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OPERATION STATUS OF J-PARC MR MACHINE PROTECTION SYSTEM AND FUTURE PLAN

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Abstract

The J-PARC MR's Machine Protection System (MR-MPS) was introduced from the start of beam operation in 2008. Since then, MR-MPS has contributed to the improvement of safety including stable operation of the accelerator and the experiment facilities [1]. The present MR-MPS needs to be reviewed from the aspects such as increase of connected equipment, addition of power distribution building, flexible beam abort processing, module uniqueness, service life etc. In this paper, we show the performance of MR-MPS and show future consideration of upgrade.

INTRODUCTION

J-PARC (Japan Proton Accelerator Research Complex) is a high-intensity proton accelerator facility. It consists of three accelerators: 400-MeV linear accelerator (LINAC), 3-GeV Rapid Cycling Synchrotron (RCS), and 30-GeV Main Ring synchrotron (MR), and three experimental facilities: Material and Life Science Experimental Facility (MLF), Neutrino Experimental Facility (NU), and Hadron Experimental Facility (HD) [2-4].

The MR has two beam operation modes: a fast extraction (FX) mode for beam delivery to the NU, a slow extraction (SX) mode for beam delivery to the HD. The MR operation cycle based a main magnet current pattern shown in Figure 1. The MR-MPS ensures the safety of accelerator and experimental facilities by stopping beam operation and abandoning beam to abort dump when accelerator components or experimental facilities components interlock signal occur.

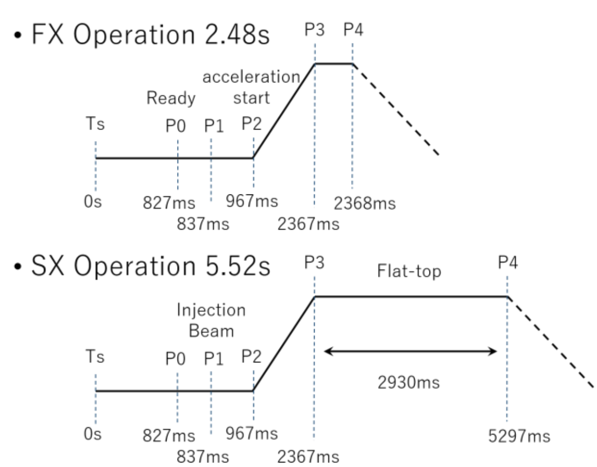

Figure 1: MR operation cycle of the two modes.

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Figure 2: Photo of MR-MPS unit.

PRESENT MR-MPS

The MR-MPS consists of 6 BLM-MPS units, 8 MR-MPS units and 5 MR-MPS units in experimental facilities. The BLM-MPS unit monitors 254 channels Beam Loss Monitor (BLM) signal of 3-50 Beam Transport line (3-50BT) and MR. The MR-MPS unit monitors 134 kinds of interlock signals of 3-50BT and MR components including BLM-MPS units in three power distribution buildings (D1-D3). A photograph of the MR-MPS unit is shown in Figure 2. The MR-MPS unit consist of 1 CPU module, 10 input modules, 4 input/output modules and 1power supply module. The input module is 3 types: an optical signal input module using ST connecter for main bending and quadrupole magnets power supply's interlock signal, a contact signal input module for interlock signal of various MR component and TTL signal input module for timing signal. The input/output module is an optical transceiver module using SC connecter for communicating between MPS units. 2 MR-MPS units and 2 BLM-MPS units are installed in the Local Control Room (LCR) of each power distribution building, 3 MR-MPS units in NU and 2 MR-MPS units in HD. The MR-MPS layout is shown in Figure 3. All MR-MPS signals are consolidated in the dedicated MR-MPS units of the D3 power distribution building. They do a beam abort by sending a signal to the kicker power supply and also stop

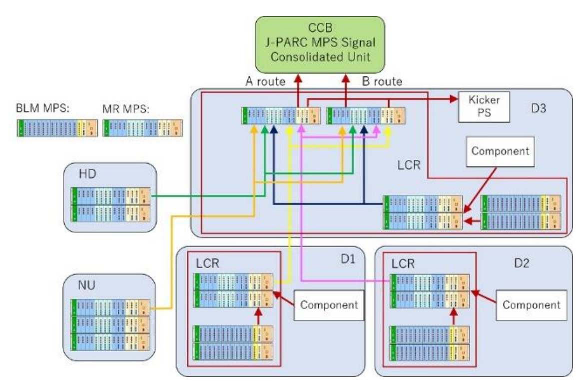

Figure 3: Layout of MR-MPS in J-PARC.

