DESIGN AND STATUS OF THE SUPERKEKB ACCELERATOR CONTROL SYSTEM

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Abstract

We have designed and upgraded the accelerator control system for SuperKEKB, the next generation B-factory experiment in Japan. The SuperKEKB control system is based on the features of the KEKB control system, while additional technologies have been implemented. In this paper, we describe the design and current status of the accelerator control system for SuperKEKB.

INTRODUCTION

SuperKEKB is the upgrade of the KEKB asymmetric energy electron-positron collider for the next generation B-factory experiment in Japan [1]. It was approved and is currently under construction. The designed luminosity is to achieve a 40-times higher luminosity than the world record by KEKB.

The KEKB control system was based on EPICS (Experimental Physics and Industrial Control System) [2] at the equipment layer and scripting languages at the operation layer. The SuperKEKB control system continues to employ those features, while we implement additional technologies for the successful operation at such a high luminosity.

In the accelerator control network system, we introduce 10 gigabit Ethernet (10GbE) for the wider bandwidth data transfer, and redundant configurations for reliability. The network security is also enhanced. For the SuperKEKB construction, the wireless network is installed into the whole area of the accelerator tunnel.

We have developed the interface modules to control thousands magnet power supplies, and introduce the EPICS embedded PLC, where EPICS runs on a CPU module. In the timing system, the new configuration for positron beams is required. For SuperKEKB, the faster response beam abort system has been developed.

This paper describes the design and status of the SuperKEKB accelerator control system.

NETWORK SYSTEM FOR SUPERKEKB

We have upgraded the accelerator control network system for SuperKEKB [3]. Fig. 1 shows the schematic view of the SuperKEKB accelerator main ring. The accelerator control network system employs a star network topology. The main network switch is located at the SuperKEKB control room. All network switches, located at 26 sub control rooms along the SuperKEKB main ring, the SuperKEKB injector linac (Linac), and AR, connect to the main switch in the SuperKEKB control room with optical cables.

In KEKB, the bandwidth of the network switches was 100MbE or 1GbE. For SuperKEKB, the 10GbE network

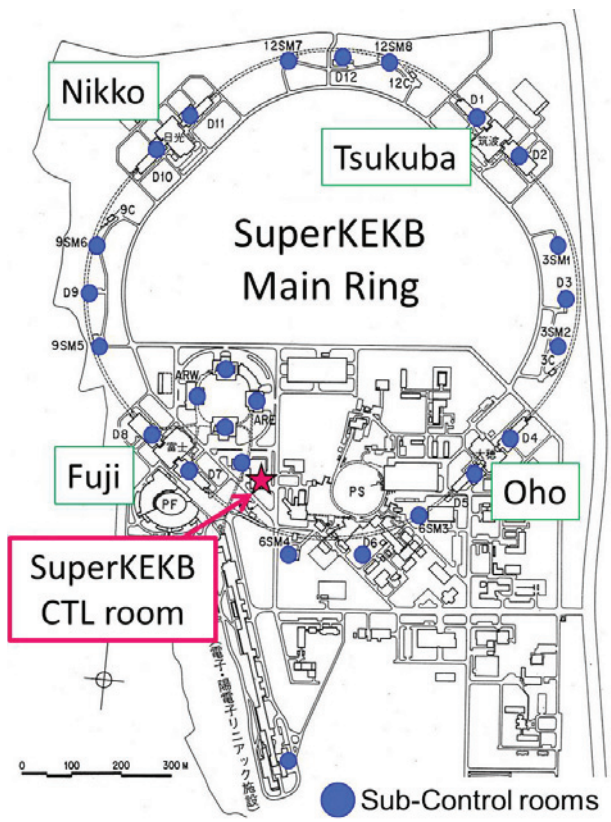

Figure 1: Schematic view of the SuperKEKB accelerator main ring. Red star indicates the SuperKEKB control room. Blue circles are the sub control rooms, located along the SuperKEKB main ring, Linac and AR.

switches will be installed into the all sub-control rooms along the SuperKEKB main ring and Linac. We have installed the single-mode optical cables to assure the 10GbE data transfer. For the redundant structure, sub-control room switches connect to the main switch with

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two lines each, and form the active-standby configuration. The 10GbE network switches will be installed within this JFY.

VLAN Segmentation for SuperKEKB

Since EPICS, which is used as the main software to control the accelerator for KEKB and SuperKEKB, uses the UDP broadcast to make communication between Operator Interfaces (OPIs) and Input/Output Controllers (IOCs), there are many UDP broadcast packets in the accelerator control network.

