PERSONNEL PROTECTION SYSTEM OF JAPAN PROTON ACCELERATOR RESEARCH COMPLEX

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Abstract

The Japan Proton Accelerator Research Complex (J-PARC) is composed of three accelerators and four experimental facilities. The maximum beam power is as high as 1 MW. Design of Personnel Protection System (PPS) of the J-PARC is described.

INTRODUCTION

The J-PARC is a joint project of Japan Atomic Energy Research Institute (JAERI) and High Energy Accelerator Research Organization (KEK). It is under construction in the Tokai site of JAERI, about 140 km northeast of Tokyo. The J-PARC consists of a 400 MeV Linac, a 3 GeV Rapid Cycle Synchrotron (RCS), a 50 GeV synchrotron (Main Ring, MR), a Material and Life science Facility (MLF), a nuclear and particle physics facility, a neutrino facility, and an accelerator-driven transmutation experimental facility.

Figure 1: J-PARC facilities.

The 3 GeV RCS delivers the beam to the MLF and the 50 GeV MR. The RCS will be operated at 25 Hz with the beam power of 1 MW. The MR has two extraction lines: the slow extraction line to the nuclear and particle experimental hall and a fast extraction line for neutrino beam to Super Kamiokande. The maximum beam power of the MR will be 0.75 MW.

Safety issues are very important to handle such high power beam.

- Personnel Protection System (PPS), and
- Machine Protection System (MPS)

are installed for the man and machine protection. The PPS protects personnel from the radiation and other hazards caused by the operation of the accelerators. The MPS protects machine components by stopping the beam when beam loss, magnet failure, etc., are detected. In the following, we describe the present design of the PPS of J-PARC.

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HARDWARE

As the PPS assures the safety of people, it must be highly reliable and fail-safe. The system is made by using Programmable Logic Controllers (PLCs). Usual computers are not used in the interlock sequence because their reliability seems still insufficient. They are used only in software development and monitoring of PLCs. The PPS is isolated from other systems, such as the accelerator control system, to prevent it from being disturbed.

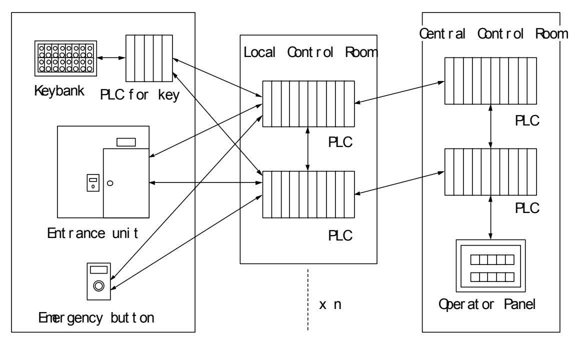

Figure 2: Hardware configuration.

In order to make the system more reliable, PLCs are installed redundantly as shown in figure 2. The signals of important devices, such as emergency buttons, door switches, etc., are also redundantly read.

Metal wires are used to connect these devices to PLCs in a local control room. The central control room and local control rooms are connected with both of optical fibers and metal wires.

ACCESS CONTROL

Access Control Area

For the convenience of the beam operation and access control, the J-PARC beam tunnels are divided into following access control areas:

- Linac area,
- 3 GeV RCS area,
- 50 GeV MR area, and
- four experimental facility areas.

These areas are separated by shielding walls. In each beam transport line which goes through the walls, at least two bending magnets are assigned to safety devices, and, in addition, one beam plug is installed for the safety of access. When people access the downstream area, these safety magnets are turned off and the beam plug is inserted into the beam transport line to prevent the beam from injecting into the area where people are working.

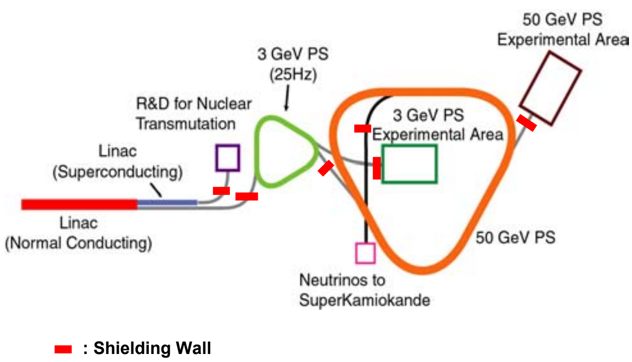

Figure 3: Access control areas.

Access State

Three access states are defined in the present system:

- Limited Access State,
- Controlled Access State, and
- No Access State.

The latter 2 access states are divided into sub-states as shown in Figure 4. Each access control area takes one of these states independently.

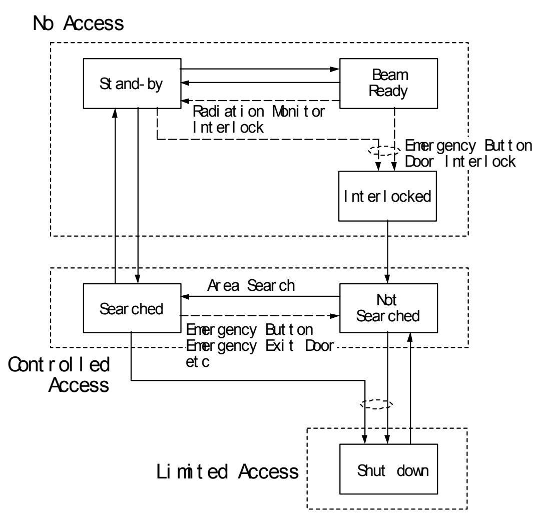

Figure 4: State transition diagram and access states.

