BEAM SWITCHING AND BEAM FEEDBACK SYSTEMS AT KEKB LINAC

K. Furukawa*, A. Enomoto, N. Kamikubota, T. Kamitani, T. Matsumoto,
Y. Ogawa, S. Ohsawa, K. Oide and T. Suwada
High Energy Accelerator Research Organization (KEK)
Oho 1-1, Tsukuba, Ibaraki, 305-0801, Japan

Abstract

The KEK 8-GeV electron / 3.5-GeV positron linac has been operated with very different beam specifications for downstream rings, KEKB, PF and PF-AR. For the reliable operation among these beam modes, intelligent beam switching and beam feedback systems have been developed and used since its commissioning.

A software panel is used to choose one of four beam modes and a switching sequence is executed in about two minutes. Most items in a sequence are simple operations followed by failure recoveries. The magnet standardization part consumes most of the time. The sequence can be easily re-arranged by accelerator operators. Linac beam modes are switched about fifty times a day using this software.

In order to stabilize the linac beam energy and orbits, as well as some accelerator equipment, about thirty software beam feedback loops have been installed. They have been routinely utilized in all beam modes, and have improved its beam quality. Since its software interfaces are standardized, it is easy to add new feedback loops simply defining monitors and actuators.

1 INTRODUCTION

The KEK electron/positron linac had been upgraded for the KEK (KEK B-factory) asymmetric electron-positron collider since 1994. Commissioning of the first part of the linac started at the end of 1997 and has already achieved the designed beam parameters after its completion in 1998[1]. It has been providing beams for the B-physics experiment (Belle) of the CP-violation study at KEKB since 1999.

The performance of the experiment depends on the integrated luminosity at KEKB, which is largely dependent on the stability and intensity of the linac beams. Since the linac must provide four beam modes which are very different (KEKB e^+, KEKB e^-, PF-Ring, PF-AR), it had been realized that it was important to achieve reproducibility and stability of each of those four beam modes[2].

2 LINAC CONTROLS

The linac control system was also upgraded[3] to support the upgraded high-intensity linac based on the system rejuvenation in 1993[4]. It consisted of layered components that communicate with each other, where hardware and lower-layer information were hidden from the upper layer and only useful features are exposed to the upper layers. New components were added to accommodate new accelerator equipment and features for the KEKB injection. Especially, software for beam position-monitors was developed and the database for equipment and beam lines was much enriched.

In the commissioning, many pieces of application software were developed as clients to the control system. Many of them were designed with a user interface on X-Window employing SAD-Tk or tcl/tk scripting languages for rapid development and simple manipulation. They use common library routines to facilitate maintenance as well as development. The number of application programs exceed 100, including those for beam studies.

3 COMMISSIONING

In commissioning of the upgraded linac, the quality of beams had gradually improved as the beam study advanced, and the design values were achieved for the short term. It was, however, realized that much effort was required to reproduce the quality and to maintain it for a longer period.

One of the main reasons was switching between four quite different beam modes. The other was short-term instabilities and long-term drifts of the equipment parameters[2].

In order to cure these, the software for beam-mode switching and feedback loops has been refined, while they had been developed since the beginning of the commissioning.

4 SOFTWARE

The software has been developed with the tcl/tk scripting language under the same environment as other application software[3].

4.1 Beam Mode Switch

In linac beam mode switching, as described above, it is important to select the operation conditions and parameters of the accelerator equipment reliably, and to achieve reproducible beam qualities. In order to meet this purpose, the software was developed to be easily re-arranged, and it currently has the following switching items:

- Suspension of beam feedback loops and other subsystems.

* e-mail: <kazuro.furukawa@kek.jp>

- De-gauss of a bending magnet (only for PF injection)
- Simple standardization of magnets.
- Selection of a gun, magnets, and rf systems.
- Parameters for magnets (mostly magnetic fields).
- Parameters for rf systems (mostly phases).
- Parameters for timing systems.
- Parameters for guns.
- Operation on positron targets and chicane.
- Operation mode of beam instrumentations and their dynamic ranges.
- Initial beam profile monitor selection.
- Initial beam repetition rate.
- Selection of beam transport lines.
- Information to downstream ring control systems.
- Review of equipment parameters.
- Display and record of equipment status and parameter differences.
- Resumption of corresponding beam feedback loops.
- Information to operators via a speech processor.