In SuperKEKB, the number of the controlled devices, which have the Ethernet interface to connect with the IOCs, increases, and these devices also receive the UDP broadcasts. Several devices cannot properly operate under the high rate UDP broadcast environment.

To prevent such UDP broadcast effects, we apply the VLAN-based network segmentation to the SuperKEKB control network. Here IOCs and the accelerator components with Ethernet interfaces are in the different VLANs. We have tested the VLAN segmentation, and confirmed that the device with an Ethernet interface in the different VLAN operates properly.

Network Reconfiguration to Connect with the KEK Network

For SuperKEKB, we reconfigure the network design as shown in Fig.2, to enhance the reliability and security of

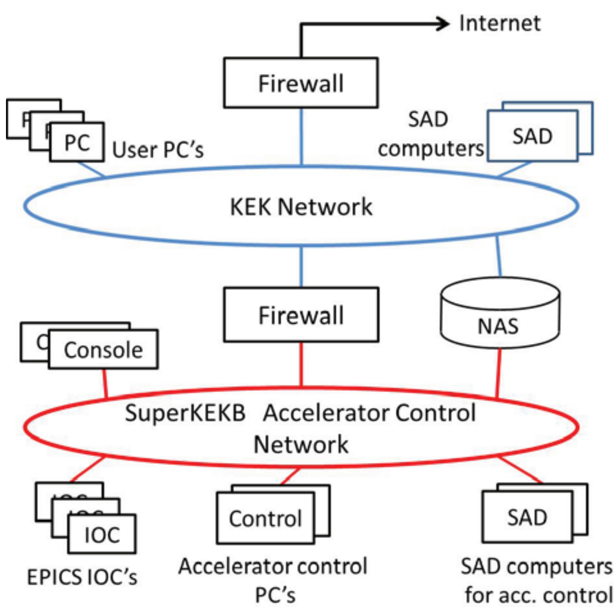

Figure 2: New configuration for the SuperKEKB accelerator control network and the KEK network connection.

the network. In KEKB, there were many computers connecting to both KEK and KEKB-accelerator-control networks. For SuperKEKB, all computers in the accelerator control network do not connect to the KEK network. We also change the account system, and the only SuperKEKB collaborators logged into the computers in the accelerator control network. This summer, we changed and applied the new network configuration.

Installation of the Wireless LAN System into the Accelerator

It is important to provide the convenient network environment for the efficient accelerator construction and maintenance of it. We install the new wireless network system based on the Leaky Coaxial (LCX) cable antennas and collinear antennas into the SuperKEKB accelerator tunnel.

The 16 20D-type 125m-length-LCX antennas, 2000m length in total, are installed into the 4 arc sections, and 16 collinear antennas are installed into the 4 linear sections covering 1000m length area.

For SuperKEKB, we have selected the LCX and collinear antennas which have good radiation hardness of more than 1MGy. Fig. 3 shows the installed LCX antenna into the SuperKEKB arc section. As shown in the figure, all access points, as well as PoE modems for power supply in the tunnel are installed within the lead boxes.

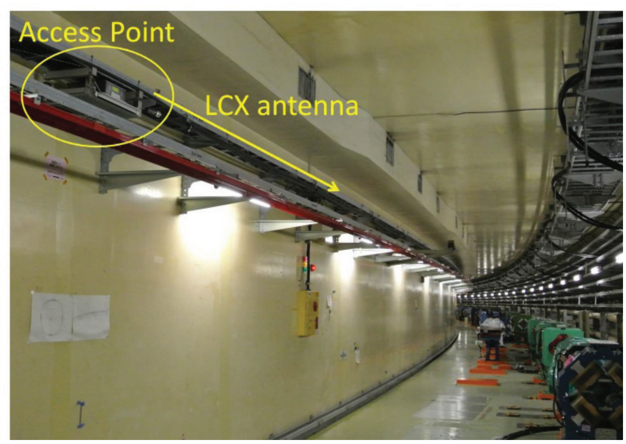

Figure 3: An access point and a 125m length LCX antenna installed at the SuperKEKB arc section. The access point is located in a lead box.

After the installation, we tested the wireless LAN system. We obtain the good performance of about 18Mbps effective transmission rate in the whole area of the SuperKEKB tunnel. In addition to the 32 access points installed in the SuperKEKB main ring, we also install the access points into AR, Linac, SuperKEKB sub control rooms, and power equipment rooms at the power equipment buildings. Total 70 new access points are controlled by an access-point controller.

