MICROWAVE MONITOR SYSTEM FOR THE KEKB INJECTOR LINAC

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Abstract

A microwave monitor system was newly developed for maintaining stable operation of the linac. Thirty monitor stations are now being installed in order to monitor 58 high-power RF sources.

The monitor station consists of microwave-measurement equipment and a VXI system containing a diskless controller, a wave-form digitizer, etc. The controller has an Ethernet connection to servers. Most of control programs on the controller and the server have been developed by means of the visual environment VEE.

The completed stations are automatically watching and measuring the wave forms and peak power levels of high-power RF pulses. Any wave form can be selected and displayed on the servers like an oscilloscope. An additional function, automatic phase control for example, will be serviced this summer.

1 INTRODUCTION

The KEK electron/positron linac had been upgraded in order 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 employed for a reinforcement of the linac RF-power source. As a consequence, the beam-energy gain would be susceptible to errors of an RF-phase-modulation timing or the SLED-cavity tuning. However, the KEKB collider ring requires the injection beam to have low energy dispersion in order to minimize the injection beam loss.

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

2 DESIGN POLICY

We attached greater importance to detecting the relative variation of the monitor signals than to measuring the absolute values.

The 30 monitor stations were installed for constantly monitoring the 58 high-power RF sources. The monitor station must detect any momentary variation of the wave form, such as a discharge in the high-power RF circuits, or jitters in the RF pulse timing. Therefore, the VXI system was chosen in order to achieve high-speed data transfer between a computer and a measurement instrument.

In our case, the RF monitor system comprises a few server computers and 30 client VXI controllers. A diskless configuration of the VXI controller is indispensable for eliminating any system failure caused by a hard-disk crash, and saving labor for file-system management. Thus, a cluster architecture by HP-UX was adopted for our server-and-diskless-clients construction.

3 CONSTRUCTION OF THE RF MONITOR STATION

Figure 1 shows a simplified diagram of the RF monitor station, which comprises a VXI system and RF instruments. Each station monitors two high-power RF sources. The VXI system comprises a diskless controller, a wave-form digitizer and a digital I/O module. An A/D converter will be added to the system for measuring monitor signals converted to DC.

The wave-form digitizer has 1M bytes of shared memory, which can be accessed by the controller via a VXI backplane for high-speed data transfer to the controller. The resolution of wave-form digitizer is only 8 bits. This means that the effective resolution might be 2%. However, a measurement with a DC offset and at a lower range gives a resolution better than 0.1% or so.

The controller operates the following RF instruments via the VXI digital I/O module or the built-in GP-IB.

3.1 Peak-power meter

The power meter and the peak-power sensor, made by Giga-tronics, were chosen by reason of the following two advantages:

First, the peak-power sensor has a differential-type detector, which reduces any interference due to common-mode noise. Second, the power meter also has an oscillator for calibrating the power sensor. The system can thus execute automatic calibration by feeding the calibration signal to the sensor via an RF switch.

The peak-power sensor measures the power level at the desired timing, which is determined by an external trigger pulse with an internal variable delay. The VXI controller reads the measured power level via GP-IB, while the detected envelope of an RF pulse is digitized and measured by the VXI wave-form digitizer.

3.2 Phase detector

As mentioned before, the monitor station will be equipped with a phase detector, and will perform automatic phase adjustment (phasing) of high-power RF sources. The principle of phasing is summarized as follows:

The phase detector measures the phase of RF signals monitored at the output port of the accelerator guide. The beam bunch passing through the accelerator guide induces microwaves in it. The phase of the induced wave and of the accelerating microwaves can be measured when the klystron RF timing is delayed in order to separate both microwaves. Then, a phase shifter of the high-power klystron is adjusted so that the accelerating RF phase is set to be 180 degrees apart from the induced wave phase.

The phase-detection technique is based on the heterodyne method. That is, a front-end part of the phase detector converts both input signals, a test signal and a reference signal into IF signals of 100 - 200 MHz. The next-stage circuits then compare both IF signals and converts the phase difference proportionally to a voltage signal.

3.3 RF switches

The monitor station is equipped with a solid-state switch and a mechanical switch in order to measure some RF signals of two high-power RF sources.

