THE CONTROL SYSTEM FOR J-PARC

H.Sakaki*, Y.Itoh, Y. Kato, M.Kawase, H.Takahashi, F.Tamura, M.Tanaka,
H.Yoshikawa, K.Watanabe
JAERI, Tokai, 319-1195, Japan
J.Chiba, K.Furukawa, N.Kamikubota, T.Katoh, H.Nakagawa, J.Odagiri,
Y.Takeuchi, N.Yamamoto
KEK, Tsukuba, 305-0801, Japan

Abstract

The J-PARC[1] is consisted of 400MeV LINAC(LI), 3GeV Rapid Cycling Synchrotron(RCS), and 50GeV Main Ring synchrotron(MR). The high intensity beam, peak current 50mA and pulse widths 500μ seconds, is produced from the LI. The beam power reaches 1MW in the RCS, and 0.75MW in the MR. Therefore, the huge nuclear radiation is emitted, when such a beam deviates from the ideal orbit and loses it all. For that purpose, we design the control system based on the ALARA(As Low As Reasonably Achievable; principle on radiological protection) principle, using the EPICS(Experimental Physics and Industrial Control System) toolkits.

In this paper, a part of the method for the ALARA in the J-PARC control system is presented.

BACKGROUND OF THE J-PARC CONTROL SYSTEM

In Japan, the only nation in the world to be bombed with atomic weapons, thus, the Japanese generally is nervous public over the radiation safety. There is a guideline value which is presented by the Japan Nuclear Safety Commission, as well as a juridical management value of effective dose in the radiation facility. And, the accelerator facilities in Japan, KEK and SPring-8, have conformed to the guideline. According to the guideline, the management target of the effective dose on the site boundary is 50 μ Sv/year. This value is 1/20 of the ICRP recommendation and the Japanese law, 1mSv/year.

Table 1: Target of effective dose in the J-PARC. And the half value of the law is targeted the inside of JAERI. Note, one week is assumed to be 40 hours.

	Target value	Japanese law
JAERI site boundary near the boundary line	$< 50\mu$Sv/year	$<$ 1mSv/year
Inside of JAERI near the J-PARC	$< 0.25\mu$Sv/hour	$< 20\mu$Sv/week

In the J-PARC which is expected to become high radiation level, the management target on the site boundary is also at this guide value Table 1, because of the ALARA principle[2].

Table 2 shows the effective dose when the 100% beam loss event happens at one point in the J-PARC. If the trouble which exceeds the target dose of 1 hour occurs, the operation will stop at once, and the operation for next 1 hour may be stopped from the reason of the radiation control. Table 2 shows that the dose of 196 hours will occur when 100% beam loss happens in the MR. Additionally, if a similar event occurs 20 times in the MR, the total dose reaches 1mSv which conflict with the law value, and we will not be able to operate for 1 year.

Table 2: Calculation value of the effective dose, when 100% full beam loss happens at one point.

Accelerator	Effective dose/pulse
LINAC	0.042μSv/pulse
RCS	0.17μSv/pulse
MR	49μSv/pulse

For we can do hands-on maintenance the accelerator, the loss target at each part is shown to Table 3. To assure this value, we should establish the method of adjusting the parameter which minimizes the loss.

Table 3: Beam loss target in the J-PARC.

Area	Beam loss target
Linac straight	0.1W/m
BT Linac to RCS	1W/m
RCS injection point	$\sim$5kW
RCS quiet line	1W/m
MR injection point	135W
MR quiet line	0.5W/m

Moreover, it is worried to cause the thermal shock by a few μ seconds order in the LI low energy part, when the spot beam collides to the accelerating component[3]. We design the high-speed beam stop system. This system has a big meaning for not only the thermal shock's evasion in the LI low energy part but also the decrease of the total dose in the J-PARC.

* sakaki@linac.tokai.jaeri.go.jp

As above, the J-PARC control system is designed these backgrounds and strategies for the ALARA.