SOFTWARE AND HARDWARE INTERFACE FOR SUPERKEKB

For KEKB and SuperKEKB, EPICS is used as the main software to control the accelerator at the equipment layer.

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The EPICS framework consists of the Operator Interfaces (OPIs) and the Input/Output Controllers (IOCs). In KEKB, our system was constructed with the EPICS base version 3.13. For SuperKEKB, we're going to update to the version 3.14, however there still remain IOCs which are based on the EPICS base v3.13. For the operation layer, several script language of SAD script, python are used.

In KEKB, VME single board computers with VxWorks are mainly used as IOCs. For SuperKEKB, as well as the VME/VxWorks, the PLC (programmable logic controller) with a CPU module where Linux is running, and the Linux PC are also used as IOCs. Fig.4 shows the picture

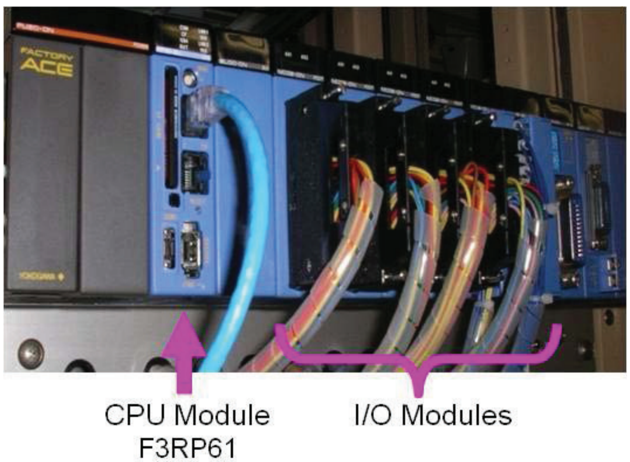

Figure 4: Picture of the PLC modules for the beam collimator controller.

of the PLC modules for the beam mask controller. In the CPU module (Yokogawa F3RP61), Linux is running, and we install EPICS into the CPU module to control the PLC. For SuperKEKB, the F3RP61 module is used to control the many devices of, for example, the vacuum system, LLRF, the automatic calibration subsystem of the large-type-magnet power supply, and beam collimators [4].

There are many kinds of fieldbus in SuperKEKB

Figure 5: Prototype of the PSICM (Power Supply Interface Controller Module), used for the magnet power supply control for SuperKEKB.

accelerator components, such as Ethernet, GP-IB, serial, VXI/MXI for BPM, ARCNET for magnet power supply, and CAMAC. For the magnet-power-supply control, we have developed the interface module [5]. Fig.5 shows the picture of the prototype PSICM (Power Supply Interface Controller Module) for SuperKEKB. The new PSICM has features of the faster data transfer rate of 10Mbps or 5Mbps (2.5Mbps in KEKB), 32-bit data handling to support the 24, 20, or 18-bit resolution DAC (the previous PSICM supports 16-bit only), and redundant timing-signal inputs.

Data Archiving System

In KEKB, we have used KBLog as a data archiving system. In SuperKEKB, we continue to use the KBLog, as a primary data archiving system which is the file based logging system. In addition, as the second option, the new data archiving system based on the CSS [6] (Control System Studio) Archiver is also used. The CSS is originally developed at DESY, and has many general software components for the device control. CSS-based Archiver is one of the CSS tools, which collects data using the EPICS Channel Access protocol, and stores the data to the backend relational database system. Here we use PostgreSQL for the database system. The database can be directly accessed with CSS, and the CSS installed users PCs can be remotely access to the database for the real-time, historical, or trend data monitoring.

Currently, the CSS Archiver with the PostgreSQL backend database is running on our system. It collects the vacuum system data and the cryogenic data for the final focusing superconducting magnet system, and works without problem so far.

Since CSS provides many tools, we also consider the alarm system with CSS for SuperKEKB.

TIMING SYSTEM FOR SUPERKEKB

In SuperKEKB, we construct the positron Damping Ring (DR) to produce the lower emittance beams. The KEKB timing system is based on a frequency divider/multiply and a digital delay technique. Since the KEKB ring RF (508.887MHz) is not a divisor of the Linac RF (2856 MHz), both of the KEKB ring and the Linac frequencies are locked with a common divisor frequency (10.385 MHz = 96ns cycle), which determines the injection timing. For the SuperKEKB positron injection, the injection timing of 96ns cycle for KEKB becomes 11.34 ms, because of the properties of DR, if we use the similar configuration as KEKB [7].

