THE NEUTRINO BEAM LINE CONTROL SYSTEM

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Abstract

The control system of the beam line for the long-baseline neutrino-oscillation experiment at KEK is reported. The fast-extracted beam from the KEK 12-GeV proton synchrotron (KEK PS) is transferred through a 400m long beam line which consists of 104 magnet power supplies, including a 2.5MW magnet power supply and two 250kA pulse power supplies for magnetic horns. The control system for these magnet power supplies is PC-based, and uses LAN, GP-IB, POD (programmable operation display with touch panel). The lower level device controllers are designed to reduce the load of the system-controller PC. When the device controller receives a message to set the output current, it performs: sequential check interlock, set polarity, turn on main transformer, then set a smooth output current, and watch the condition. For the 250kA pulse power supply, the controller performs not only the ordinary function of the magnet power supply, but also timing control of the high-voltage capacitor charging unit and the triggering unit to synchronize with the KEK PS. The condition of the magnet power supplies is available to monitor through the Web browser. The run started January 1999. The initial problems or fixed are also reported.

1 INTRODUCTION

Figure 1 shows the neutrino beam line. The north counter hall is a physics experimental area. There is a primary beam line, EP1, which transfers the proton beam to the neutrino beam line and a parasitic beam line, EP1-B, and two secondary beam lines, K5 and K6. The neutrino beam line is 250m long, and transfers protons to a target embedded in the 250kA pulse current magnetic horn (horn-1). Horn-1 and a following horn (horn-2) focus the pion particles produced by the target, and transfer them to the next section decay volume tunnel.

Table 1 gives the number of magnets and power supplies equipped in the north experimental area. Table 2 lists special power supplies for the neutrino beam line. Those power supplies are installed in three sites: the north hall, power station 1, and power station 2. Each site is far from the control room of the north hall. It then decreases the efficiency of the check-up and maintenance work of the power supplies, the magnets, and the control system.

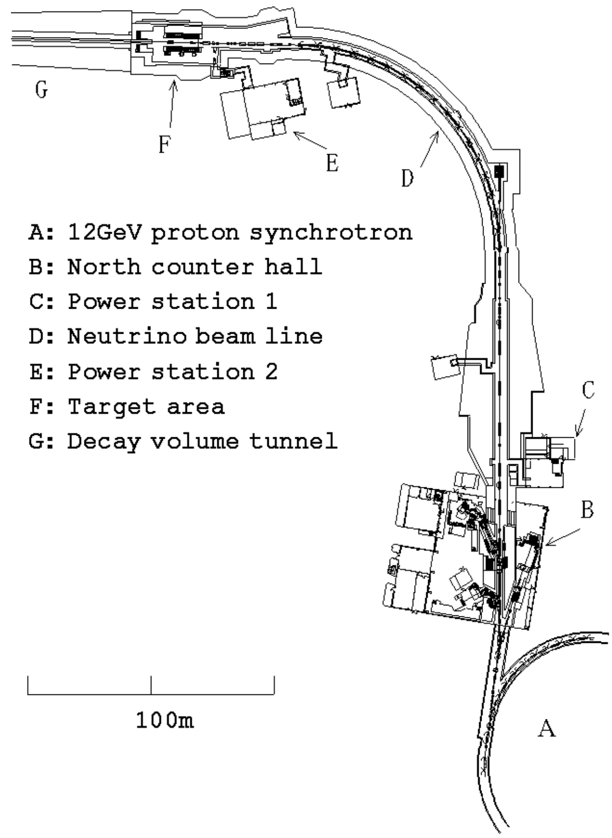

Figure 1: 12GeV-PS, North counter hall, and neutrino beam line

Line	Magnet	Power supply	Location
EP1	29	29	North hall
EP1-B	13	14	North hall
Neutrino 1	34	23	Power station-1
Neutrino 2	49	40	Power station-2

Table 1: Equipped magnets and power supplies

Arc section 17 magnets	2.5MW DC	1 set
17 collection coils	90A, 40V dc /GPIB	17
Horn 1 / Horn 2	250kA 2msec,half-sin	2

Table 2: Special power supplies

Therefore, the control system must provide not only an operation interface for the operator, but also effective support to the check-up and maintenance work on both periods of the construction and the following usual run. Then, to control the neutrino beam line, two types of power supply controllers were developed. One (PSCx8) was for eight magnet power supplies of the ordinal type. The other (HMPSC) was for the pulse power supply of the 250kA magnetic horn. The features of the controllers are given below:

1. The operation and check procedures of the magnet power supply are programmed in those controllers (PSCx8 and HMPSC).
2. It reduces the load of the system (beam line) controller PC.
3. The HMPSC not only has the ordinary control function for power supplies, but also timing control to synchronize with the fast-extraction beam.
4. Those controllers could easily control the power supplies by PC and an interpretive language (e.g. BASIC or visual language HP-VEE). It was effective in the construction stage of the neutrino beam line. It saved time and labor of the check-up work and test operation of the equipment, magnets and power supplies at the local sites.