OVERVIEW OF THE SYSTEM

Figure 1 shows outline of the control system for the J-PARC with the EPICS toolkits [4].

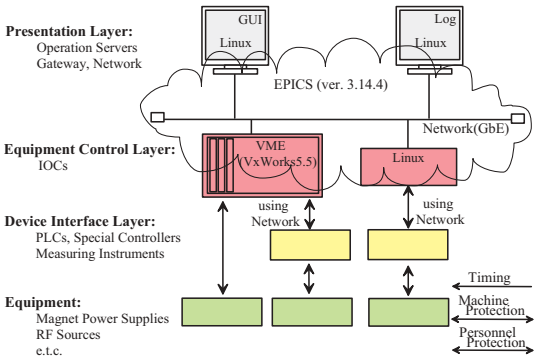

Figure 1: Overview of the J-PARC control system.

This system consists of three hierarchies. They are the presentation layer, the equipment control layer, and the device interface layer.

At the presentation layer, the operation PC using the Linux is scheduled to be put on this layer. The Gigabit Ether-net(GbE) contains in it, too. At the equipment control layer, IOCs(Input/Output Controllers) of the EPICS is set up. VME(VxWorks) and PC(Linux) are applied to IOC. When VME is used as IOC, VME will become with both the equipment control layer's device and the device interface layer's device. When PC is used as IOC, we use only the function as the equipment control layer's device to access the network devices. At the device interface layer, a lot of adopted devices are PLC(Programmable Logical Controller) which has the network and local I/O functions.

FOR THE ALARA PRINCIPLE

Because we operate the high intensity beam in the J-PARC, the control system should have the ALARA principle. In this section, a part of the procedure for the ALARA designed in the J-PARC control system is described.

Parameter setup

Access limitation using EPICS ASG:

In the J-PARC accelerator, the multiple operation modes exist; the LI single mode, the LI-RCS mode and etc. To permit the operation of each mode, it is the absolute requirement that equipments which respond to the selected mode are in working order. For instance, when the LI single mode is selected, the beam must not be injected toward the RCS absolutely; the bending magnets on LI-RCS Beam Transport line(L3BT) is not energized. This case, the control system does not permit to energize using the hard-wire interlock signal. In addition, using Access Security Group (ASG) with the EPICS function, Figure 2, the parameter is made to change only by the main control PC. We are going to vouch for the selected mode's safety from the signal and the software tools.

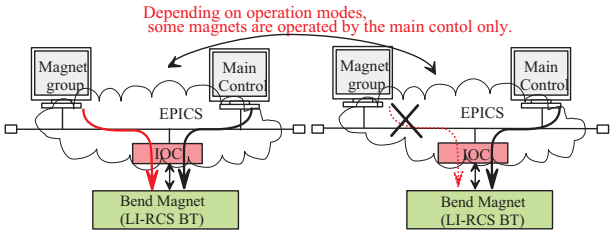

Figure 2: Operation using the EPICS ASG. Setting parameter by the user group, this case Magnet, is limited in the selected on case by case.

Timing when parameter is changed:

The accelerator parameter wiil be changed frequently by the operator at the commissioning phase. In this phase, the operator will have a priority to save the commissioning time. And, as shown in Figure 3 left side, the parameter may be changed while beam injecting. However, the operation of such efficiency increases the beam loss and it contradicts the ALARA principle. Then, we are considering whether an ideal beam injection which avoids a transitional situation on the equipment, as shown in Figure 3.

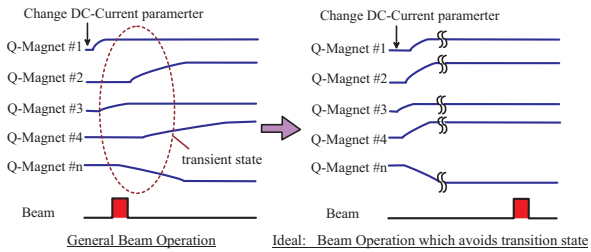

Figure 3: Parameter change for the ALARA. The beam timing and the parameter change must not synchronize.

