

IMPROVEMENT OF PERSONNEL AND MACHINE PROTECTION SYSTEM IN SuperKEKB INJECTOR LINAC

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Abstract

Since summer of 2010, the radiation control area for the KEK electron positron injector Linac had been split at the around 3 GeV point by a concrete wall into upstream and downstream parts with independent beam sources. This was so as to allow operation of the downstream part for beam injection into photon factory rings while construction and development of new electron guns proceed in the upstream part. In summer of 2017, this arrangement was revised and the entire injector Linac was reconsolidated into a single radiation control area. Along with this reconsolidation, the personnel and machine protection systems were modified and improved. In this paper we report the renewed personnel and machine protection system of SuperKEKB injector Linac in detail.

UPGRADE OF LINAC

The SuperKEKB injector Linac is a linear accelerator with a total length of about 600 m. It provides four independent storage rings with electron and positron beams of different parameters [1,2]. The beam to the SuperKEKB is currently being reinforced for the low emittance and high intensity beams. The injection beam energy of positron to the SuperKEKB is increased from 3.5 GeV to 4 GeV. In SuperKEKB Phase II project, in order to realize a positron beam of low emittance, the damping ring (DR) was constructed adjacent to the middle of Linac and operation started as shown in Fig. 1. Linac is operated for the four rings by simultaneous top up injection, which is fast switching beams with different energy and beam characteristics to the five rings [3].

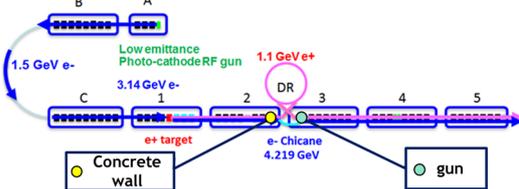


Figure 1: Schematic layout of the SuperKEKB injector

The accelerator structures and magnets of Linac are installed in the underground tunnel. The underground area was spatially divided by the concrete wall for radiation shielding capability with interlocked doors at the middle point from September 2010 to May 2017. This wall was constructed with concrete blocks with a thickness of 1 m. Meanwhile, in Sector A to Sector 2 (upstream side), we restored the damaged ground framed by the earthquake, enhanced strength of them and were doing research and development for SuperKEKB. On the other hand, it was

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possible to supply the beam for the user experiment of the PF ring in downstream side. The electron guns were installed at the most upstream of Sector A and Sector 3. In order to construct the junction between DR and Linac, it was necessary to remove the dividing wall and the electron gun in the middle part. As a result, the Linac beams always originate from the electron source in the far upstream end.

RADIATION MANAGEMENT

Since radiation level is high in the accelerator area during Linac operation, we must keep radiation safety. The state where human safety is guaranteed and operation is possible is called "LINAC READY" as shown in Fig. 2. This is the interlock system (Personnel Protection System) intended for personnel protection in Linac.

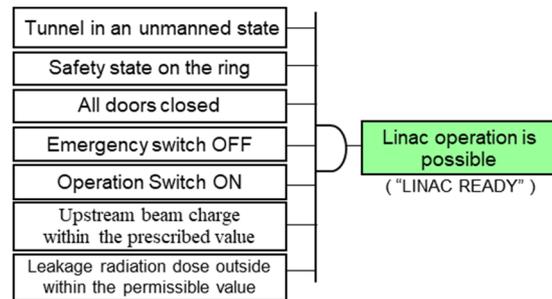


Figure 2: Linac operation conditions taking human safety into consideration on radiation.

Furthermore, it is necessary to reduce the influence of radiation on equipment after guaranteeing human protection. Various signals are consolidated in Programmable Logic Controller (PLC), and logical configuration for safety management is performed on PLC. However, Linac emergency stop system is constructed using only mechanical relay without passing the PLC. It severally has constructed a logical configuration of upstream and downstream before the integration of the radiation control area for independent operation [4]. There was no stopper to stop the upstream beam physically at the dividing point. For this reason, the condition signal of "downstream side operation is permitted" was one of the necessary condition of the upstream side operation. After the integration, it changed so that all signals are managed collectively.

SOFTWARE UPDATE OF THE SAFETY MANAGEMENT SYSTEM

There are three PLCs in the control room at two places, which constitute the basis of the safety management system. Furthermore, two dedicated communication PLCs serve as gateways for transmitting the signals to the LAN.

The flow of information there is one-way, so even if a failure occurs on the LAN, the system is unaffected. The SuperKEKB accelerator which is one of the downstream rings has high beam incidence frequency, and it is necessary to cooperate closely with SuperKEKB. For this reason, the Linac control terminal is provided in the SuperKEKB control room and remote control is possible. To perform beam operation remotely, one set of PLC and touch panel is installed. There are six PLCs in total in the system as shown in Fig. 3. Table 1 shows number of signal input and output points per PLC. DC voltage of 24 V is used for all signals. The software for all PLCs and PCs for displaying system status were revised. Furthermore, the design of the display screen on the control console PC has also been updated as shown in Fig. 4. These updates spread over wide range of Linac.

