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New control system for the KEK photon factory

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Abstract

A new control system for the Photon Factory (PF) electron storage ring has been developed, incorporating modern technologies in both high-level and low-level control layers. The Experimental Physics and Industrial Control System (EPICS) software toolkit was introduced as a major framework in the middle- and high-level control layers. In the low-level layer, Programmable Logic Controllers (PLC) was used for a safety control system, for RF klystron control boards and for the vacuum control system, etc. Old VME-board computers with the HP-RT operating system were replaced by Linux-based board computers, which were used as low-level input/output controllers. The new control system has been running without any serious problems since its commissioning in September 2005.

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Keywords: Accelerator control; EPICS; Timing system; Light source

1. Introduction

The Photon Factory (PF) 2.5-GeV electron storage ring was established in 1982. At the beginning of operation, for the control system, seven 16-bit minicomputers connected through a star-type network were utilized. This control system was replaced with four 32-bit minicomputers linked through a token-ring network in 1985. At that moment, storage-ring equipments were connected with field buses, such as CAMAC, GPIB, and RS232. The controllers of CAMAC crates were directly connected to the system bus of the minicomputers with a real-time system [1,2]. In 1998, the emittance of the PF was reduced from 130 to 36 nmrad [3]. Along with an upgrade in the emittance, the existing minicomputers were replaced with engineering workstations (EWSs) and server computers. We also introduced VME-based controllers for many fields, and employed personal computers (PCs) as CAMAC controllers. Operator consoles with a touch-panel interface were replaced with a graphical user interface (GUI) on the EWSs and PCs. In March 2005, further upgrade project, which aimed to introduce four new straight sections to short-gap undulator, was carried out. We also enlarged the length of the existing straight sections [4,5]. At this time, we planned to introduce a control system incorporating modern technologies in both the high- and low-level control layers [6].

This paper describes a design concept and its implementation of the newly introduced control system. Section 2 describes the design concept. The details of the hardware systems are mentioned in Section 3, and the software framework is described in Section 4. Other software-related developments, such as archiving, web servers, and a simple control framework for insertion devices, are also described in this section.

2. Design concept of the new control system

In the previous control system, "Data Channel (DCh)" for data sharing and "Device Server" for equipment control were developed. The collection of these in-house programs, called "DCh-based software", had been used as a control framework in the PF [3]. The DCh-based software had an advantage of its simple structure and

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lightweight feature, and porting to many operating systems was easy. However, there was some dissatisfaction concerning this software: (1) it was not suitable to develop event-driven type programs due to a lack of an event notification mechanism; (2) on rare occasions, namely once every few years, the main DCh server program stopped when too many clients tried to connect to one server. The later occasion was not caused by a bug of the server program, but by mistakes in writing the client program. Further robustness was aspired on the server program for ease in developing client-side programs.

In order to reduce these dissatisfactions, we decided to introduce modern software frameworks in the control system. There are many software frameworks for accelerator control, which are already adopted in many laboratories. For example, TANGO [7] is one of the major framework that can create an object oriented and distributed control system developed by ESRF and other European facilities. After we evaluated several control frameworks, the Experimental Physics and Industrial Control System (EPICS) [8], which is a collection of many software tools and libraries to create a distributed control system, were introduced as a new control framework of the PF. One of the most important reasons to introduce EPICS was that the KEK B-Factory (KEKB) had already introduced the EPICS, and achieved steady success in constructing the control system [9]. Furthermore, the PF planned Top-up injection from an injector linac, which provides electron or positron beams to four storage rings: KEKB high-energy ring, KEKB low-energy ring, PF advanced ring, and PF ring. By introducing the EPICS, information sharing, and seamless operation between four accelerators became practical in the future. There is another advantage of introducing the EPICS: the EPICS had been developed with the collaboration of many accelerator laboratories, and many tools were already developed as the open source product. We did not need to develop many kind of software from scratch.

Since some of the instruments did not need to replace the control system, we partially continued to use the existing DCh-based programs for legacy parts. To realize transparent operation between two software frameworks, we developed a gateway program, namely, DCh to the EPICS gateway and EPICS to the DCh gateway.

An outline of the control software and hardware is shown in Fig. 1. More than 12 input/output controllers (IOC) were installed in the new control system. These IOCs communicated with client program or other IOC using the Channel Access (CA) protocol through the Ethernet. We build a new fiber-optic cable and installed a new gigabit Ethernet switch to prepare for an increase in the network traffic. Some of the IOCs were connected to the storage ring hardware directly, or through CAMAC, Ethernet, etc. During the last 25 years, many CAMAC crates and modules had been used as an interfaces between control software and hardware. Most of the equipment connected to the CAMAC modules was not changed, while a newly installed IOC controlled the CAMAC in order to minimize the load and the construction cost of the new control system.

A programmable logic controller (PLC) had been used mainly for safety control purposes. We decided to use it for various types of device controls, since the reliability of the PLC is sufficiently high. It was also one of the reasons to use PLC for hardware control, because an easy-to-use software-development environment has been readily available in recent years.

The multi-tiered and distributed feature of the EPICS framework was desirable from reliability and stability points of view. Needless to say, the reliability of the control system was one of the important issues in designing the control system. The ratio of the actual user's time to the scheduled time reached more than 98% in recent years. The new control system must not spoil this availability by any failure of the system. In addition to maintaining the reliability, it is also important to enable easy and rapid application development for the control system. The scripting language interface of the EPICS helped the development greatly. Details of the software are described in Section 4.

3. Hardware systems

3.1. Network and computers

In the previous control system, the backbone of the control network was ATM/Ethernet, which had a maximum speed of 155 Mbps. The network operated without any trouble since 1997; however, its communication speed was not fast enough compared to recent developments in network technology. Also, the manufacturer had already discontinued support for this ATM network. In the summer of 2005, we laid a new fiber-optic cable that can be used at a maximum speed of 100 Gbps, and installed both a new gigabit Ethernet switch (Cisco/Catalyst R4507R) and 12 switching hubs (Cisco/Catalyst 2950G-24) distributed around the building. The network traffic is monitored by dedicated software all of the time, and the link statuses of every port are logged to one server workstation. A firewall computer isolates the control network from the laboratory network to maintain security. No other computers have simultaneous connections to two networks.

To ensure reliability and stable operation, we installed a Hewlett-Packard server (HP9000 series) with a disk array (RAID5) and a daily backup system using the Digital Linear Tape (DLT) library. Many client machines or operation consoles connect to the server with Network File System (NFS), and use the common disk area where the control programs are stored.

More than 25 operator consoles are on line in the control room. Most of these consoles use Linux or Windows as the operating system. To control the personal computers that are not located in the control room, the remote-operation