Control System Design for KEKB accelerators

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Abstract

The KEKB project, constructing an asymmetric electron-positron collider for B physics in Japan, has officially approved and has started in 1994. The goal of the KEKB accelerator control system is to provide a powerful, flexible, and extendible control system for both accelerator physicists, who need beam information and are not so patient, and operators, who control all equipment. To achieve this goal on schedule, we decided to use standard technology where it is applicable. We have studied some existing control systems based on “Standard Model” of the modern accelerator control systems, such as EPICS[1] or V-system[2] , as a framework of the control system and have chosen the base of the control system according to this study. Another key issue in the KEKB accelerator control system is use of database management system for unified management of the information which the control system requires. Integration of control system with the modeling software, SAD[3], is also discussed.

I. The KEKB project

The KEKB[5] is the project to build an asymmetric, double ring $e^+ - e^-$ collider in KEK, Japan. The KEKB will be built inside the existing TRISTAN[4] main ring (MR) tunnel. The whole KEKB accelerator complex is shown in Figure 1. The high energy ring (HER) and the low energy ring (LER) will be installed side by side in the tunnel of the TRISTAN MR. To build the two rings equal circumferences, a cross-over zone is created in the Fuji section as shown in Figure 2.

The KEKB is designed for the detailed studies on B meson. Electrons accelerated up to 8 GeV by the upgraded LINAC will be stored in HER while LER stores positrons at 3.5 GeV. A low $\beta_y^* = 1$ cm, low emittance and a small emittance ratio should be maintained for sufficiently long period of time in order to achieve the design luminosity $1 \times 10^{34} cm^{-2} s^{-1}$ and to work as a B-factory for the high energy experiments.

The KEKB project was approved and started 1994. TRISTAN MR will be shut down at the end of 1995 and will be removed from the MR tunnel. Installation of the hardware in the tunnel will start at the end of 1996. The first commissioning of the KEKB is expected at the end of 1998. The control system should be installed at least one year before that time.

II. Design goal of the KEKB accelerator control system

A. Functional Requirements.

Before starting the design of KEKB accelerator control system, we reviewed functional requirements for the KEKB accelerator control system. In the process of the review, we find

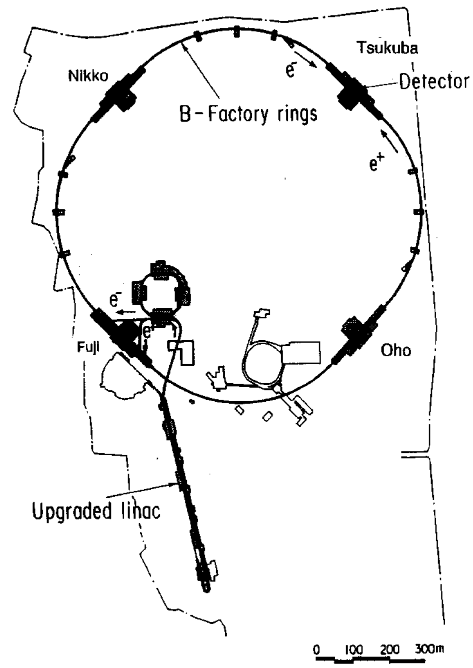

Figure. 1. KEKB Accelerator Complex.

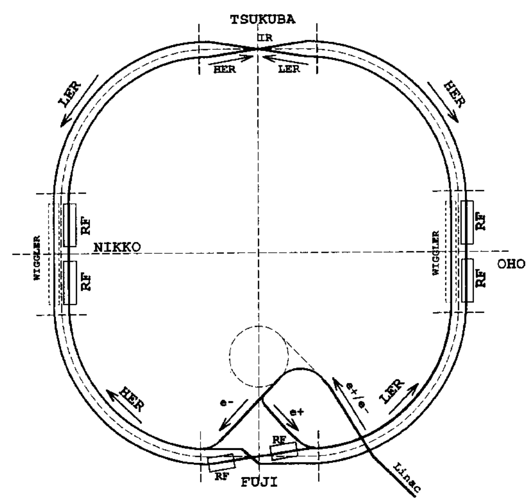

Figure. 2. KEKB Accelerator Configuration.

that users of an accelerator control system consists of three groups. 1) *Hardware Group* : They will construct accelerator hardwares and need basic controls over their hardware, such as set/read/monitor/alarm/log data. 2) *Accelerator Operators* : They operate accelerators in a steady state. They initiate automated operation programs , monitor the performance of the machine and adjust some parameters to improve machine performance as required. They also respond to an alarm system and fix the problem pointed by the alarm system. 3) *Accelerator Physicist*: They use the accelerator as their experimental equipment. They collect data from the accelerator and analyze them to find a new knowledge on accelerator physics. Their effort will be resulted in a performance improvement of the machine, i.e. higher luminosity.

Each group has their own requirements for the accelerator control system.

1. *Hardware Group*:
   (a) Easy access to the hardware in a hardware interface development phase.
   (b) Standalone operation of the hardware subsystem independent from the other part of the accelerator.
2. *Operators*:
   (a) The control system should be operator-friendly.
   (b) Operator interfaces should have quick response, less than a few seconds.
   (c) All the operation should be recorded for later inspection.
3. *Accelerator Physicist*: Their basic requirement can be summarized as three principles,
   (a) All the data that are possible to take should be taken.
   (b) All the data that are taken should be saved for later analyses.
   (c) All the operation should be recorded for later inspection.
   Requirements to the control system for data analysis are,
   (a) Stored data should be easily extracted.
   (b) The data should be easily analyzed.
   (c) It should be possible to analyze data and the computer simulation reslut with the same tool.
   (d) The programming system for application programs should be programmer-friendly.

