3 PF-AR

3-1 Operation Summary

The KEK B factory (KEKB), which shares the beam transport (BT) line with PF-AR, was shut down on June 30, 2010 and the upgrade toward the Super KEKB will continue until FY2014. At the same time as the KEKB's upgrade, we are going to increase the injection energy of PF-AR from 3 GeV to 4 GeV in order to enable the simultaneous injection with KEKB and PF ring. By installing a pulsed bending magnet in the middle of the BT line of the low energy ring (LER), the 4-GeV positron beam will be selectively kicked out for the PF-AR injection. The reconstruction of the AR BT line will be accomplished by the commissioning of the Super KEKB.

The history of the total operation time is shown in Fig. 1. The operation of PF-AR was scheduled to be matched with the KEKB operation before, but after the shutdown of KEKB, the start of operation of PF-AR will inevitably be delayed by several days after starting the PF ring. As a result, the total operation time of FY2010 was slightly decreased compared with the previous two years. The operation statistics of PF-AR during the last six years are summarized in Table 1. As the machine time used for the accelerator development was reduced to every two weeks from FY2008, the user time was much longer than that of FY2007 of the comparable total operation time.

The mean time between failures (MTBF) was estimated as the quotient of the scheduled user time divided by the total number of failures. Any troubles which interrupted the user time by the beam dump or by closing the beam shutter of all SR beamlines were taken into account as failures. The down time included recovering from failures, re-injection and the whole time until the beam shutter is reopened for users.

The MTBF of FY2010 decreased to about half of the previous year, though the ratio of total down time to the scheduled user time was slightly improved. The mean down time (MDT) of FY2009 was worse mainly because vacuum leaks of the beam duct occurred twice in a year.

The sources of failures are classified in Table 2. As in usual years, the most frequent failure in FY2010 was a sudden drop of beam lifetime attributed to the dust-trapping phenomenon. The frequency of dust trapping tended to decrease, but remained a main source of interruption of user time. The second-most frequent failure was the safety interlock of the SR beamlines. Most of the troubles were caused by malfunctions of the cooling-water flow meters installed in the summer maintenance. The procedure for checking the quality of the flow meters before installation has been improved and this problem has been resolved.

There was a noticeable increase in failures in the magnet power supply in FY2010. Most troubles occurred in series during the autumn and winter operations after the KEKB was shut down.

At the beginning of the autumn operation, there was a failure in accelerating from the injection energy to the stored energy. This was the first acceleration failure to occur since the new bending magnet power supply was installed in FY2006. Though the true cause of the acceleration failure is not yet clear, the only way of recovering the normal acceleration was to switch off and reset all power supplies including the bending and quadrupole magnets in the proper order. In order to investigate the precise synchronization of the power supplies during the acceleration, a fast data logger which can record the transient magnet current has been installed.

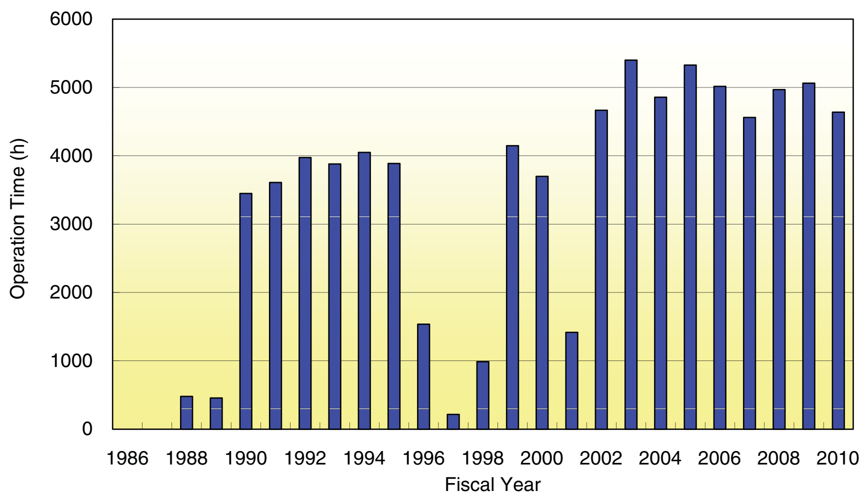

Figure 1
Operation time as a function of fiscal year.