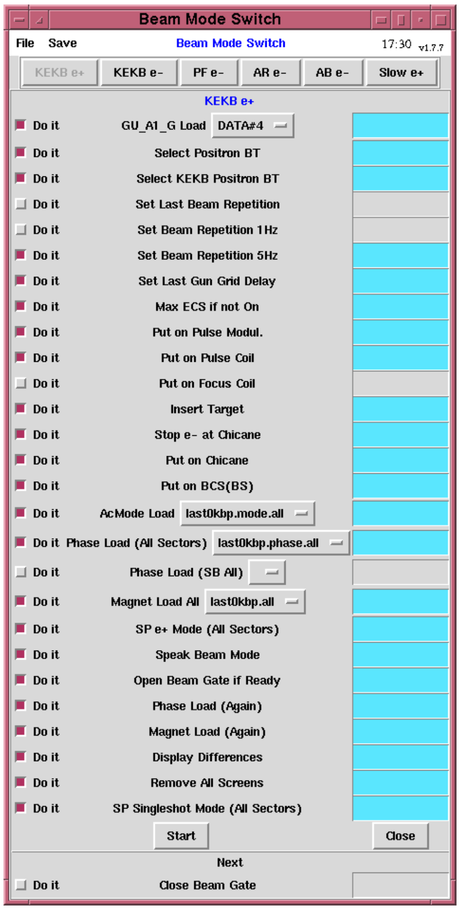

Figure 1: An example of the linac beam mode switch panel. In this example, KEKB e^+ injection was selected. The check-buttons on the left are used to select items to go through. Pull-down-menus are used to choose parameter files. The boxes on the right show the execution status.

Items related to the radiation safety are not included, and are handled by a separate safety-interlock system.

Fig. 1 shows an example of the software panel. Each item on the panel can be enabled or disabled by any operator, and its status can be saved or restored. New items can be introduced by adding entries to the database. If some problems occur, which cannot be removed through the control system, that event is reported to the operator, who may retry it after the problem has been removed.

The items listed as 'Parameters' are normally taken from the equipment parameters when the last time the same beam mode was used, while other parameter sets can be chosen from the menu if a operator needs one.

For the initialization of the magnets following issues are repeatedly tested: reproducibility of magnetic fields, tolerance of the power supplies to the steep current changes and failure recoveries in control and application software. Since this part consumes most of the time in the switch, it is still being improved.

4.2 *Beam Feedback Loops*

Software feedback loops installed in the linac are categorized into three groups: stabilization for equipment parameters, the beam energy and the beam orbit. Their basic software structure is the same and is built of following parts:

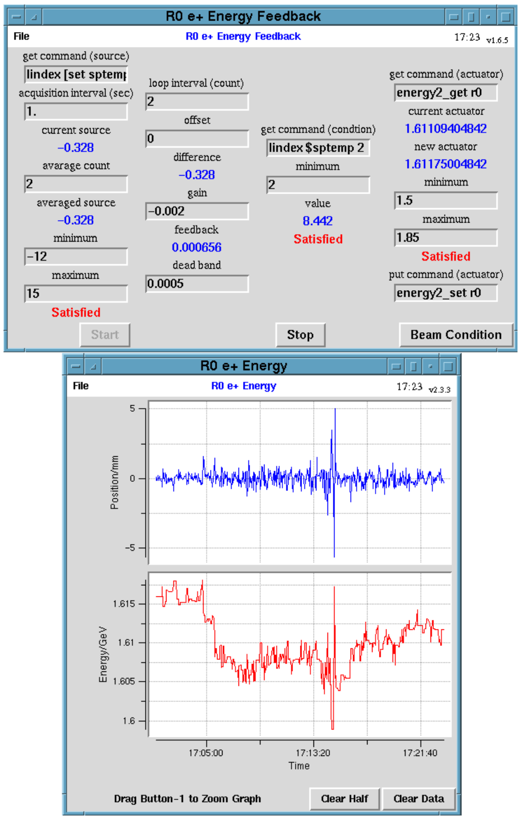

Figure 2: Energy feedback panel at the R sector as an example. The parameters and processing specifications can be modified anytime.

- Check the conditions of beam modes, beam current, parameter limit, etc.
- Read the monitor value applying moving average, limit check and other specific post-processing.
- Derive the feedback amount applying conversion factors, gain and limit check.
- Set the actuator value applying limit check and other specific pre-processing.
- Flow control, graphics display, recording and interface to other software.

