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Magnet Power Supply and Beam Line Control

for a Secondary Beam Line K6

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Abstract

K6 is a secondary separated-beam line with momentum range up to 2.0 GeV/c in the north experimental hall at the KEK 12 GeV Proton Synchrotron (KEK-PS). On the construction, newly developed magnet power supplies (MPSs), in each of them a microprocessor is embedded, are introduced. The features of the MPS are as follows:
1, The MPS is connected to an upper-level beam line controller (BLC) by GPIB highway for exchanging simple messages.
2, All the operations of the MPS are supervised by the microprocessor, which has its individual parameters and fault messages. It reduces the load of the upper-level controller.
3, The MPS has functions to inspect itself and to report the result. It saves much time and labor of maintenance.

INTRODUCTION

On the KEK-PS site, there are two experimental halls for high energy physics experiments. The one is the East experimental hall (E-hall), that has been servicing since 1977. The other is the North experimental hall (N-hall) built in 1990, where the construction of the new beam line K6 construction is under going.

In N-hall, the beam lines were designed for high-intensity proton beams against high radiation field. The R&D for the beam line components has made during the last few years. The design of the magnets and vacuum system were reported in [1]. On the other hand, magnet power supply (MPS) and control system have also been developing [2].

On the construction of the K6 beam line, newly developed MPSs were introduced. Each MPS has a microprocessor, ADC(analog to digital converter), DACs (digital to analog converter), relay I/O(input and output), and GPIB(IEEE-488) interface. The digital processing unit i.e. magnet power supply controller (PSC) is incorporated into the MPS to have functions; ON, OFF, reset of interlocks circuit, polarity switch, current/ voltage control mode, current setting with appropriate speed, and checking the health of the MPS without help of upper-level beam line controller. These functions are invoked by a simple message, for example; current setting message; "A 1234.0" means to set output-current to 1234.0 ampere. This message is sent to MPS from BLC through a single coaxial cable; GPIB highway.

These design concepts were reported several years ago, [3], [4]. Though effective, those design concepts have been applied to few devices on the accelerator field up to present.

We introduced this design concept in to beam line control system, and developed MPS. Now we are saving cost, time, and trouble.

This paper report this MPS's PSC and beam line control for K6. The details on soft program and hardware will be reported elsewhere.[5]

POWER SUPPLY CONTROLLER (PSC)

Hardware

PSC consists of five boards (STD: IEEE-961):

(1) CPU board: Z-80, GPIB communication interface.

(2) DAC board: 16-bit DAC, for reference voltage.

(3) ADC board: 16-bit ADC, for monitoring DCCT (output current).

(4) ADC board: 12-bit ADC, 16-channel multiplexer.
This board is used for monitoring the following values:
1, Reference voltage (16-bit DAC).
2, MPS's DC output voltage
3, MPS's output voltage for monitoring Wave Form.
4, MPS's AC input current .
5, Input voltage of firing module.
6, Seven points on low-voltage power supplies.

(5) Relay I/O board: for control and monitor.
The control points are:
1, ON/OFF
2, Reset of interlock logic.
3, Polarity switch.
4, Regulation mode (voltage or current).
5, Remote or Local

Input points for monitoring status are:
1, Control power ON/OFF.
2, Remote/ Local.
3, Main switch, ON/OFF.
4, Polarity +/-.

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5, Magnet #1 Ready/ Trouble.
6, Magnet #2 Ready/ Trouble.
7, Fault; DC over current.
8, Fault; DC current leak,
9, Fault; MPS over heat #1.
10, Fault; MPS over heat #2.
11, Fault; cooling fan
12, Fault; MPS's door open.
13, Fault; magnet #1; over temperature.
14, Fault; magnet #1; cooling water flow trouble.

Software

All the PSC's soft programs are written in assembler language. They mainly consist of :

(1), GPIB communication program.
(2), MPS operation program.
(3), Watching program.
(4), Fault or error message list for diagnosis of MPS.

Messages [1] BLC--> PSC

The messages sent to PSC in MPS from BCL are the followings:

1), "ST$"
requests PSC to send status message of MPS. This message includes the following:

ON/ OFF,
REMOTE/ LOCAL,
READY/ NOT READY,
+/ - , : polarity
CC/ CV, : regulation mode
Reference value,
DAC value,
DCCT value,
Voltage value,
AC input current value.

2), "ST1$" , or "ST3$".
These messages request PSC to send MPS's status as follows;

DCCT value, or absolute output current [A].
Voltage value, or absolute output voltage [V].
+/ - , : polarity
CC/ CV, : regulation mode
Ac input current value [A].