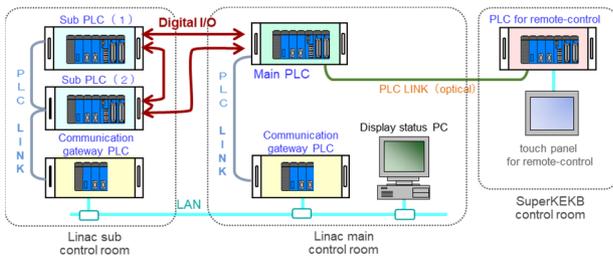


Figure 3: Schematic layout of safety management interlock system of Linac.

Table 1: Number of Signal Input/Output Points of the Safety System PLC (approximate number)

PLC	Input	Output
Main PLC	200	140
Sub PLC (1)	50	30
Sub PLC (2)	40	10



Figure 4: Image example of Interlock status display after system update (top) and before system update (bottom).

HARDWARE UPDATE OF THE SAFETY MANAGEMENT SYSTEM

Personal Key System

Two personal key boxes had been used for upstream and downstream before the integration. They were installed at the entrance of the Linac, respectively, and there were personal keys and door keys as shown in Fig. 5. When entering the accelerator room for equipment maintenance or remodelling, the operator carries one personal key. This personal key was also assigned as the entrance door key to the accelerator room. The downstream personal key was also the key of the downstream entrance door. Each person's ID card is used for management of personal key and door keys. When the key card is inserted to the card reader, the key card data recorded in the key card is compared with the registration data and it is judged whether to unlock the key. 50 people for upstream and 32 people for downstream were allowed to enter simultaneously. Accelerator operation is impossible unless all the personal keys are returned. To prevent taking the key out of the controlled area, an RF tag (self-sounding) is attached to each key tag (Fig. 5). When approaching the entrance gate of Linac, the buzzer sounds within the range of about 2 m of each gate on both sides.

The upstream personal key box has a board computer inside, exchanges contact signals with the safety system main PLC, and manages the personal key box as shown in Fig. 6. There are two PCs. One is the PC displaying the key lending status, and the other is on the injector network PC. This display PC and the key box exchange entry/exit information via RS-232C. With the integration of Linac, the downstream side personal key box was removed. After the integration, only one key box (formerly for the upstream part) is used for the entire Linac. The downstream door keys of the accelerator room have been matched with the door keys of the whole area key box.

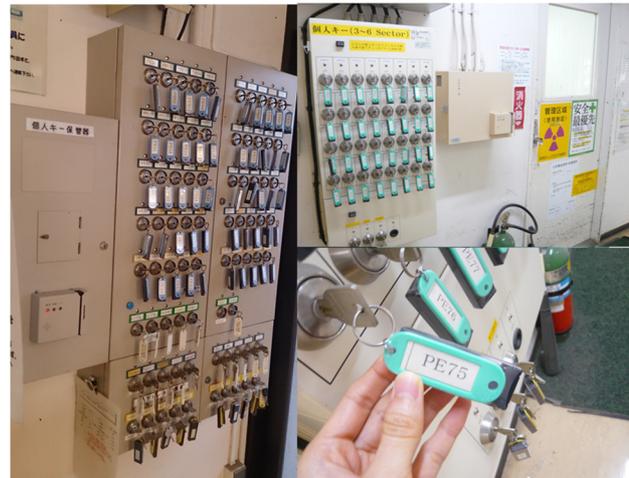


Figure 5: Picture of integrated personal key box (left), downstream personal key box (top right) and a personal key (down right).

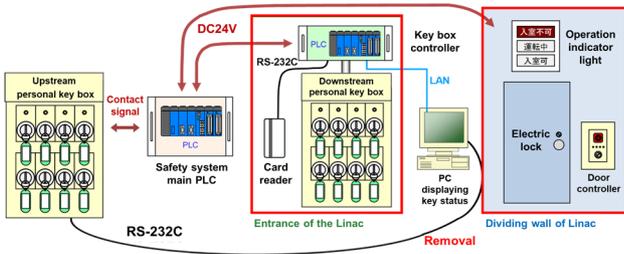


Figure 6: Schematic layout of the updated personal key management system to enter the accelerator room.

Operation Indicator Light

The equipment attached to the removed wall is the operation indicator light and the door controller as shown in Fig. 7. They exchange 24 V DC contact signal with the safety system PLC. Operation status was displayed on the shield wall until its removal in May, 2017. The operation indicator light indicates “entry prohibition”, “accelerator in operation” or “entrance permitted”. The operation indicator lights are located at two entrances of the accelerator room. For the entrance permission of the linac tunnel, “No beam in DR” condition has been added.