2 SYSTEM CONFIGURATION

Figure 2 shows the configuration of the control system. Table 3 shows the equipped devices and those for storage. In consideration of less maintenance work, those devices are selected. The magnet power supplies are installed at three sites. At each site, the magnet power supplies are divided into groups of eight. The eight magnet power supplies are connected to one PSCx8 with short standardized cables. Those PSCx8s and a Windows PC system controller are connected through GP-IB extenders and coaxial cables At the initial design of this part, the connection between the PC and PSCx8s was expected to use LAN, and had been tested. But at the final stage of the construction, it was changed to a direct connection through coaxial cables to increase the reliability.

PC	System controller	Windows NT/Hard disc
POD	Human interface	Flash memory
PSCx8	Eight Power supplies controller	ROM-base
HMPSC	Horn Power supply controller	ROM-base
TCS-7146	LAN/RS-232C converter	Flash memory
HP-E2050	GP-IB extender	Hard logic

Table 3: Devises and their storage

For operation, POD (programmable operation display) was introduced into this control system. The main purpose of the manufactured POD was to be used with PLC (programmable logic controller) in a production line. The POD has a colored display; touch switches on the display, and a serial interface (RS 232c). Four PODs are equipped. One in the control room is directly connected to the PC. Others are connected with RS 232c/LAN converters.

