Remote monitoring system for the cryogenic system of superconducting magnets in the SuperKEKB interaction region

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Background

Super KEKB accelerator is under construction in KEK to conduct high energy physics experiment with **Belle II** detector.

- The aimed luminosity is extremely high. 8×10^{35} cm^{-2} s^{-1} : 40 times higher than that of KEKB.
- To realize high luminosity, the beam final focusing system in the interaction region is important.
- The beam final focusing system consists of superconducting quadrupole and corrective magnets (**QCSL magnets and QCSR magnets**) surrounded by the large superconducting solenoid (**Belle solenoid**) of Belle II detector system.

Objectives

Development of powerful monitoring system was required **to monitor all cryogenic components in the interaction region.**

- **Remote monitoring of real-time data at fast cycle time.**
- **Various functions (graphs and graphics) necessary for monitoring.**
- **Easy data-sharing with multiple groups.**

Summary

The remote monitoring system based on software infrastructure of **EPICS** was developed.

- According to the infrastructure of EPICS, software components (**IOC, CSS archiver, RDB and CSS client**) were built. For CSS clients, many real-time graphs and graphics of three apparatuses (QCSL, QCSR and Belle solenoid) were created.
- The developed monitoring system made it possible for users to monitor all data of the **EX-8000** with a cycle time of 1 second.
- Functions (graphs and graphics) of the CSS client on various network environments were tested. It was proved that the developed remote monitoring system worked well.
- Data sharing can be easily realized among multiple groups using EPICS.

EPICS: The Experimental Physics and Industrial Control System
IOC: Input/Output Controllers **CSS archiver**: ArchiveEngine for CSS (Control System Studio)
RDB: Relational Data Base managed by management software **CSS client**: Client software for CSS
EX-8000: Hitachi integrated instrumentation system to control all cryogenic components.

SuperKEKB and Belle II detector

The **SuperKEKB** accelerator is an electron-positron collider under construction in KEK.

- high luminosity: 8×10^{35} cm^{-2} s^{-1}
- Single interaction point:
  - The beam final focusing system (consisting of **QCSR** and **QCSL**)
  - **Belle II** detector (including **Belle solenoid**)
- Upgraded systems of the previous KEKB accelerator and Belle detector.
- Physics experiments are planned to start in January 2019.

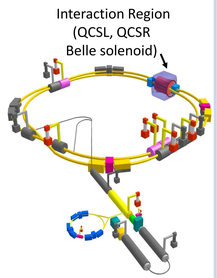

Fig 1. SuperKEKB
e$^-$ (HER): 7-GeV, e$^+$ (LER): 4-GeV

Superconducting magnets and helium cryogenic system

Superconducting magnets

- The beam final focusing system has superconducting magnets (quadrupole doublets for each beam, 43 corrector coils and 4 compensation solenoids) assembled into 2 cryostats, **QCSR** and **QCSL**.
- The **Belle solenoid** in a dedicated cryostat is a large superconducting magnet (central magnetic field: 1.5 T).
- QCSR and QCSL are inserted into the bore of the Belle solenoid during physics experiments.

Cryogenic systems

- The Belle solenoid, QCSR, and QCSL are each cooled by a medium-sized helium cryogenic system.
- Three cryogenic systems have the same structure and capacity, 250 W at 4.4 K (or 160 W at 4.4 K + 28.4 L/h).

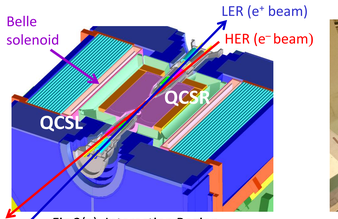

Fig 2(a). Interaction Region

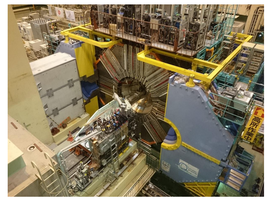

Fig 2(b). QCSR and Belle II detector

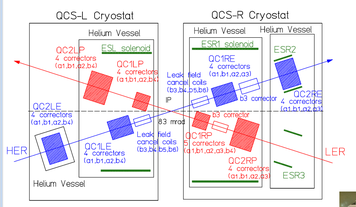

Fig 2(c). Beam final focusing system

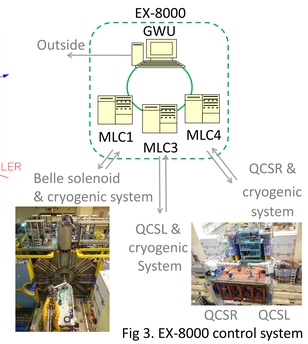

Fig 3. EX-8000 control system

Control system for superconducting magnets and cryogenic systems

All cryogenic components are controlled by EX-8000 on a dedicated local network.
EX-8000: the Hitachi integrated instrumentation system.
Cycle time: 1 s.