Fig. 2 shows an example panel for one of the energy feedback loops. Each parameter in the panel can be modified at any time.

Energy feedback loops are composed of a monitor of a beam position at a large dispersion and an actuator of rf phases at two adjacent klystron stations, in order to maintain a small energy spread. This type of energy feedback is installed at 4 locations at 180-degree arc and the end of the linac. Some parameters are different, depending on the beam modes[5].

Orbit feedback loops use beam positions as monitor values and steering magnets as actuators. A monitor value is actually a weighed average of beam position monitors (BPM's) over a betatron wavelength according to the response function for the corresponding steering magnet. Normally, two subsequent regions, which are apart by 90-degree betatron phase, are grouped as in Fig. 3. Some feedback loops read only one BPM, and are used to maintain the beam position at the end of the linac.

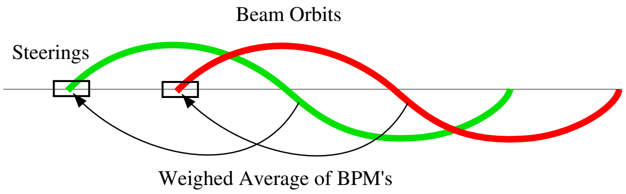

Figure 3: Group of orbit feedback loops. The weighed average of BPM's over a betatron wavelength as a response function is fed into a steering magnet strength.

This type of orbit feedback loop is installed at many sectors, and the current number of groups has reached 15.

Since BPM's can be read at 1 Hz, most of the beam feedback loops are operated at this speed[6]. The feedback gains are chosen to be small, 0.2 to 0.5, in order to avoid oscillation.

The same feedback software has been applied to stabilize the accelerator equipment. Although these loops may be gradually moved to local controllers, or even to the hardware, they are effective to suppress newly found instabilities in the accelerator equipment. Recently, it was applied to suppress a long-term drift of the trigger timing of the electron gun, and were found to be effective[7].

New feedback loops can be easily built simply by defining monitors, actuators and some parameters. Standard software libraries provide an environment to tune those new loops, even during operation.

In order to manage a large number of feedback loops, several software panels were developed, such as a global feedback status display and a feedback history viewer.

5 CONCLUSIONS

Software was developed to stabilize the linac beam, and successfully improved the beam reproducibility and reliability. Since it was designed to be re-arranged easily, operators could solve problems by modifying the software parameters, even when a beam operation mode had to be modified.

The beam-mode switching panel has become very reliable, and has reproduced beams sufficiently with switching more than 50 times a day. The switching time, which is important for the integrated luminosity, was shorten to be 90 to 120 seconds.

Feedback loops cured both the short-term instabilities and long-term drifts of the beam energy, orbits and equipment parameters. Depending on the accelerator status, they suppressed the beam instability to one half and drifts to one fifth without any operator manipulations. It was also useful to keep beams when beam studies were carried under unusual beam conditions and to find some anomalies in the accelerator.

Those software systems were used in routine operation and contributed to enhance the KEKB experiment efficiency.

6 REFERENCES

[1] A. Enomoto *et al.*, "Performance of the KEK 8-GeV Electron Linac", Proc. EPAC2000, Vienna, Austria, to be published.

[2] K. Furukawa *et al.*, "Towards Reliable Acceleration of High-Energy and High-Intensity Electron Beams", these proceedings.

[3] K. Furukawa *et al.*, "Accelerator Controls in KEKB Linac Commissioning", Proc. ICALEPCS'99, Trieste, Italy, 1999, p.98.

[4] K. Furukawa *et al.*, "Upgrade Plan for the Control System of the KEK e^-/e^+ Linac", Proc. ICALEPCS'91, Tsukuba, Japan, 1991, p.89.

[5] K. Furukawa *et al.*, "Energy Feedback Systems at KEKB Injector Linac", Proc. ICALEPCS'99, Trieste, Italy, 1999, p.248.

[6] N. Kamikubota *et al.*, "Data Acquisition of Beam-Position Monitors for the KEKB Injector-Linac", Proc. ICALEPCS'99, Trieste, Italy, 1999, p.217.
T. Suwada *et al.*, "New Data-Acquisition System of Beam-Position and Wall-Current Monitors for the KEKB", Proc. APAC'98, Tsukuba, Japan, 1998, p.531.

[7] S. Ohsawa *et al.*, "Pre-injector of the KEKB Linac", Proc. EPAC2000, Vienna, Austria, to be published.