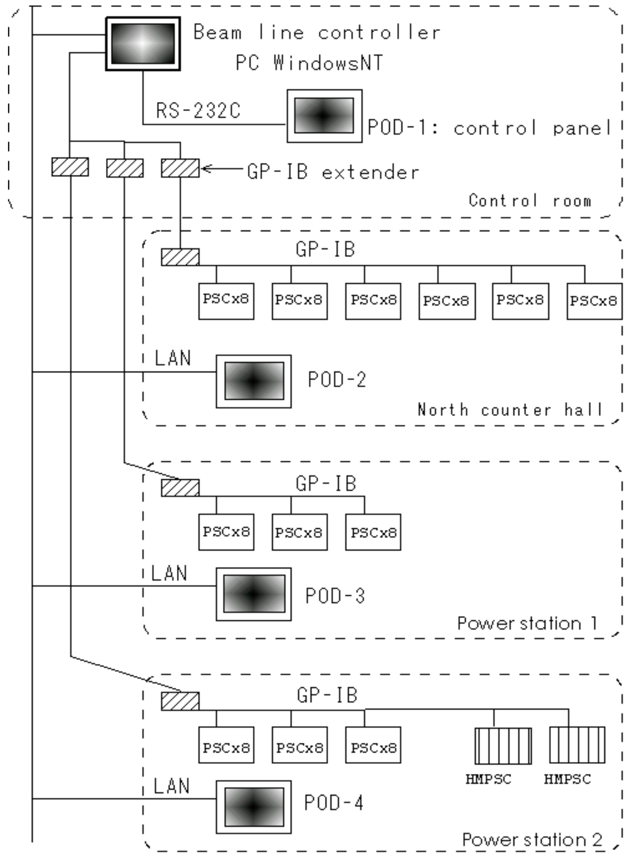

Figure 2: Configuration of control system

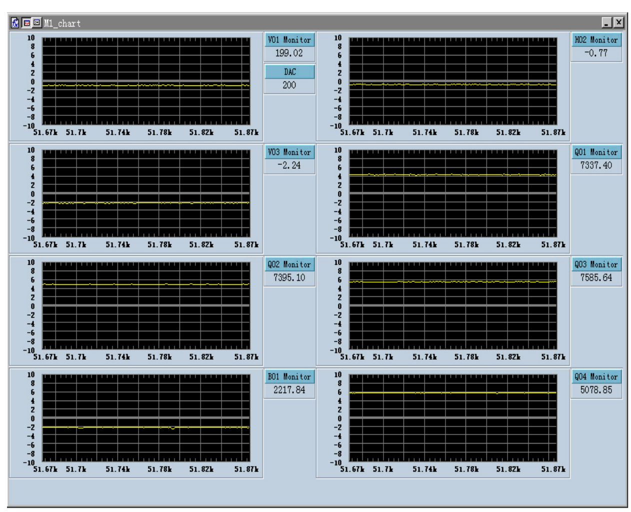

Figure 3: a Web page shows current stability

The POD offers sixteen programmed screens to operate and monitor the power supplies. Loading to display the screens and to treat data input is performed by the POD, itself. Then, loading of the PC becomes less than that using a terminal. The PC's program of the control system including Web pages was developed by a visual programming language (HP-VEE). The development time was comparatively short in spite of including effective human interface. The PC periodically monitors the status of the magnets and power supplies. The result of the monitoring is used to make Web pages. Figure 3 shows a Web page used to monitor the current stability of the magnets.

3 POWER SUPPLY CONTROLLER

The PSCx8 is a controller for eight power supplies. It acts as a good tool, and reduces the time and labor for the testing operation of the power supplies. Likewise, it reduces the load of the beam-line controller PC. The PSCx8 consists of cards installed in a STD-BUS (IEEE-961) card rack. Table 4 gives a list of the circuit boards. Table 5 gives a list of the steps performed by the PSCx8 when the data of the output currents of the eight power-supplies are received.

Board	Function	Character
CPU	Z-80	4MHz, ROM-base
GP-IB	TMS-9914	
DAC	16-bit x8	0 t0 10V, 1mV-resolution
16ch-MPX		Output current and voltage monitoring
ADC	AD1170	
IN	24-bit x3	Read status
OUT	24-bit x1	Actuate on/off, polarity, reset-interlock
DIP-SW	8 bytes	Power supply rating

Table 4: Circuit boards for PSCx8

1	Check status (Local/Remote) and interlocks
2	Set polarity switch
3	Reset interlock circuit and check status
4	Main transformer turn ON
5	Check turn ON status
6	Current set ramp-up and status-check loop
7	Report the result by SRQ
8	Current monitor and status watch loop--- SRQ
9	Continue --- receive current 0 data
10	Current down to 0 and status-check loop
11	Turn OFF, check status
12	Report the result by SRQ
13	Stand-by (monitor loop of status, output current, and voltage)

Table 5: Control Sequence of magnet power supply

4 HORN POWER SUPPLY CONTROLLER

The HMPSC is a controller for one horn-magnet power supply. This controller is also designed [1] based on the same policy as the PSCx8. Also, the hardware configuration is almost the same. The timing controls of the high-voltage capacitor charging unit and the trigger of the output pulse are different. This part is performed effectively by a combination of the Z80 interrupt function, Z80-CTC (counter timer circuit chip), and some additional circuits. Table 6 gives a list of the circuit boards. Table 7 shows action of the HMPSC receives trigger signals from the accelerator.

Board	Function	Character
DAC	DAC701	Reference voltage
DAC-2	AD7546	Modulate reference voltage to ramp wave form
Isolation		Timing signal, interrupt

Table 6: Unique circuit boards for HMPS

Trigger	Action
A	Charger ON/OFF. Generate Reference voltage
B	Delay timing control. 250kA pulse

Table 7: Trigger signals

5 CONCLUSION

Based on the initial design [2] of this control system, a UNIX workstation and x-terminals were expected to be used. Later, however, those devices were changed to Windows PC and PODs. The choice greatly reduced the time to develop the human-interface program. During the final-stage one-week work on this control system construction, the time was short and tight, the PSCx8s and HMPSCs effectively supported engineers to check-up and test the magnets and the power supplies. After completion, it has provided a good operator interface and Web pages. The low-level controllers (PSCx8s and HMPSCs) and the human interface PODs reduce the load of the system controller PC, and contribute to the realization of this economical control system; that is to say, the functions are properly distributed.

6 REFERENCES

[1] Y. Suzuki et al., 'Control and Timing of the 250kA pulsed Magnetic Horn', ICALEPCS'97, Beijing, China, November 3-7,1997

[2] Y. Suzuki et al., 'An interface for the neutrino beam line control system', IWCSMSA96, KEK, Tsukuba, Japan, November 11-15, 1996