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Figure 4: GUI of MR-MPS made by CSS.

the beam operation by communicating with the superior J-PARC MPS. The MR-MPS signal is monitored on the screen shown in Figure 4.

FANCTION OF MR-MPS

There are two functions of the MR-MPS: (1) a beam operation stops function and (2) a beam abort function. (1) there are two types of beam stop processes of MR-MPS: All-stop signal and MR-inhibit signal. All-stop signal stops beam operation of all accelerators in J-PARC. MR-inhibit stops only beam operation in MR [5]. (2) there are three types of beam abort processes: an abort signal is sent a trigger signal to the FX Kicker at the scheduled P4 timing, a SX-abort signal is sent stop instruction to the SX component in real time [6] and milli-second(msec)-abort is sent a trigger signal to the FX Kicker in real time. The msec-abort signal will be introduced by 2018. These signals are set as to which to output

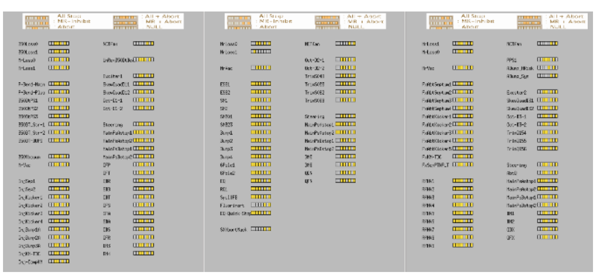

Figure 5: MR-MPS signal mask setting.

for each monitoring MR component. A screen of MR-MPS signal setting is shown in Figure 5.

As mentioned above, MR switches between two operation modes. therefore, MR-MPS is set so that the monitoring target MR components are automatically switched in the operation mode. There are four operation mode settings in MR-MPS: in the Abort mode, the signal is masked if the beam destination is not a beam abort dump in FX and SX operation, in HD mode, the signal is masked if the beam destination is not a HD target, in NU mode, the signal is masked if the beam destination is not a NU target, and in continuance mode, the signal is masked when one shot operation. Like the MR - MPS signal, it is set for each MR component. A screen of MR-MPS monitoring setting is shown in Figure 6.

Figure 6: Operation mode setting in MR-MPS.

Also, it is possible to mask the output of the MR-MPS signal at an arbitrary timing. In MR-MPS, the operation cycle of MR is divided into six of Ts-P0, P0-P1, P1-P2, P2-P3, P3-P4, P4-Ts. These signal processes are set in the CPU and processed using the FPGA. Figure 7 shows an example of signal processing when some MR component interlock signal occur. Firstly, the signal is masked if the beam destination is not NU or abort. Secondly, if it is not during beam injection or beam acceleration, the signal is masked. Finally, if the above two conditions are satisfied, the MR-MPS outputs a beam stop signal and a beam stop signal. Since the signal processing is completed in 300

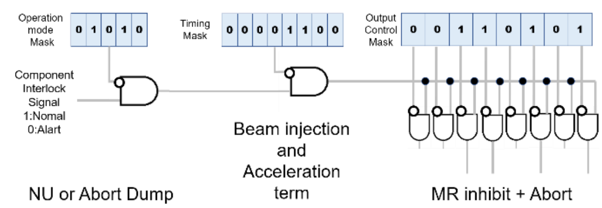

Figure 7: MR-MPS signal output logic.

nanoseconds and the signal transfer between the power stations requires a maximum of about 3 microseconds, the beam stop can be completed with 6 microseconds.

