. in June, 2001 [6].

### 2.2 Windows PC

Since the end of the 1980'es, we have had strong interest in using PCs. The PC-based operator's console system started with DOS PCs [7], and later reinforced with Windows PCs [8], has been successfully used for more than ten years. In the early phase, the following points were preferable for us: a) enhanced capability of 2-byte code (Japanese characters) handling, b) good development environment of graphic applications, and c) low cost.

The present console system comprises about ten PCs (Windows NT and Windows 2000). The surveillance applications for accelerator devices were developed in Visual Basic, and have been used in daily operation. The operation log-book using MS-SQL and Access [9] is extensively used everyday with this console system.

Communication with the control system, which runs at the Unix workstations, is made by a gateway (a Windows PC). When the gateway receives a control request from a console PC by the OLE, it communicates with the appropriate device server(s) by using the RPC protocol (see Fig. 1). The gateway and the present console system have been successfully used over the past six years.

### *2.3 PLC*

The main part of the control system for the KEK linac was renewed in 1993 [4]. However, the local controllers (shown as SBC[1] in Table 1) remained. In recent years the maintenance of these local controllers has become difficult. Thus, we decided to replace them with new controllers.

Table 1: Replacement of local controllers.

| device and transition | before 1993 | transition phase | present status |
|---|---|---|---|
| Klystron '97-'98 | CAMAC –>SBC | VME –>SBC | Ethernet –>PLCx70 |
| Magnet '96-'00 | CAMAC –>SBC | VME –>SBC | Ethernet –>PLCx51 |
| Vacuum '96-'97 | CAMAC –>SBC | VME –>SBC | Ethernet –>PLCx18 |
| Trigger '97-now | CAMAC –>SBC | VME –>SBC | Ethernet –>CAMACx11 |
| BPM since '97 | none | | Ethernet –>VMEx19 |

A typical local controller should have a) a few hundred I/O points, b) simple but programmable control logic, and c) a communication path to the main control system. Among some candidates, a PLC with a direct network port (Yokogawa FA-M3) was chosen for klystron modulators, magnet power-supplies, and vacuum controllers. The VME computer was a candidate, but was not selected, because the PLC is less expensive. The replacements of local controllers since 1996 are summarized in Table 1.

It is interesting that all of the new controllers shown in Table 1 have an Ethernet port. A background fact is that world-standard field networks (CAN-bus, Profi-bus, MIL1553, etc.) are not popular in Japan, and we want to use Ethernet as a field network. The use of a standard Ethernet is preferable for long-term maintenance and cost reduction. In addition, we use optic-fiber cables for the network to local controllers in order to avoid electro-magnetic noise from the klystron modulators.

### *2.4 Web and Related Topics*

We have recently experienced fast improvements of information technologies. The world-wide-web services at the KEK linac started in May, 1994 [10]. Up to now, we have developed many web pages to inform about the linac operation status.

**a) Status of accelerator devices** The web-server machine is a part of the control system. Thus, by using the CGI (Common Gateway Interface) script, it is easy to develop a homepage to show the status of any linac device. A large number of pages have already been developed.

**b) Real-time display by Java and CORBA** Feasibility studies of a web-based real-time display using Java and CORBA have been carried out. The measured round-trip time between a Java applet and a CORBA server (at an Unix workstation) was 50 ms [11, 12]. The server does not consume CPU resources compared with the CGI-based services. Recent updates have enabled realistic demonstration of the beam-current history at the KEK linac [13].

## 3 DISCUSSION

### *3.1 Problems with Subsystems*

**a) Windows PC** The main language for the Windows-based console PCs is Visual Basic, while the sources at the Unix side have been developed in C language. For example, the sources for the RPC use socket (Winsock) functions at the Unix (Windows) side. Thus, the maintenances have been made independently. This fact implies that when we have some improvements at the Unix side, it always takes time for the improvements influence the Windows side.

We have operated a TCP/IP network system which contains both Unix workstations and Windows PCs. As the number of Windows PCs has increased, we experienced communication errors by two specific intervals (2 hours and 12 minutes). They were removed by changing the default settings of MS Office and Samba [15]. We also experienced an accident in which the network burst from Windows PCs occupied the network system, followed by a short-time mistake of network cable connections. At the time of the accident, the burst stopped all network modules of the PLC controllers. We modified the parameters at the network routers so as not to enhance the burst broadcasts.

**b) PLC** After the KEKB commissioning started in 1997, we developed various slow-feedback applications [14] in order to realize stable beam injections to the KEKB rings. By the end of 1998, the CPU capabilities of Unix workstations were found to be insufficient for increasing demands. The analysis showed that the klystron server (see Fig. 1) consumed a very large fraction of the CPU resources for network communication with PLC controllers. In the summer of 1999, we prepared on-memory cache areas to keep klystron data at the Unix workstations. Two linux PCs have been used to update the cached data by polling the PLC controllers [15, 16]. The network traffic decreased to one fourth, and the problem disappeared.

[1] Such old local controllers were controlled by Single Board Computers with micro-processors [3].

Up to now we have introduced the cached scheme even for other devices.[2]. Considering the number of control transactions [6], we can conclude that the intelligence of the PLCs was not sufficient for our case. Thus, we added more intelligent devices (PCs) between the device servers and the PLC controllers, as shown in Fig. 1.