Table 1
Mean time between failures (MTBF) of PF-AR during FY2005 – FY2010.

Fiscal year	2005	2006	2007	2008	2009	2010
Total operation time (h)	5313	5016	4561	4969	5063	4608
Scheduled user time (h)	4456	4032	3624	4344	4392	4032
Number of failures	79	51	60	40	41	74
Total down time (h)	69.3	55.1	45.2	41.7	91.0	73.7
Ratio of total down time (%)	1.6	1.4	1.2	1.0	2.1	1.8
MTBF (h)	56.4	79.1	60.4	108.6	107.1	54.5
Mean down time (h)	0.9	1.1	0.8	1.0	2.2	1.0

Table 2
Classification of failures based on the source of trouble.

Fiscal Year	2005	2006	2007	2008	2009	2010
RF	12	10	1	4	8	10
Magnet	4	1	1	2	2	10
Injection	4	3	8	9	1	6
Vacuum	2	6	2	0	2	1
Dust trap	37	24	39	15	16	24
Insertion devices	0	1	0	0	0	0
Control/ monitor	4	0	1	1	1	2
Cooling water	5	1	0	3	4	4
Safety/ beamline	9	4	5	5	7	17
Earthquake	2	0	1	0	0	0
Electricity	0	1	2	1	0	0
Total	79	51	60	40	41	74

One of the largest quadrupole power supplies, QF, dumped the beam several times due to a direct current ground interlock in November. The QF is a new power supply installed in FY2009. The insulation of the rubber hose for the cooling water deteriorated and the leakage current exceeded the threshold.

Fluctuations and errors in the sextupole power supplies occurred at the end of January, and continued for a month, affecting the stability of the stored beam. At the beginning of March, external interference from the abnormally oscillated power amplifier for the bunch feedback system was found and identified as the cause of the sextupole troubles. Two of the four sextupole power supplies had large errors and fluctuations caused by the external interference.

In October, there was a beam dump caused by a vacuum pressure interlock at the in-vacuum undulator, ID-NW2. The vacuum pressure rose suddenly while closing the gap of the magnetic arrays. The cause of this trouble was found to be orbit distortion of over 2 mm due to errors in the signal transmission of the beam position monitor (BPM) system.

Following renewal of the bending magnet power supply in FY2006, the two main quadrupole magnet power supplies, QF and QD, were renewed by FY2010. There are another 26-aged quadrupole supplies operating in PF-AR and most of the other magnet power supplies for sextupole and octupole are also older than 25 years. Some failures of the old beam instrumentation system caused troubles in the magnet power supply and vacuum. We are preparing to replace the coaxial cables of the BPM and renew the signal processing system for the COD measurement. Constant maintenance and renewal of aged accelerator components are important for maintaining stable operation of PF-AR.

3-2 Update of QD2 Magnet Power Supply

In the spring of 2011, we exchanged the QD2 power supply. The updated QD2 is shown in Fig. 2.

Until 2000, the QD power supply was connected to 16 defocusing quadrupole magnets in series. In order to install a new X-ray beamline from an undulator, two specially designed quadrupole magnets were required. As two defocusing quadrupole magnets were abandoned, the load on the QD power supply reduced to 14 magnets. The new system, which is connected to two special magnets, is called QD2. As a temporary measure due to severe budget restrictions, an old spare power supply was adopted. We have now successfully updated the QD2 power supply which was fabricated as a dedicated power supply.

The principal circuit consists of a thyristor pre-regulator and a transistor regulator. The resistance and inductance of the load are 21 mΩ and 12 mH, respectively. The maximum current and voltage are 1340 A and 30 V, respectively. The current stability is about 10 ppm in 8 hours, and the current ripple is about 1 ppm.

The design is based on the KEKB magnet power supply design philosophy. In the current regulation controller, the output current is measured by a high-precision DCCT and compared with a reference current. The reference source is a 16-bit DAC with 9.5 V DC full-scale. The purpose is to compensate the long-term variation of circuit elements up to 10 V. The calibration constant is stored in PROM on a board. The load resistor of the DCCT, the DAC and the current-error amplifier are built in a box with a temperature-regulated environment. The temperature regulation is accomplished by

Figure 2
QD2 magnet power supply.

cooling the inside with a Peltier device or heating the inside. The temperature is maintained within ±0.5°C at 25°C. The differential voltage between the DAC and DCCT is sent to the transistor bank in order to stabilize the output current.