A solid-state switch was adopted for frequent measurements, because it has a higher switching speed and long lifetime independent of the number of switchings. It, however, has the following disadvantage compared with a mechanical switch. First, it has a higher insertion loss. Besides, the nonlinearity of the insertion loss distorts the RF output signal when the input power exceeds a certain level. Second, the amplitude and phase of the output RF signal depend on its temperature. After those factors were seriously taken into account, a PIN diode made by HP was selected.

On the other hand, a mechanical switch is employed for measuring the faint beam-induced signal accurately, and feeding the calibration signal to a peak-power sensor, because it has the advantage of low insertion loss. However, a phase adjustment or the sensor calibration is performed only once a week at most. Therefore, a short switching lifetime of the mechanical switch will not be a problem.

3.4 VSWR meter

A VSWR meter was installed in every high-power RF source in order to protect the klystron from reflected RF power. It monitors the forward-going power level and the reflected power level, and then computes the VSWR constantly. When the VSWR exceeds a limit level, an alarm signal is detected by a safety-interlock circuit of the modulator.

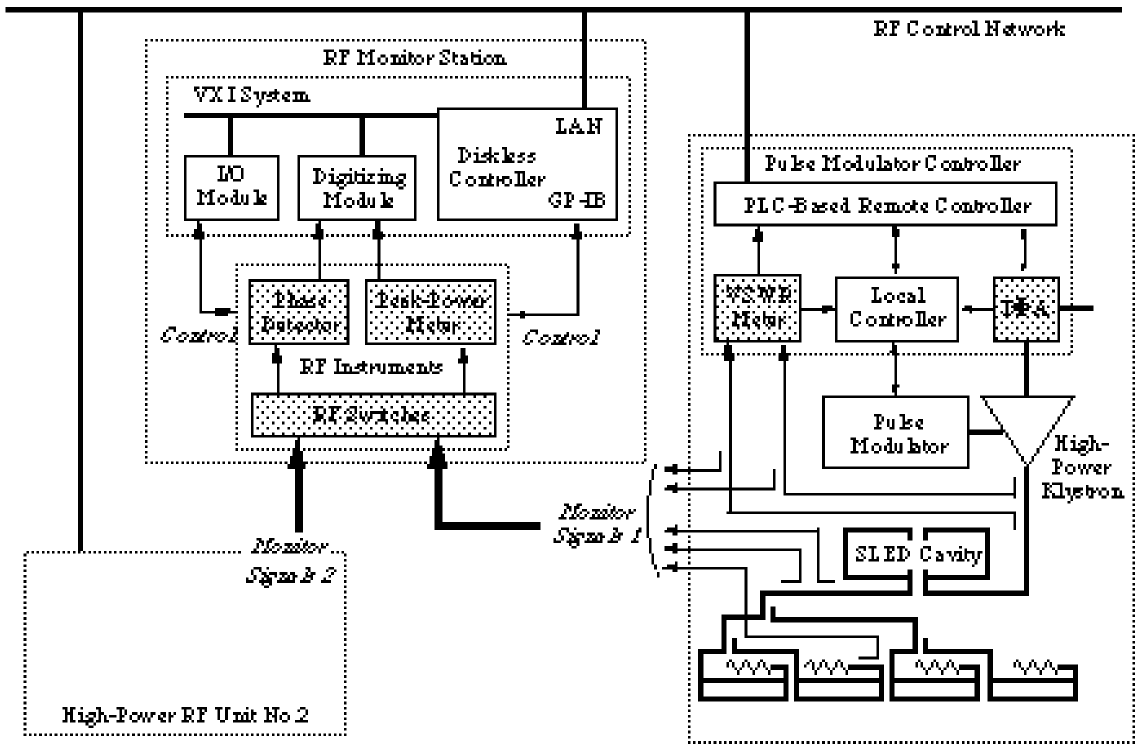

Figure 1 Diagram of the RF monitor station

4 RF CONTROL NETWORK

The computer-network system of the KEKB injector linac comprises a main network and several segmented device-group networks as presented in Figure 2. The network form is based on a star-like topology in order to ease any trouble-shooting. The reasons for adopting the separated device-group networks were to localize any problems and to ease traffic. An optical Ethernet is employed for the device-group networks in order to reduce any noise interference caused by the high-power klystron modulators.[2]

An RF control network, which is one of the device-group networks, handles the VXI systems, server computers, and PLC-based modulator controllers.[3] The server computers provide some services, such as NFS, BOOTP and TFTP for the client VXI controllers. Currently, two server computers manage 29 diskless VXI controllers. Besides, we are planning to prepare another server computer for backup.