**c) Web** Web presentation of the KEK linac status would consume larger CPU and network resources than dedicated applications. The considerable increase of web accesses in recent years implies that we will need more computer resources in our control system. A more serious problem is that we will need more man-power to maintain both dedicated applications and web-based services. We are eager for some tools which would enable us automatically generate web contents.

### *3.2 Transition of Control Architecture*

We are now ready to discuss the long-term transition of the basic architecture of the control system for large accelerators. Taking into account various accelerator control systems in the past 20 years, the transitions of control standards are given in Table 2 (upper). Private expectations for the next decade (2000'es) are shown in Table 2 (lower).

Table 2: Transition of large accelerator control.

| | 1980'es | 1990'es |
|---|---|---|
| console | CUI<br>(text-base) | GUI on X<br>(window-base) |
| base-machine<br>(language) | mini-computer<br>FORTRAN | Unix workstation<br>C |
| network | dedicated network<br>dedicated protocol | standard Ethernet<br>on TCP/IP |
| local-<br>controller | CAMAC | VME with<br>RT-OS |

| | 2000'es (private expectation) |
|---|---|
| console | a) GUI on Windows-PC (for operation)<br>b) toolkit/environment (for study)<br>c) Web/cell-phone (for announcement) |
| base-machine<br>(language) | Linux, or 64/128bit Unix<br>Java, C++ |
| network | TCP/IP and CORBA<br>http (for web) |
| local-<br>controller | PLC with Ethernet (for simple I/O)<br>Linux box (for intelligent controller) |

The present control system for the KEK linac, which started in 1993, can be expressed as a typical standard of the 1990'es model. We conclude that our extensions (introducing subsystems in the past eight years) can be understood as an evolution toward the new standard of 2000'es.

[2]The vacuum system started to use cache in June, 2000. For magnet power-supplies, we had a Windows PC as a gateway since 1997 [15]. The BPM servers use cache from the start of the service in 1997.

## 4 ACKNOWLEDGMENT

The authors acknowledge Prof. A. Enomoto and Prof. K. Nakahara for kindly supervising our work. We thank I. Abe for discussions on using Windows PCs with Unix workstations. The various improvements of PLC-based local controllers have been carried out by A. Shirakawa. We also thank the KEK linac operators for cooperative and successful works to improve our control system.

## 5 REFERENCES

[1] J.Tanaka, Nucl. Instr. Meth. 177(1980)101-105

[2] Y.Ogawa and Linac Commissioning Group (LCG), "Commissioning Status of the KEKB Linac", Proc. PAC'99, New York, Mar.-Apr.1999, p.2984-2986

[3] K.Nakahara, I.Abe, R.P.Bissonnette, A.Enomoto, Y.Otake, T.Urano and J.Tanaka, Nucl. Instr. Meth. A251(1986)327

[4] N.Kamikubota, K.Furukawa, K.Nakahara and I.Abe, Nucl. Instr. Meth. A352(1994)131-134

[5] N.Kamikubota *et al.*, "Improvements to Realize a Higher Reliability of the KEK Linac Control System", Proc. ICALEPCS'95, Chicago, Oct.-Nov.1995, p.1052-1055

[6] N.Kamikubota *et al.*, "Growth of Control Transactions of the KEK Linac during the KEKB Commissioning", Proc. APAC'01, Beijing, Sep.2001; KEK-Preprint 2001-124

[7] K.Nakahara, I.Abe, N.Kamikubota and K.Furukawa, Nucl. Instr. Meth. A293(1990)446-449

[8] I.Abe, H.Kobayashi and M.Tanaka, "PC based Control System using ActiveX in the KEK e-/e+ Linac", Proc. PCaPAC'99, Tsukuba, Jan.1999, KEK-Proceedings 98-10

[9] M.Tanaka, I.Abe and H.Kobayashi, "Database system in the KEK Linac PC-based Control", Proc. PCaPAC'99, Tsukuba, Jan.1999, KEK-Proceedings 98-10

[10] http://www-linac.kek.jp

[11] S.Kusano, N.Kamikubota and K.Furukawa, "Real-time Display of Accelerator Status Using JAVA and CORBA", Proc. PCaPAC'99, Tsukuba, Jan.1999, KEK-Proceedings 98-10

[12] S.Kusano, N.Kamikubota and K.Furukawa, "Study of Sharable Applications Using Java and CORBA", Proc. ICALEPCS'99, Trieste, Oct.1999, p.535-537

[13] N.Kamikubota, S.Kusano and K.Furukawa, "Archive Databases as Distributed CORBA Objects", presentation at JPS meeting, Okinawa, Sep.2001

[14] K.Furukawa *et al.*, "Beam Switching and Beam Feedback Systems at KEKB Linac", Proc. LINAC2000, Monterey, CA, Aug.2000, p.633-635

[15] N.Kamikubota, "Introducing PCs to Unix-based control systems", presentation at PCaPAC2000, Hamburg, Oct.2000

[16] S.Kusano, N.Kamikubota and K.Furukawa, "Use of Linux PCs for Device Surveillance at the KEK Injector-linac", to be submitted