OPERATION STATUS OF MR-MPS

The MR-MPS started operation since 2008. It has contributed to the improvement of safety including stable operation of the accelerator and the experiment facilities. Up to now, one hardware trouble and three network troubles occurred while operating MR-MPS. Hardware trouble is that normal signal cannot be output due to aged deterioration of power supply. However, since the MR-MPS is a normally closed system, the beam operation was immediately stopped and there was no problem in MR safety. Trouble was solved soon by replacing the power supply. All three are troubles that the state of MR - MPS cannot be monitored by central control building due to software bug. They have also been solved by software debugging [7]. The present MR-MPS is very trouble-free and excellent. This is because signal processing has been simplified as much as possible.

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MR-MPS FUTURE PLAN

MR-MPS future plans to add additional functions, noise suppression by improving the optical line in power distribution buildings and to develop a new MR-MPS unit in order to operate more smoothly.

Firstly, the additional function is about the visualization of the occurrence order of MPS. When multiple MPS occurred in a short time, we cannot immediately know the occurrence order of MPS. It is because the MPS archive data is recorded only every 0.1 seconds. However, the MR-MPS cannot record the occurrence state at high speed [8]. It can record data for about 24 seconds every about

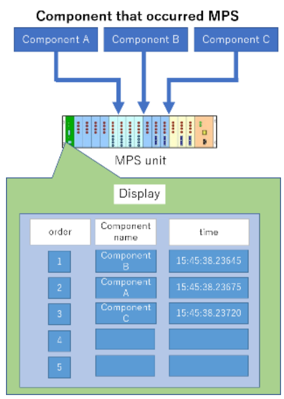

Figure 8: MR-MPS signal output logic.

1.5 microseconds. Unfortunately, its function is not synchronized with the MR operation cycle. In order to visualize the occurrence order of MPS, it is necessary to synchronize with the MR operation cycle using software. Figure 8 shows the MPS occurrence order recording function. Its function displays the occurrence order and occurrence time.

The second plan is the conversion of interlock signal to optical line for noise reduction. Currently, the interlock

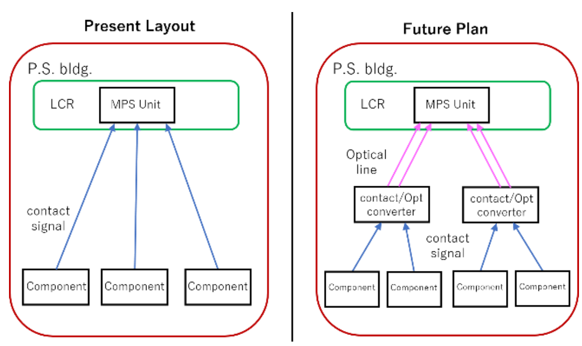

Figure 9: MR-MPS layout future plan in P.S. bldg.

signal of most MR components is input to the MR-MPS unit in the LCR with the contact signal. It is an inflow source of noise into LCR, which may cause malfunction of other control devices. As shown in Figure 9, after converting the contact signal into the optical signal in the power distribution building, it is input to the MPS unit to prevent noise inflow.

The final plan is the development of the new MR-MPS unit. The MR-MPS unit update is necessary for 10 years from operation start. On the present MR-MPS backplane, four types of 8-channel MPS signals can be output, but five types of outputs are already required. Therefore, backplane redesign is necessary. The design of new MR-MPS does not change much from the present one performing signal processing using FPGA. We are considering whether to use proprietary backplane or micro-TCA. We will choose the backplane in 2017. We will test prototype produced in 2018. We plan to update to the new MR-MPS unit in 2019.

CONCLUSION

We introduced the operation of present MR-MPS and future plans. The MR-MPS in operation up to now has very few troubles. It has also demonstrated sufficient performance for safe and efficient beam operation of accelerators and facilities. However, it was developed ten years ago and needs to be updated. We are planning to develop a new MR-MPS unit. We also aim to improve the safety of accelerator and laboratory facilities.

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