

# A NEW PULSED MAGNET CONTROL SYSTEM IN THE KEK ELECTRON POSITRON LINAC

Y. Enomoto\*, K. Furukawa, T. Natsui, M. Satoh, KEK, Tsukuba, Japan  
 H. Saotome, Kanto Information Service Tsukuba, Japan

## Abstract

In 2017, sixty-four pulsed magnets (28 quadrupoles and 36 steerings) were installed in the KEK electron positron LINAC for simultaneous injection to four different rings. Since each ring requires different injection energy, magnetic field in the injector LINAC has to be changed shot by shot (every 20 ms) according to the destination of the beam. To realize such operation, a PXI express based new control system was installed. At present, 13 units are stably in operation to control 64 magnets. Further installation of the magnets and control system is planned in 2018.

## INTRODUCTION

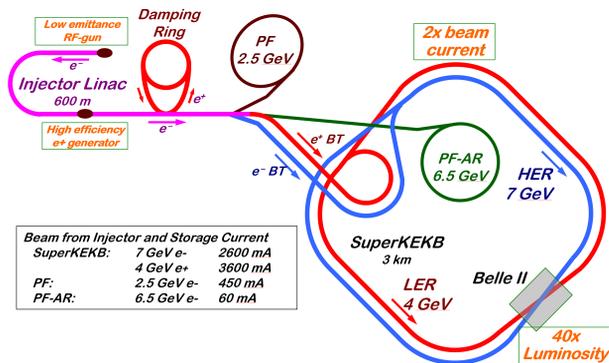


Figure 1: A schematic view of electron and positron accelerator complex in the KEK.

Figure 1 shows electron and positron accelerator complex in the KEK. There are four storage rings, i.e. two rings for light source, PF and PF-AR, and two rings for electron positron collider, SuperKEKB HER and LER. In addition to them, positron damping ring have been in operation since February 2018. All of the rings require full energy injection but the value of energy is different as shown in the Fig. 1. To satisfy the requirement, 64 pulsed magnets were installed in 2017. Using these magnets, magnetic field can be changed shot by shot in 20 ms and was optimized for each destination. In this paper, the control system for the pulsed power supply using PXI express unit with event timing system controlled by EPICS and LabVIEW is shown in detail.

## OVERVIEW OF THE SYSTEM

Figure 2 shows a block diagram of the system. One standard unit consist of a PXI express unit for fast control, DC power supplies, pulse drivers and NI cRIO unit for interlock and slow data acquisition. There is one computer to control and monitor all of the 64 DC power supplies. A CSS archiver

\* yoshinori.enomoto@kek.jp

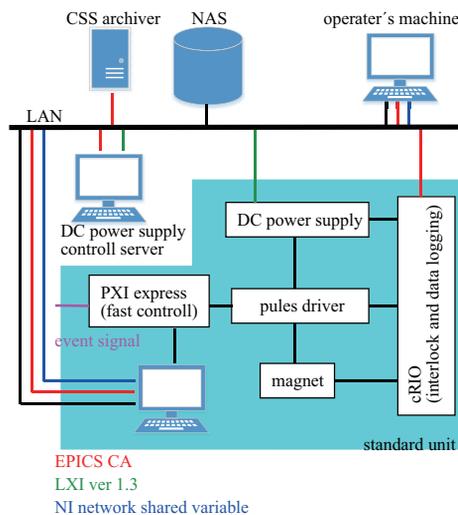


Figure 2: Block diagram of the system.

and A Network attached storage are used to log various data not only output current of the power supplies but temperature of the IGBT in the pulse driver, status of the DC power supplies and so on. EPICS channel access protocol is mainly used for the communication among computers. LXI version 1.3 protocol is used to control the DC power supplies and NI network shared variable is used to send fast waveform data. As for the event timing system, dedicated optical fiber is directly connected to the module. Most of the software is written in LabVIEW 2016 (32 bit) with NI DSC module.

## PXI AND EVENT TIMING SYSTEM

For the fast control, PXI express unit plays major role. The unit, shown in Fig. 3, consists of a PC and a PXI express chassis with four cards, a controller board to connect to the PC, an event receiver board (EVR), a DAC board, and a ADC board, which can set and monitor output current up to 8 pulsed power supply independently in 16 bit resolution with 1 MSa/s sampling or update rate. They are placed in the same rack and connected by a metal cable. An EVR board in PXI form factor is used to integrate the timing system to the LINAC timing system. In our LINAC, event timing system by Micro-Research Finland Oy (MRF) is adopted. The EVR receive not only the timing information but also the mode number and shot ID. The mode number is used to determine the next output setting. The shot ID is used to tag the monitored information. The trigger timing is precisely (in the order of a few times 10 ps) adjusted 3 ms before the beam arrival. Since the rising and falling time of the magnet current is in the order of ms, pulsed shape of the power supply does not important as long as the reproducibility is assured.