3), "ST2$"
requests to send

Absolute output current [A],
Absolute output voltage [V].

4) "FL"
requests to send fault messages to help diagnosis of the MPS. Its message is text-format message.

5), "AC"
requests to send AC power source input current [A].

6), "OW"
requests to send wave form data of MPS's output voltage; 255 words binary data with EOI, its sampling period is about 25 millisecond. Figure 1 shows an example of the wave form.

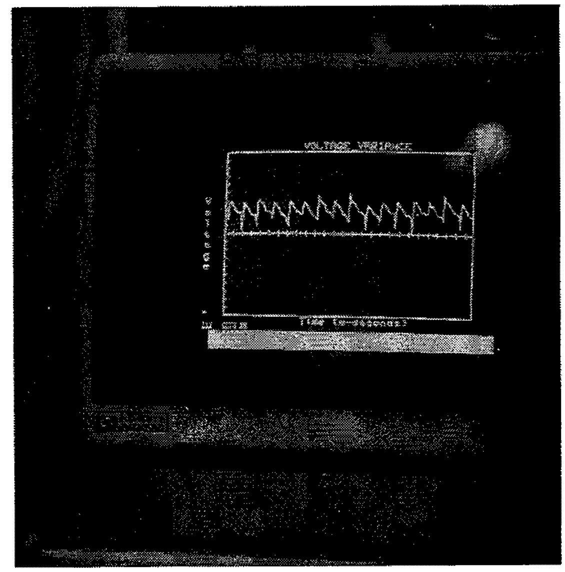

Figure 1: Wave form of MPS's output voltage

7), "ID"
requests to send MPS's identifying message;
It includes MPS's rating, factory name fabricated the MPS, etc.

8), "Y0"
requests to send DCCT output voltage for monitoring.

9), "X0","X1","X2", , , "X15"
request to send the value of ADC(with 16 channel multiplexer) for monitoring.

10), "A xxx.xx"
requests MPS to set output current xxx.xx [A] smoothly.

11), "V xxx.xx"
requests MPS to set output voltage xxx.xx [V] smoothly.

12), "D x" : (-10000<= x <= +10000)
requests PSC to set xxxx data to DAC smoothly.

13), "T1", "T2", "T3"
are setting speeds of output current or voltage.

T1: fast.
T2: middle.
T3: slow.

14), "L x"
sets the limit value of output current for watching.

15), "CC"
sets MPSs to constant current regulation mode.

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16), "CV"
sets MPS to constant voltage regulation mode.

17), "CK".
It invokes check program to check MPS. When MPS is OFF state, the check program checks Interlock's fault signal, low voltage power supplies, DAC output voltage, and function of main switch and polarity switch. When MPS is running, it initializes check list and fault flag, then check program starts.

18), DC, SDC : GPIB command.
initialize PSC and MPS. Main SW is off, and all data is clear.

Message [2] PSC--> BLC

The messages sent to BLC form PSC have described already in the above section without SRQ.
The SRQ is a signal of PSC to request BLC. One status byte is sent to BLC.
The bit assignment is listed below.

Bit 0, 0: MPS is OFF state.
1: MPS is ON.
Bit 1, 1: Local control mode.
Bit 2, 1: Fault on interlock.
Bit 3, 1: Fault on ON, OFF, polarity SW procedure.
Bit 4, 1: Fault on Values; output current, low voltages, or DAC: reference voltage.
Bit 5, 1: Message error.
Bit 6, 1: SRQ
Bit 7, 1: This bit is set after the check program runs, and indicates that the fault-list is available for read-out.

MPS operation

All the operation of MPS is done by PSC in MPS. When current setting message is received, the MPS's operation is as follows.

Step 1, Receive "A xxx.xx".
Step 2, Invoked MPS operation program.
Step 3, Reset MPS interlocks.
Step 4, Check Interlocks fault signal.
Step 5, Check MPS's low voltage power supplies, MPS output current, and DAC output voltage for reference.
Step 6, Set MPS to current or voltage regulation mode.
Step 7, Check polarity, and turn polarity switch.
Step 8, Main power switch ON, and check.
Step 9, Current setting and check trouble loop.
Step 10, Current setting end, and SRQ.
Step 11, Set limit values for watching program.
Step 12, Watching: check status (ON/OFF, interlock signal, remote or local), output current, reference DAC, and low voltage power supplies.

On this state, when MPS receives "A-xxx.xx" message, the following steps are done.