- MLCs: Multi-Loop Controllers
- GWU: Gate Way Unit to read/write data between the EX-8000 and external devices.

Development of remote monitoring system

EPICS

- EPICS is a set of software tools and applications to provide a software infrastructure in building distributed control systems: **IOC, CSS archiver, RDB and CSS client**
- EPICS has been widely used for accelerator control.

Application of EPICS to the remote monitoring system

- IOC part

"StreamDevice" software tool of the EPICS IOC was used to read/write data in TCP/IP between IOC and GWU.

- ArchiveEngine and RDB parts

CSS archiver was built for Archive Engine with PostgreSQL (RDB management software). The same was installed in 2 PCs (Fig.4).

- CSS-based client parts

Many graphs simulating the EX-8000 and graphics using CSS tools were developed.

Performance of the remote monitoring system

Remote monitoring in the same cycle time as EX-8000 was realized: 1-s cycle

- Total 1048 data (AI, AO, DI, DO and calculated data – Table 1) are collected from EX-8000 via GWU in 1-s cycle, using simple binary commands of GWU in EPICS IOC.
- Function and operation of CSS client from PCs on various networks were tested and proved to work well. (networks: SuperKEKB-accelerator-LAN, KEK-LAN, J-LAN, VPN)
- Real time data on the developed graphs and graphics were compared with EX-8000 data. They proved to be accurate. Fig 5(a), (b), (c), (d)
- Data-sharing can be realized easily with other groups using EPICS. Currently, performance tests for QCSL and QCSR are underway. Data is actually being shared with other groups.

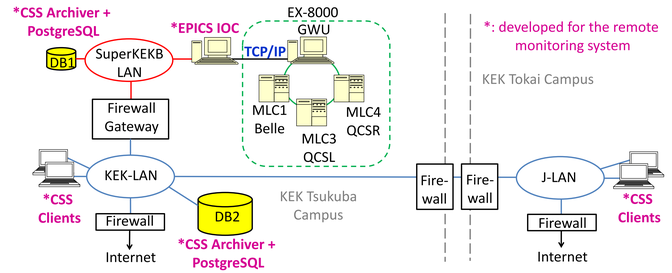

Fig 4. Remote monitoring system

Table 1. Number of data samples monitored by remote monitoring system.

MLC No.	System	Number of data
MLC1	Belle solenoid & cryogenic system	260 (AI:101, AO:33, DI:64, DO:48, Calculated:14)
MLC3	QCSL & cryogenic system	410 (AI:224, AO:42, DI:72, DO:44, Calculated:28)
MLC4	QCSR & cryogenic system	378 (AI:199, AO:43, DI:68, DO:39, Calculated:29)

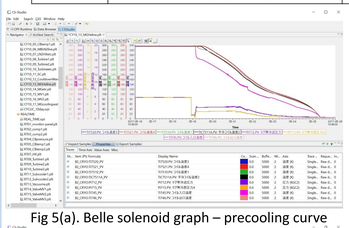

Fig 5(a). Belle solenoid graph – precooling curve

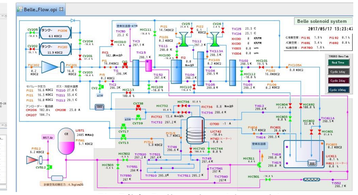

Fig 5(b). Belle solenoid graphics

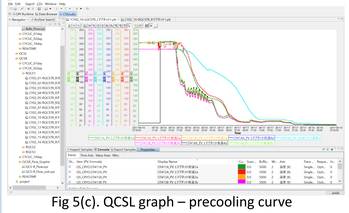

Fig 5(c). QCSL graph – precooling curve

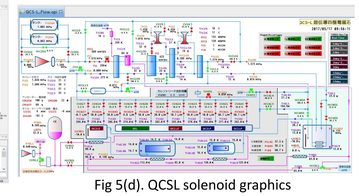

Fig 5(d). QCSL solenoid graphics

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