Content from this work may be used under the terms of the CC BY 3.0 licence (© 2018). Any distribution of this work must maintain attribution to the author(s), title of the work, publisher, and DOI.

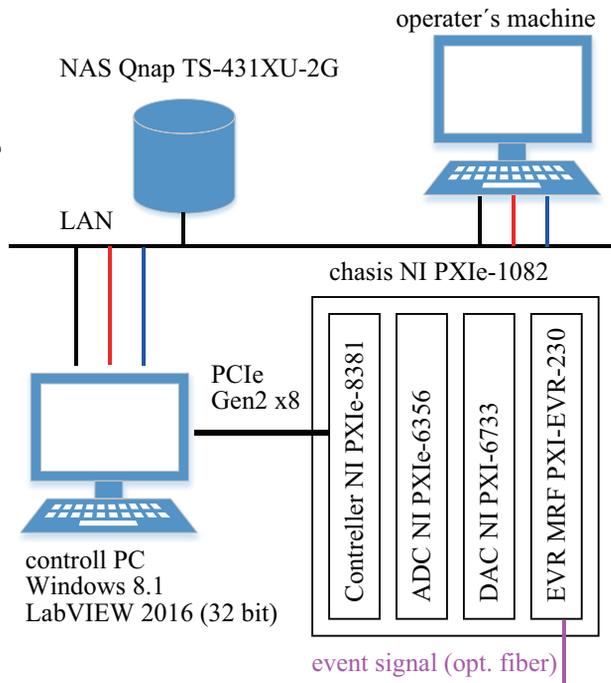


Figure 3: PXI express unit.

### SOFTWARE

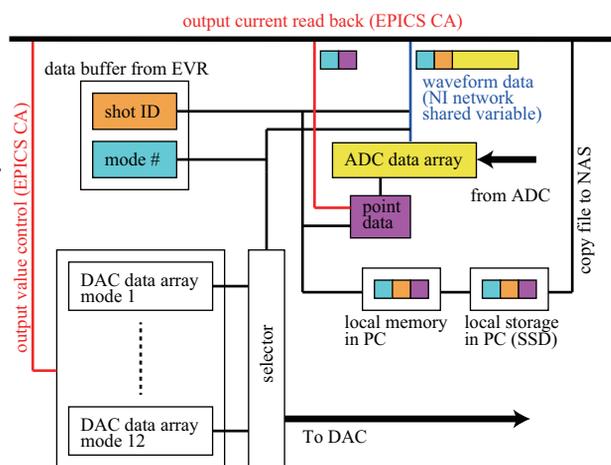


Figure 4: Data flow in software.

In terms of software, Windows 8.1 and LabVIEW 2016 (32 bit) with DSC module are mainly adopted to control the hardware. EPICS channel access (CA) protocol and NI network shared variable protocol are used to communicate with operator's interface panels. Figure 4 shows data flow in the software. Twelve DAC data array according to the beam mode are prepared in advance in the PC's memory. Each DAC data is recalculated by putting a new value using EPICS channel access protocol. Data buffer information from the EVR is delivered to the main software a few millisecond after the last trigger. Then, one of the DAC data array is selected according to the next beam mode and updated to the DAC's memory. By the trigger signal from the EVR, the DAC and the ADC start outputting and digitizing data for 6 ms. Acquired ADC data array is concatenated with shot ID and mode number, then issued to the network using NI

network shared variable protocol every 20 ms. At the same time, one point, at the timing of the beam passing through, in the ADC data array is chosen and issued to the network with mode number using EPICS channel access protocol. Every one point data with timestamp, shot ID and mode number is buffered in the memory of the control PC for 10 s then they are dumped to the text file in the local storage of the PC. The file is copied to the NAS every 60 s by another process. By this way, output current of the power supply for all of the shot (every 20 ms) is stored in the disk. Even though the windows is not a real-time OS, the data loss rate is less than ppm which is acceptable value for us. The amount of the data is about 3 TB/year for 64 ch. In addition to real-time monitoring, logging by CSS archiver every 10 s is also available for all the channel. Supplementary software such as, remote monitoring ADC data array, detecting hung-up of the main programs etc. are also prepared by LabVIEW and running on the windows machine in the control room.