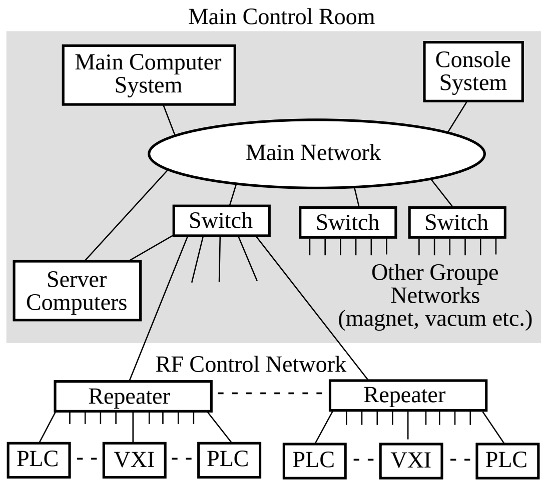

Figure 2 Network construction

5 CONTROL PROGRAMS FOR THE RF MONITOR SYSTEM

HP VEE (Visual Engineering Environment), which is a visual programming language for instrument control, was employed for developing the application programs for the RF monitor system.

The RF monitor system is controlled by a combination of an instrument control program on each VXI controller and a total management program on the server computers.

5-1 Instrument control program

The instrument control program has the following functions:

1) Automatic measurement
This is a routine task on the VXI controllers. Currently, it measures the peak-power level, pulse height, pulse width, etc. of the RF monitor signals; a phase measurement will be added. The measured data will be stored periodically, so that any long-term variation of the data can be displayed as a trend graph. Moreover, raw data of the wave form are stored when a momentary variation is detected. The raw data will be utilized for wave-form diagnosis in the future.

2) Instrument remote-control service
When the instrument control program accepts a remote-control request from the servers, this program suspends any automatic measurement, and permits the server to control the instruments.

3) Further functions
The phase adjustment and peak-power sensor calibration will also be performed when the program accepts a request from the server this summer.

Thus, the VXI controller performs automatic measurements as a routine task, and must simultaneously accept any request, such as instrument control, phase adjustment and sensor calibration from the server computers.

Incidentally, X Window achieves a remote control of the monitor station. However, the instrument control by X Window will conflict with the automatic measurement, because both processes run independently. That is, compatibility between both the processes is required.

First, the VEE's communication routine based on TCP was tried, but could not satisfy the required throughput. Finally, optimized UDP communication routines, which can be called by the VEE application, were newly written in C language.

5-2 Management program

The management program on the servers has the following functions as the linac operator's interface:

1) Instrument control panel
It can select any monitor signal, and control a wave-form digitizer like an oscilloscope. The raw data of the wave form is traced at about a 100 ms interval. Figure 3 shows the traced SLED-monitor signal.

2) Display logged data
It reads the measured data from a storage disk, and displays them as a trend graph.

A phase-adjustment control and a sensor-calibration control are to be added this summer.

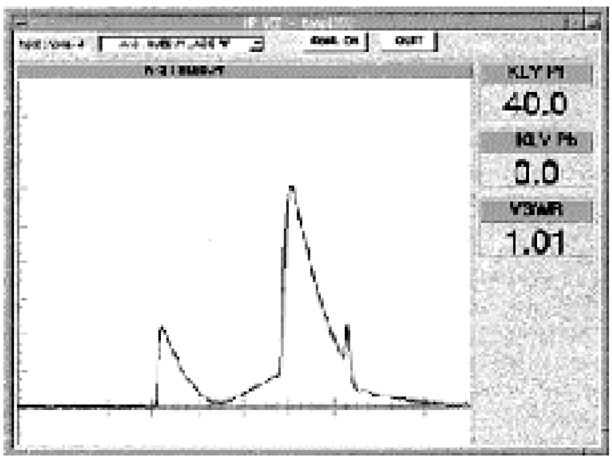

Figure 3 Example of instrument control panel

6 REFERENCES

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[2] K. Furukawa, et al., "Microwave Control and Measurement System at the KEKB Linac", Proceedings of the International Conference on Accelerator and Large Experimental Physics Control System '97, IHEP, Beijing, China, 1997.

[3] H. Hanaki, et al., "Low-Power RF Systems for KEKB Injector Linac", in this proceedings.