RF MONITORING SYSTEM IN THE INJECTOR LINAC

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Abstract

A new microwave monitor system has been installed as part of the upgrade of the 8.0-GeV KEKB injector Linac. Thirty monitor stations constantly monitor the waveforms, peak-power levels, and phases of 59 high-power RF sources.

The monitor stations, based on VXI, make it possible to measure pulse-to-pulse events. Data obtained by monitor stations is accumulated and presented along with beam position monitor data to the operator for beam adjustment. Beam diagnosis can also be performed.

1 INTRODUCTION

The KEK electron/positron linac was upgraded to increase its energy from 2.5 GeV to 8 GeV for the KEKB project. A SLED, which is an RF pulse-compression device, and a 50-MW klystron were added to increase available linac RF power. As a consequence, the beam-energy gain would be susceptible to errors of RF-phase-modulation timing or SLED-cavity tuning. However, the KEKB collider ring requires the injected beam to have low-energy dispersion to minimize injected beam loss.

We thus completely redesigned the RF-monitor system of the linac to realize stable operation of the RF system. [1]

2 THE RF MONITOR STATION

Thirty RF monitor stations were installed to constantly monitor the 59 high-power RF sources. Currently, they also monitor 8 sub-booster systems. Moreover, monitoring of the SHB (Sub-Harmonic Bunchier) will be added to the system

Figure 1 shows a simplified diagram of the RF monitor station, which consists of a VXI-based control system and RF instruments. Any monitor signal can be connected to the power sensor and phase detector through RF switches. The VXI-based control system can measure power level and phase signals that are simultaneously detected by power-sensor and phase detectors.

Furthermore, some ideas for measuring the phase of beam-induced field were introduced into the design.

2.1 VXI-based control system

The VXI-based control system, which consists of a disk-less controller, a waveform digitizer and a digital I/O, was chosen for the following advantages.

First, a high-speed measurement of pulsed-waveform is required. The monitor station must detect any pulse-to-pulse event, such as a discharge in the high-power RF circuits, or jitter in the RF pulse timing. The waveform digitizer has 1M bytes of shared memory, which can be accessed by the controller via the VXI backplane. High-speed data transfer by a shared memory protocol has achieved repetitive measurements at 25Hz.

Second, the adoption of a built-in type VXI controller has the advantage of more immunity to electro-magnetic noise interference. Reduction of noise interference was taken seriously, because the monitor station had to be installed beside the pulse modulator for the high-power klystron.

2.2 Phase detector

A newly developed phase detector was installed. The phase-detection technique is based on a heterodyne method. That is, the front-end of the phase detector converts both input signals, a test signal and a reference signal, into IF signals of 180 MHz. The next-stage circuit then compares digitally both IF-signals. Finally, the phase difference is converted to a voltage signal.

The principal advantage is that the output voltage is proportional to the phase difference. However, it has a characteristic that causes inaccuracies in the detection of a phase difference at around 0 degrees. To overcome this problem, a phase shifter which can shift by 180 degrees was introduced into the reference line.

To measure a beam-induced field, the dynamic range for the input power is required to be more than 50 dB. The beam-induced RF power and the accelerating RF power are measured alternately when the klystron trigger timing is delayed. The power difference between both signals is about 50 dB. However, the original dynamic range of the detector was only 30 dB. Thus, an attenuator, which is externally controlled, was added to extend dynamic range. The attenuator control is synchronized with the beam trigger.

2.3 Power meter

A power sensor having a differential-type detector and a universal power meter was chosen. The sensor reduces any interference due to common-mode noise.

At present, the waveform digitizer measures the voltage-signal from the power sensor. Although the voltage signal output is nonlinear relative to the input power level, detection of the relative variation is possible.

2.4 RF switches

The monitor station must constantly measure any monitor signals of two RF sources. Therefore, a newly developed PIN-diode switch having 8 input-ports was installed for repetitive signal selection and measurement. The PIN-diode switch was chosen because of its durability for frequent switching operations. Incidentally, the switch is operated at about 10 seconds/cycle in the monitor station.