Network

The operation authorities of all accelerators are collected only in the central control room. Because a large amount of control data is concentrated to the central control room by LAN, the network system based on the Gigabit Ether-net is adopted in the J-PARC. In this case, we have the risk that the operation stops due to LAN trouble. Hence LAN design of the redundant routes, and ESRP(Extreme Standby Router Protocol) is adopted for the routing protocol. When the LAN trouble occurs as shown in Figure 4, the switch change the route automatically.

The test bench of the designed LAN is prepared. And, the switching time is measured $\sim$ 6 seconds. Judging from the switching time of the intranet in the digital TV broadcasting-station aims at 10 seconds[5], we think this speed must be the fastest level.

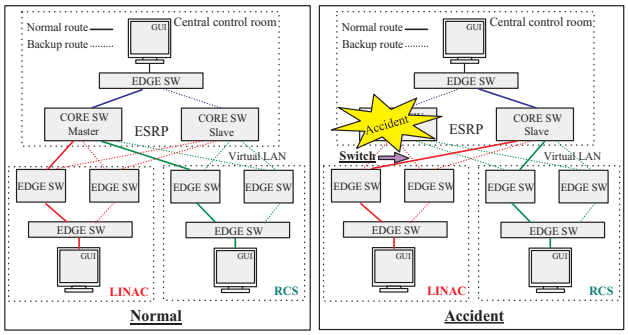

Figure 4: Network image. At the accident, the network is switched automatically. In the test bench, the system give ∼6 seconds at the switching.

Timing system

For the ALARA principle, the timing system is also very important. If the correspondence of timing in each system is not managed, the beam loss may be increased by the private timing adjustment. The scheduled timing system is defined in the J-PARC, and the timing is managed collectively over all factions, it's now testing[6].

Fast beam stop system

Procedure:
When the beam loss event occur in the operation, the high-speed beam stop procedure is done. We call this system MPS(MachineProtectionSystem). The outline of the system is shown in Figure 5. This system is composed of the beam loss monitor, MPS units, and the logic of the LI RFQ power shut down part.

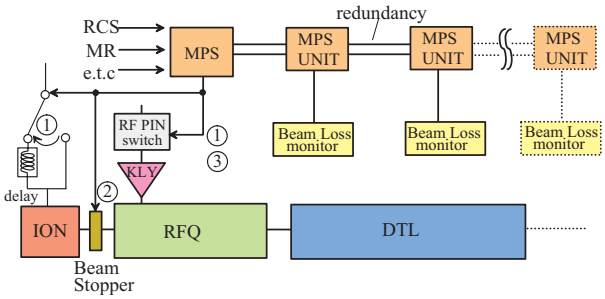

Figure 5: Beam stopping procedure of MPS.

In the MR, it is necessary to consider the method of the beam aborting system from the dose problem. We are designing the logical abort system that uses FPGA in the MR. This abort system is used together with the MPS shown in Figure 5.

Response time:
The example of the signal transmission speed test using the MPS units are shown in Figure 6. The response time is 1.4μ seconds/245m. From this data, we think that the system will respond $\leq 5\mu$ seconds in the LI downstream part from the loss event starting to the beam stop[7].

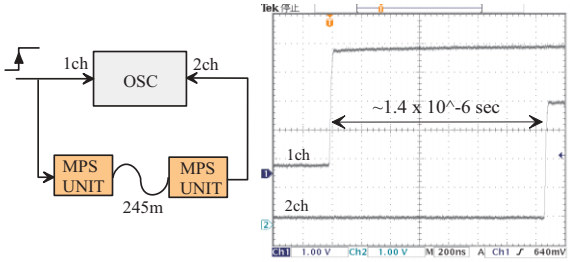

Figure 6: Transmission speed test of interlock signal using the MPS units.

SUMMARY

In this paper, a part of the J-PARC control system based the ALARA principle is presented. As just described , we are challenging the J-PARC control system that achieves the lowest radiation level.

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