### INTERLOCK SYSTEM

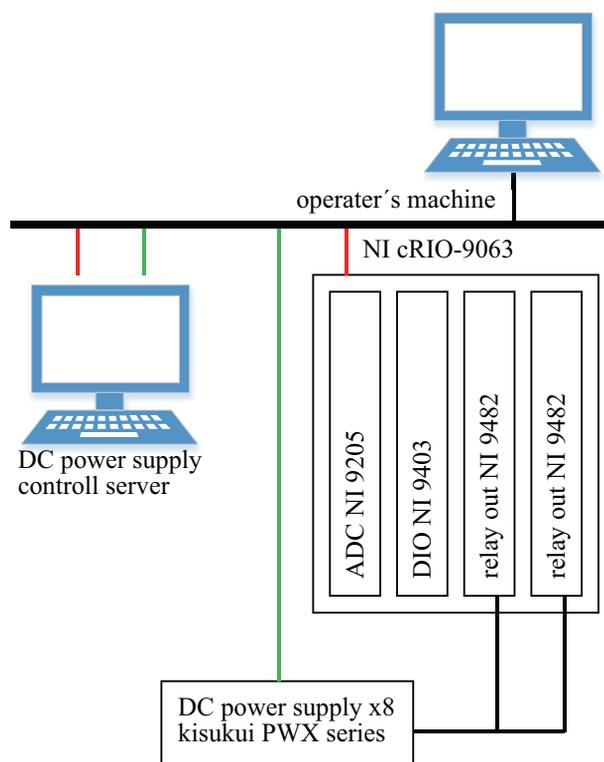


Figure 5: Interlock system.

NI compactRIO unit is used for the interlock and slow data acquisition (Fig. 5). One unit consists of a 32 ch 250 kSa/s/ch ADC module, a 32 ch TTL digital I/O module and two 4 ch relay output modules. It covers 4ch of the pulsed power supply, namely for one PXI express unit (8 ch), two cRIO units are needed. To realize robust interlock system, cRIO is working not in a scan engine mode but in a FPGA mode. On the upper layer, EPICS CA server is running on the NI RT Linux. Not only the PVs for the ADC and DIO data, but the PVs for the high and low threshold, average number to control data acquisition are also prepared which

can be set and read using EPICS CA protocol. Between each analog and digital input channel and each relay output channel, matrix mask information PVs are prepared, that determine which input channels are used for interlock signal of the which output channels(see Fig. 6). This method make it possible for us to flexibly change the interlock setting.

November, simultaneous injection using the newly installed pulsed magnets were demonstrated successfully. Since the SuperKEKB phase two operation start from March in 2018 and light source rings restart in May, real simultaneous injection operation start in the middle of May in 2018.

## CONCLUSION

A new pulsed magnet control system using PXI express unit with event timing system are developed and installed in 2017. They are now working in the KEK electron positron injector LINAC without any severe trouble for 7 months.

## UPDATE PLAN

In summer shutdown in 2018, another 32 pulsed magnets are plan to be installed. The same control system will be adopted but the major update of the software is planned. One of the important update is to synchronous data acquisition among different PXI express unit and further different equipment like RF monitors and beam position monitors for better beam analysis and control.

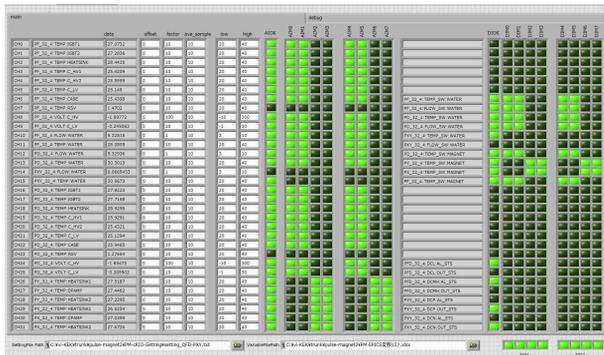


Figure 6: Matrix mask setting panel.

## OPERATION

After four months installation work from May, comprehensive test was done for a month in September in 2017. In

Content from this work may be used under the terms of the CC BY 3.0 licence (© 2018). Any distribution of this work must maintain attribution to the author(s), title of the work, publisher, and DOI.