In addition, a mechanical RF switch having low insertion-loss is used to measure a low level beam-induced signal.

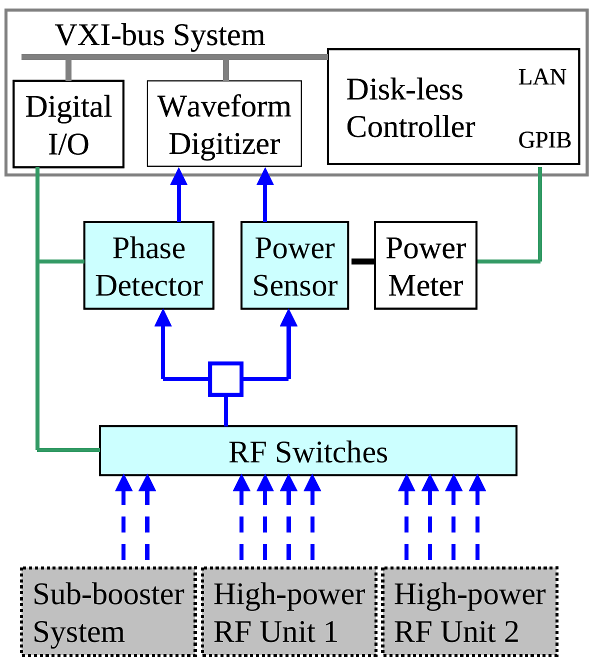

Figure 1: Construction of the RF monitor station.

3 SYSTEM ADMINISTRATION

The RF monitor system consists of 30 VXI systems and two server computers. A disk-less configuration of the VXI controller is indispensable for eliminating any system failure caused by a hard-disk crash. The cluster architecture of HP-UX was employed to achieve our server and disk-less client configuration. Currently, the NFS disk-less architecture of the HP-UX version 10.20 is operating stably.

The network for the linac control consists of a main network and several segmented device-group networks. The RF monitor system is in an RF control network, which is part of a device-group. Cluster servers and clients for the monitor system utilize some network services from the linac control system, such as NFS, DNS, NIS and NTP. Those services are useful for cluster system administration. [2]

4 APPLICATIONS FOR THE MONITOR STATION

HP VEE (Visual Engineering Environment), which is a visual programming language for instrument control, was employed for developing the application programs of the RF monitor station. It brings higher productivity, although we had expected that the execution speed would be insufficient for practical applications. However, a compile mode, which was appended to VEE version 4, improved the execution speed. As a consequence, the greater part of the application is still written in VEE. Parts of the application were written in the C language and linked to the VEE application to obtain higher throughput.

4.1 Automatic measurement

The RF monitor station normally performs an automatic measurement for any monitor signal.

The process acquires and accumulates waveform data of 200 pulses at 40-millisecond cycle. A routine for accessing the VXI shared memory is written in C language. After the routine reads 1000 words of raw data, the power level and phase are computed. Thus, the data obtained for 200 pulses is averaged to improve the accuracy. Moreover, maximum value, minimum value and standard deviation are computed. Those parameters are stored on the server's storage disk.

Raw data of the waveform for 200 pulses is temporarily maintained in the shared memory on the VXI controller. This continuous waveform data can be utilized in the future for the diagnosis of RF sources and accelerating structures.

At first, we expected that the effective resolution of the waveform digitizer might be 2%, because the digitizer has only an 8 bit A/D converter. But the effective resolution was improved by the following technique. The measurement is made at a higher sensitivity with an added DC offset. That is, the digitizer measures some expanded part of the waveform. With this technique, a phase resolution of 0.2 degree was achieved.

4.2 Remote control service

To provide remote control of the monitor stations for the linac operator, a remote-control service has been added. The service suspends automatic measurement, and permits remote control upon a request from the operator. A UDP based communication routine, which was written in C language, communicates with the remote-control program.