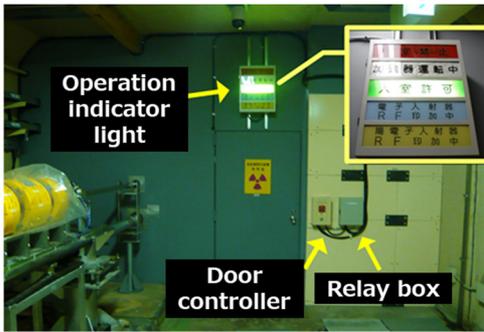


Figure 7: Picture of the operation indicator light and the door controller attached to shield wall before removal at the dividing point of Linac.

New Operation Control Panel

The operation control panel was modified with introduction of DR as shown in Fig. 8. The panel and the safety system main PLC exchange information with digital I/O. The panel operates Linac and is installed in Linac and KEKB. “READY” signal is information for confirming the safety state on the downstream ring side. “Beam Mode” indicates the operation mode in which the beam charge and energy are different. In the new panel, we added “DR READY” and “DR mode” indicator, and we removed the downstream beam key. Also, those which color-coded upstream and downstream were unified. The lower right part of Fig. 8 is the part related to the electron gun. Pushing this switch selects which of the electron guns (thermionic or photo cathode RF gun) will emit the beam. We added a switch related to beam incidence by RF gun. This was remodeled so that the condition of the RF gun can be easily

understood with the Open and Close button of the RF gun shutter.

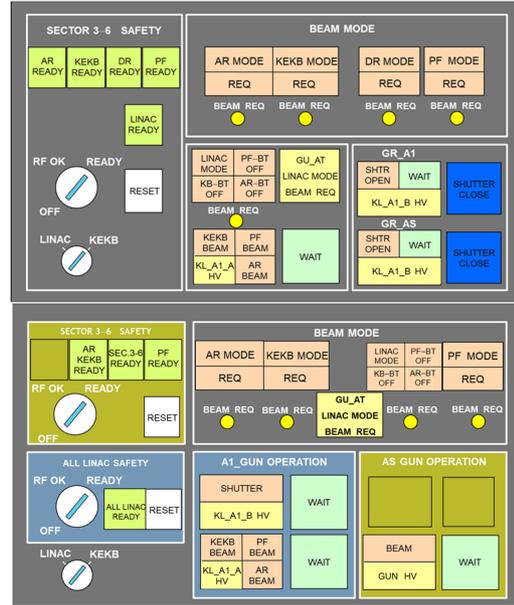


Figure 8: Image example of the modified (top) and old version (bottom) operation control panel.

DISCUSSION

The safety interlock management system must guarantee safety of both people and equipment regardless of accelerator operation and stoppage. Therefore, it is necessary to establish a reliable and efficient test method after updating. It is difficult to consider the test environment and influences on various aspects, and we are still searching for appropriate and efficient method.

SUMMARY

We removed part of the shield wall and its door in the tunnel together with related equipment such as, the personal key system for the downstream part. Interlock signal lines for the DR and RF guns were added. The operation panel of the main console was modified accordingly. In addition, the screen displays of the interlock status was updated. This was in conjunction with the introduction of the 1.1 GeV positron DR for Phase II operation of SuperKEKB and successful development of new electron RF guns in the upstream part of the Linac.

This system is currently stable in SuperKEKB Phase II project. We plan to further improve the system with high operability and accuracy in the future. The updated safety interlock system will contribute greatly to the stable beam operation in the SuperKEKB injector Linac.

ACKNOWLEDGMENT

Authors would like to acknowledge K. Hisazumi and H. Kumano for their collaboration to establish safety interlock architecture for Linac reconsolidation.

REFERENCES

- [1] Mitsuo Akemoto *et al.*, *Prog. Theor. Exp. Phys.* (2013) 03A002.
- [2] K. Furukawa *et al.*, “Rejuvenation of 7-GeV SuperKEKB Injector Linac”, in Proceedings of the 9th International Particle Accelerator Conference (IPAC'18), Vancouver, Canada, Apr. 29-May. 4, 2018, paper MOPMF073.
- [3] M. Satoh *et al.*, “Commissioning Status of SuperKEKB Injector Linac”, in Proceedings of the 9th International Particle Accelerator Conference (IPAC'18), Vancouver, Canada, Apr. 29-May. 4, 2018, paper MOPMF075.
- [4] A. Shirakawa *et al.*, “Upgrade of Safety Interlock System of e^+/e^- LINAC for SuperKEKB Project”, in Proceedings of the 4th International Particle Accelerator Conference, Shanghai, China, May 12-17, 2013, pp. 3161-3163.