Step 13, Current setting starts to 0 [A].
Step 14, Main power switch OFF.
Step 15, Jump to the above step 2.
Final state is negative (-) xxx.xx [A].

On the step 15, when MPS receives "V+ xx.x" message, the following steps are done.
Step 16, Current setting starts -xxx.xx[A] to 0 [A].
Step 17, Main power switch OFF.
Step 18, Jump to above step 2.
Final state is positive(+) xx.x [V] on voltage

On the OFF state, when MPS receives "CK" message, the following steps are done.
Step 19, Reset interlocks, check fault signal.
Step 20, Check output voltages of low-voltage power supplies, DAC, and DCCT(output current).
Step 21, Turn polarity switch, check its status.
Step 22, Turn main switch ON, check its status.
Step 23 Check output voltages of low-voltage power supplies, DAC, and DCCT.
Step 24, Turn main switch OFF, check its status.
Step 25, Send SPQ, bit 7 added in order to indicate check-end.

BEAM LINE CONTROL

MPSs and control system for K6

The control system for K6 using new MPSs is shown in figure 2. All the MPSs are connected through GPIB highway to the BLC by a coaxial cable. A terminal display connected to the BLC is offered to a user group to operate the beam line. The BLC computer is dedicated for the beam line control and the MPS's maintenance work.

On construction stage of the beam line, this new MPS's function is effective for checking MPSs. All the function of MPS is performed through the microprocessor embedded in the MPS. Then commands or messages to the MPS is simple, those MPSs can be operated easily by direct command of personal computer with interpretive language (BASIC) too. The diagnostic information of the MPSs are able to get without checking program on the BLC, for its checking or test program is stored in each of MPSs.

On this configuration BLC programing becomes simple, and no checking program is running constantly on BLC. As the result, the GPIB communication line between MPSs and BLC becomes quiet, there is no problem with speed.

The equipments for K6 beam line control system are:
BLC: Personal computer with BASIC language HP-300
TRM: Terminal for user of K6 beam line.
EX: GPIB bus extender for long distance up to 1250m, 60k bytes/s. HP 37204A
MPSs: listed bellow.

Name	Address	KW	A	V
D1	1	260	2000	130
Q1	2	65	1300	50
Q2	3	105	1600	65
Q3	4	200	2000	100

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Q4	5	160	2000	80
CM1	6	85	1300	65
CM2	7	85	1300	65
Sext	8	50	1000	50
Q5	9	65	1300	50
Q6	10	85	1300	65
Q7	11	105	1600	65
Q8	12	120	2000	60
D2	13	500	2500	200
Q9	14	120	2000	60
Q10	15	160	2000	80

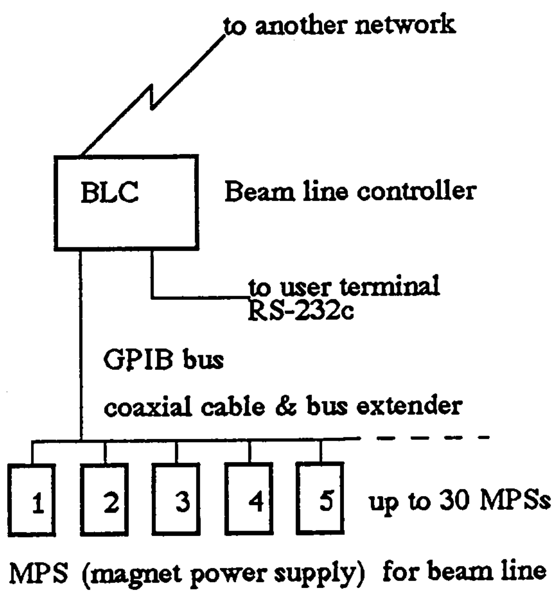

Figure 2. Configuration of K6 beam line control

The soft program for K6 beam line is written by BASIC language, which does not include the operation procedures or the fault messages of MPSs, therefore it becomes simple.

The operation procedure or the specifications or the fault messages of MPS are MPS's own. It is better that they are not separated from MPS's body, because they form MPS's character. If they were separated, in case of worst case of MPS exchanging, it needs more work, e.g. exchanging of procedure program and fault messages for individual MPS in BLC.

CONCLUSION

We have developed new MPSs, and introduced the MPSs in K6 beam line. Both the specifications and the source program of the PSC were offered at free to factory or workshop for MPS fabrication. By using this type of MPS, we rationalized the work on control wiring, check and maintenance work of MPSs, and BLC programing.

No longer on BLC programing the programer need to be concerned with the specifications or the fault messages or codes of MPSs.

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