5 APPLICATIONS FOR LINAC OPERATION

5.1 *Remote controller similer*

The linac operator can control any monitor stations via the remote-control program without having to log-in to a remote host. The program, which is produced by VEE, communicates with each monitor station for instrument control. It can select any monitor signal, and control a waveform digitizer in a manner similer to an oscilloscope.

The program is utilized for the diagnosis and adjustment of RF sources such as SLED cavity tuning. Figure 2 shows the SLED-monitor signal.

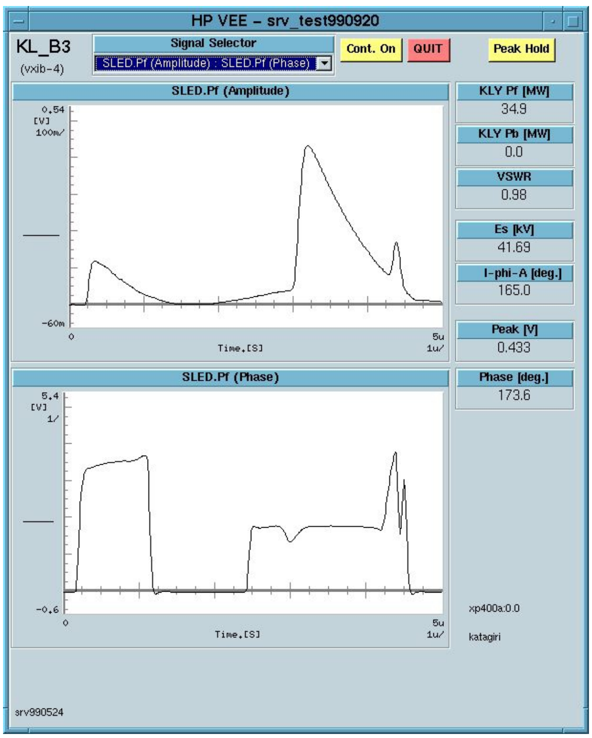

Figure 2: Remote control program.

5.2 *Data viewers*

A viewer program, which is written in Tcl/TK language, is available for searches and displays of stored data. Tcl/TK is utilized for many linac operation applications.

The RF trend program shows graphically the power level and the phase history of RF sources. Figure 3 shows the RF trend program.

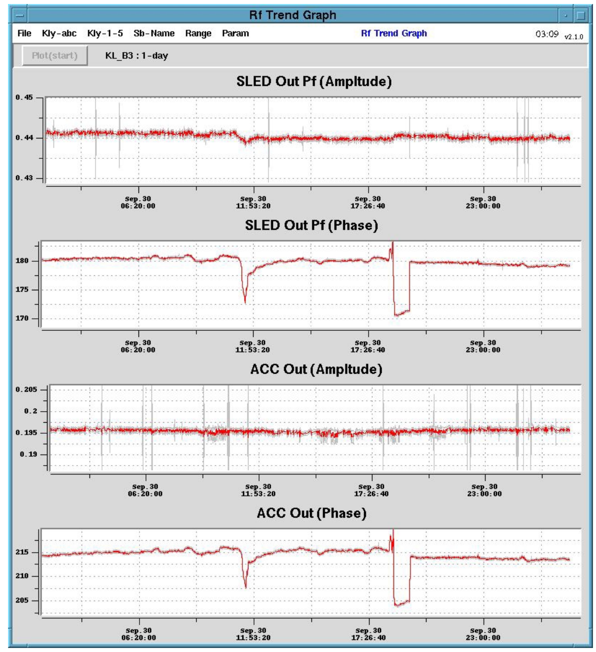

Figure 3: RF trend graph.

6 CONCLUSION

The installation of monitor stations has almost been completed. Several application programs are in routine use for linac operation. Especially, consider a phase-variation trend of the injector affects. The phase-stability of the injector directly beam stability. The phase variation trend is also helpful for reconfirming the phase setting when a beam parameter has been changed.

A phase measurement of the beam-induced field caused by single bunch beam was achieved. Thus, a phase adjustment by a beam-induced method is being studied.

7 ACKNOWLEDGMENT

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