Instead of this, we have developed the new timing system, which generates the injection timing signals. Fig.6 shows the layout of the event timing system located at the Linac main trigger station for the SuperKEKB positron injection. The system consists with two layers of event generators (EVGs). As EVG detects the external trigger, EVG generates and sends the timing signal to the

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event receivers (EVRs). The trigger for the upper layer EVG (global EVG) is a coincidence between 50Hz and 11.34 ms cycle, which corresponds to a few second cycle.

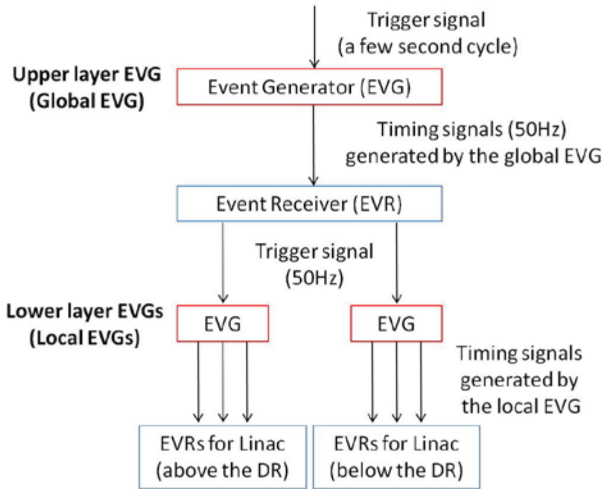

Figure 6: Layout of the event timing system at the Linac main trigger station for SuperKEKB positron injections.

The global EVG sends the 50Hz timing signal for EVR. The EVR outputs 50Hz trigger signals to the lower layer EVGs (local EVGs). The local EVG for the Linac below the DR generates the timing signals, in taking account for the proper positron injections. Currently, several feasibility studies are carried out.

SUPERKEKB BEAM ABORT SYSTEM

We have developed the faster response beam abort system for SuperKEKB. Figure 7 shows the layout of the abort system for SuperKEKB.

There are over 130 points which monitor the beam status and issue the abort signal. The abort signal is E/O converted, and received by the VME abort modules located at the local control rooms. 20 local abort modules are connected to the abort module in the SuperKEKB control room, which gathers the local abort module signals, takes OR of them, and issues the trigger signal to

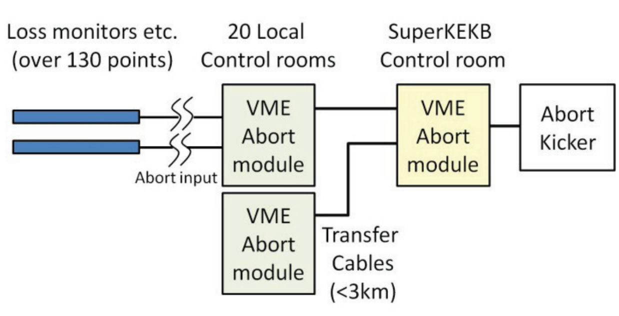

Figure 7: Layout of the abort system for SuperKEKB.

the abort kicker. In KEKB, these modules are connected with wires, and low pass filters which caused time delay of ~100μs were necessary for the noise reduction. For SuperKEKB, we have adopted the E/O conversion, replaced the wires with the optical fibers to transfer the signal, and removed the low pass filters from the system. The total abort system response time is improved to 20 μs.

RENOVATION OF THE CONTROL ROOM

We are currently renovating the SuperKEKB control room and the computing room. We removed old panel-board cabinets and server racks from the computing room. Total 3t weight signal and power cables, which were used at TRISTAN and KEKB, are removed from computing and control rooms. New server racks, located at the computing room have the plugs with a power monitor. We install modules for power supply into the server racks. The new server racks and power supply modules are installed by this November. We have also design the consoles for the SuperKEKB control room.

SUMMARY

We have improved the accelerator control system for SuperKEKB operations under the 40-times higher luminosity than the world record achieved by KEKB. Based on the KEKB accelerator control system, we have implemented the new features of the redundant and wider band width network, the improved control software tools and interfaces, the new data archiving system, the new timing system, and the faster response abort system. We have also renovated the main control room and have been preparing for the first SuperKEKB operation in 2015.

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