The controls group itself has its requirements on the control system.

1. Easy integration of control sub-systems into the accelerator control system.
2. All the machine parameters and data about the machine components should be saved in the database.
3. Incremental upgrade and replacement should be possible.
4. Tight integration with the LINAC control system and the KEKB accelerator control system. It is important because of tight requirement on the beam injected to the KEKB rings.
5. CAMAC modules used and accumulated in the TRISTAN accelerator control system should be reused for economical and efficiency reason.

III. Basic Design Concepts

Considering requirements stated above, the basic concepts in KEKB accelerator control system are concluded as follows.

1. Design the system using so-called “Standard Model” of the accelerator control system.

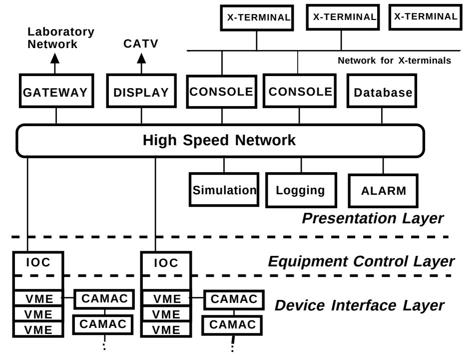

Figure. 3. KEKB Accelerator Control System Architecture

2. For the later upgrading or for maintenance, the interfaces between three layers should be well defined by using international standards.
3. As the interfaces between the control system and the equipment to be controlled, international standards such as CAMAC, VME, VXI and GPIB should be used.
4. To get quick response, high-speed networks should be used to connect computers.
5. To minimize man-power and efforts, the international collaboration or commercially available products should be applied.
6. For the application programmers, the object-oriented technique or abstraction should be fully utilized to hide the hardware behind.
7. Adopt the “Linkmen” system as in the construction of TRISTAN control system, where the linkmen make equipment database and code device drivers for the application programmers because they know the equipment best.

IV. KEKB Accelerator Control System Architecture

Our design of KEKB accelerator control system is based on EPICS[1]. The control system is divided into three layers; presentation layer, equipment control layer, and device interface layer, as shown in Figure 3. The first two layers are connected with each other through the high-speed network such as FDDI. To separate the network traffic between these layers from the traffic between console computers and X-terminals, another network and/or a network switch will be used.

A. Presentation Layer

The presentation layer includes operator’s consoles, database manager, simulation computer, alarm generation/recording, data logging, display, and a gateway to KEK in site network. Workstations and/or CPU servers running UNIX operating systems are used in this layer. X-terminals with multiple displays will be used as operator consoles. The database manager keeps all the information concerning KEKB accelerators, for example machine parameters, equipment specifications, location, and so on. The simulation computer is used for accelerator physics calculations for such purpose as orbit correction. Failures of the equipment are monitored by each equipment computer and are reported to the alarm computer for broadcasting and recording purposes. The data logging computer collects data from various equipment control computers for later analyses. The display computer displays data and transmits information over the KEKB site through the CATV network and other media. There is also a gateway computer which connects KEKB accelerator control computer network with the KEK laboratory network. The gateway computer makes it possible for staffs of accelerator department to reach KEKB accelerator equipment from their office. To avoid network jam caused by the access through the laboratory network, a proxy channel access(CA) server will be used on the gateway computer. This proxy CA server will intercept and bundle CA requests from the laboratory network.

The software environment required for this layer is very important in the whole system. The fundamental functions to display status and measured values graphically, to control each equipment, etc., should be supported from the beginning of installation of machine equipment. The programmer-friendly interfaces must be provided for the accelerator physicists to make application programs easily. And it is also important to have a very efficient data retrieval and analysis system from the database system.

B. Equipment Control Layer

The equipment control layer consists of computers that functionally control equipment of each hardware group, e.g. magnet, RF, beam monitor and so on. The equipment control computer, IOC(Input/Outpu Controller) in EPICS terminology, is a VME board-computer running real time operating system. In the VME bus, there will be CAMAC serial drivers and optional VME boards as the hardware interface between IOC and the device interface layers. The control computer may be replaced with the PC with VME bus interface for the maintenance reason.

C. Device Interface Layer

The lowest device interface layer consists of CAMAC crates and CAMAC modules inside the crates. We need to use VXI/VME interface for some hardwares, such as high speed BPM because of various reasons. The KEKB accelerator control system will also accept these interfaces. The CAMAC crates are connected by CAMAC serial highways or CAMAC branch highways corresponding to the characteristics required. For this layer, software drivers are provided on IOC's. These drivers are coded by the linkmen who have best knowledge of equipment to be controlled.

D. Data management

The database system is very important for the system. Any information related to the hardware components of the accelerators should be stored into the database system. Logging data, archived data and configuration data should also be accessible from the database system with same interface. Two commercial relational database software systems, ORACLE and SYBASE, are under evaluation.

V. Interface to the modeling program

The final goal of SAD[3] is to build a virtual accelerator on a digital computer. The user of SAD should be able to control this virtual accelerator through the same operator interface used in a real accelerator. To realize this idea, we will develop an interface program between SAD and portable CA server, which will run on UNIX workstations. CA clients can access the virtual accelerator through this CA server using ordinal CA protocol.

VI. Conclusion

The conceptual design of the KEKB accelerator control system was presented. The detailed design is underway and will be finished soon. The construction will start then and will be finished by the second quarter of 1998. It is essential to use commercially available products and make use of software sharing to save required man-power and efforts. The system should be friendly to the accelerator physicists who make application programs. The database system will become the core of the KEKB accelerator control system and will make us possible to integrate all the sub-systems into one large system.

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