The interface board communicates with the central computers via ARCNET. The current pattern of acceleration, which is a collection of 16-bit digital data, is remotely set in a RAM from the central computers. In the acceleration, the data in the RAM is counted up according to the internal clock in the board, and the output of the DAC is used as a reference current of the power supply. The status and fault-status signals are sent to an IOC module in a VME crate, which is connected to the computer system which uses EPICS.

Many old quadrupole power supplies are still in operation, which we plan to update in the future.

3-3 Renewal of the ID Control System at the PF-AR

The insertion device (ID) control system for the PF-AR is based on EPICS with an input-output controller (IOC). At first, only one VME-based IOC controlled all six IDs for five beamlines. With this system, when a control trouble which requires rebooting of the IOC occurs in one of the six IDs, the other beamlines cannot use their IDs during the troubleshooting. To solve this problem, we are now replacing this VME-based hard IOC with six soft IOCs assigned individual IDs.

Figure 3 shows the previous system using one hard IOC with VME on VxWorks. The IOC controls six IDs running in parallel. Each local ID control system consists of an ID controller, four power supplies for end correction magnets and a temperature monitor (only an ID controller is drawn) connected via GPIB. The LAN/GPIB connects the local ID control system to the KEKB network. The KEKB network is separated by the router from the user local network at every ID beamline. Each ID beamline user can access the ID server through the router from the registered PC on their local network. The ID server checks which beamline the command comes from and accesses the proper process variable to execute the command.

Figure 4 shows the target system based on soft IOCs. Instead of one hard IOC, there are soft IOCs running in PC rack servers on linux for each beamline. Each ID server runs on the same respective PC.

Renewal of the ID control system has now almost finished: five of the six IDs are controlled by their dedicated soft IOC, but the hard IOC still remains and is used for the last ID (ID-NW12). Replacement of the last ID-NW12 by soft IOC will be completed by the summer of 2011.

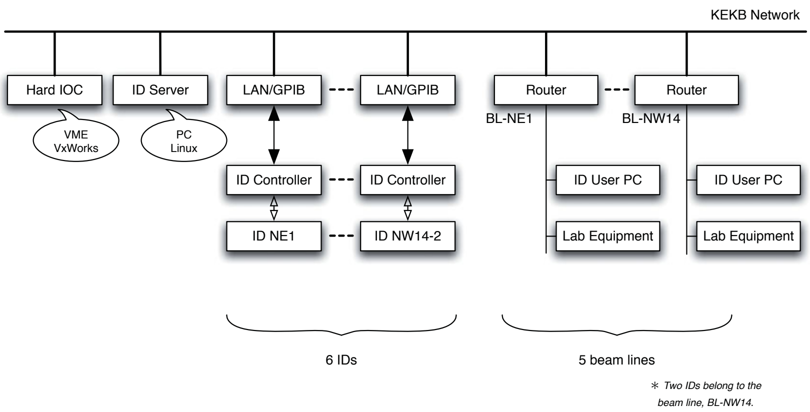

Figure 3
The previous ID control system using one hard IOC with VME on VxWorks.

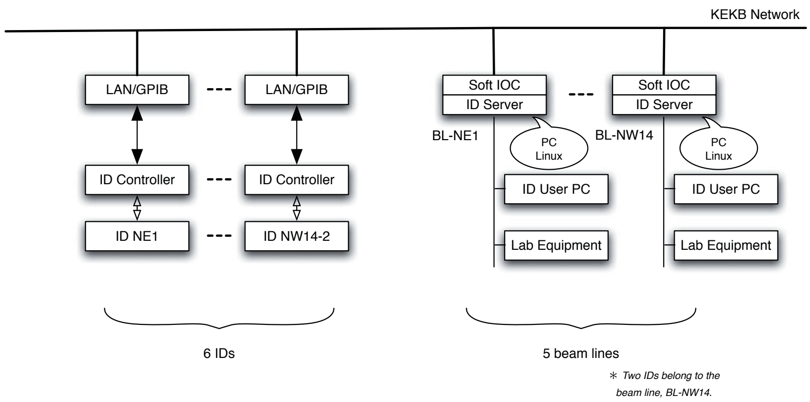

Figure 4
Schematic view of the new ID control system based on soft IOCs.