When an accelerator is in long shut-down, the area of the accelerator is in the Limited Access State. Even in such period, the access is not completely free because the residual radiation level is considered to be high.

Before the beam operation, the area is searched and secured. After that, it is kept in the Controlled Access State. In this state, every access is controlled and supervised by the operator in the central control room.

Access Control Booth

In the Controlled Access State, the access is remotely controlled from the central control room. For the convenience of this control, an access control booth is installed at each tunnel entrance.

The booth has two doors with electromagnetic locks. There is a bank of safety keys in front of the booth. Each personnel accessing the area removes a safety key by using his ID card, unlock the doors with the key, and enter the area. He has to keep the safety key with him during the stay in the area.

The key release and door unlock can be enabled or disabled remotely from the central control room.

As the J-PARC is the facility of high-intensity proton accelerators, the residual radiation level will be rather high. For the protection against excess exposure, every person is required to wear an APD (Alarm Pocket Dosimeter) when accessing the tunnel. Remove of safety keys is not allowed for people without APD.

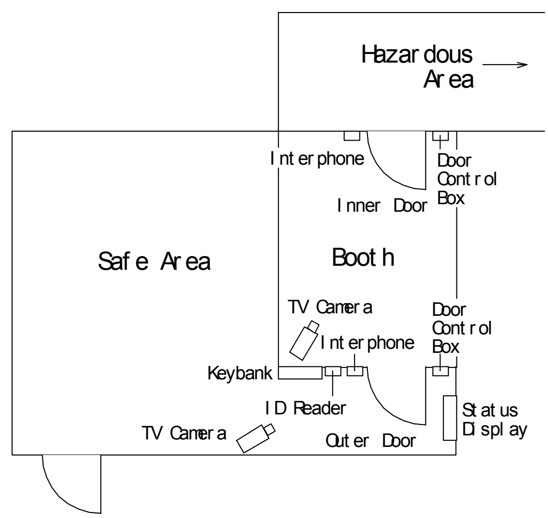

Figure 5: Conceptual drawing of the access control booth.

BEAM INTERLOCK

We will have at least two interlock levels. In case of the level 1 interlock (emergency button, door interlock, etc.):

- the ion source is interlocked off,
- three beam stoppers in LEBT and MEBT1 are inserted,
- the safety bends for the interlocked area are turned off,
- the beam plug for the area is inserted into the beam line, and
- high power equipment of the area is turned off.

In case of the level 2 interlock (radiation monitor interlock, etc.):

- one or two beam stoppers in the LEBT and/or MEBT1 are inserted into the beam line.

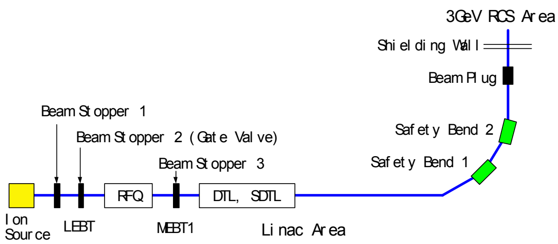

Figure 6: Schematic drawing of the Linac Area. The ion source and the stoppers in the LEBT and MEBT1 are shown. When people access the 3 GeV RCS Area, Safety Bend 1 and 2 are turned off, and Beam Plug is inserted.

OPERATION MODE

The operation mode is defined by the combination of area mode and beam destination, as shown in table 1.

The area mode determines in which area the beam can exist. It is selected by the PPS because it is closely related with the access control and beam interlock. On the other hand, the beam destination is selected by the accelerator control system.

As can be seen in the table, there are several beam dumps for accelerator tuning. The power limits of these dumps are 600 W to about 10 kW, which are considerably lower than the maximum beam power of 1 MW. Therefore, the beam power (or beam current) should be restricted within the limits when the beam is led to dumps. The PPS receives the beam destination information from the control system and the beam current information from the beam monitor system, and interlocks the beam off when the current exceeds the limits.

SUMMARY

Basic Design of the J-PARC PPS is completed although many details are left to be determined. In this paper, mainly considered is the PPS of the accelerators. The PPS of the experimental facilities is also important. For its design, close collaboration between accelerator and experimental facilities is required.

The author would like to thank the members of the PPS group for their valuable discussions.

Table 1: Operation mode.
K: Nuclear and Particle physics experimental area. N: Neutrino beam line. More dumps may be added.

		Area Mode											
		Ion Source	Linac	3GeV	50GeV	MLF	MLF, 50GeV	MLF, K	MLF, N	MLF, K, N	K	N	K, N
Beam Destination	LEBT Beam Shutter	○	○	○	○	○	○	○	○	○	○	○	○
	Linac Dump (0 deg)		○	○	○	○	○	○	○	○	○	○	○
	Linac Dump (30 deg)		○	○	○	○	○	○	○	○	○	○	○
	L3BT Dump			○	○	○	○	○	○	○	○	○	○
	3NBT Dump			○	○	○	○	○	○	○	○	○	○
	MLF Muon Target					○	○	○	○	○			
	MLF Neutron Target					○	○	○	○	○			
	50GeV Inj. Dump				○		○	○	○	○	○	○	○
	50GeV Ext. Dump				○		○	○	○	○	○	○	○
	K Target							○		○	○		○
	N Target								○	○		○	○