THE CONTROL SYSTEM FOR TRIM-COIL RELAY-SELECTORS IN J-PARC MR

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Abstract

In J-PARC main ring, each of the main magnets (Bending, Quadrupole and Sextupole) has a trim-coil. The primary aim of trim-coil is to correct small deviation of each magnetic field. In addition, we use them for other purposes such as: (1) In Beam-Based-Alignment studies, (2) as flux monitors, and (3) to make a short-circuit to reduce ripples of magnetic field. At a moment, each trim-coil can be used for only one purpose. We developed a relay-selector system which enables selection of connection to equipment depending on purpose. When we switch the connection, we have to change 1,200 on-site relays manually, distributed in three buildings. Thus, a control system for trim-coil relay-selectors have been developed in 2014-2015. EPICS tools and environment are used to develop the system. The system comprises PLC I/O modules with a controller running EPICS on Linux. Its operation begun in April, 2015. By using the system, we expect much easier switching of relay-selectors and reduce overheads than before.

INTRODUCTION

J-PARC (Japan Proton Accelerator Research Complex) is a high-intensity proton accelerator facility. It has been operated collaboratively by Japan Atomic Energy Agency (JAEA) and High Energy Accelerator Research Organization (KEK). It consists of three accelerators: a linear accelerator (LINAC), a Rapid Cycling Synchrotron (RCS), and a Main Ring (MR). MR started beam operation in 2008 [1]. MR is an accelerator with circumstance of about 1570 meter. This paper aim to main magnets accelerator components.

There are 3 types in the MR main magnets: bending magnet (BM), quadrupole magnet (QM) and sextupole magnet (SM). The number of BM (QM, SM) is 96 (216, 72). They are arranged with a 3-fold symmetry in the MR tunnel. The main power supplies are installed in the MR power-supply buildings. As an example, the cabling layout of a typical family "QFN" is shown in figure 1. The power supply for QFN is located in the second power-supply building, and QFN magnets are wired clockwise. Each of these magnets has an independent trim-coil.

The trim-coil can be connected to four different equipment such as:

- "Harmonic" - to correct small deviation of each magnetic field.
- "BBA" - in Beam-Based-Alignment studies.

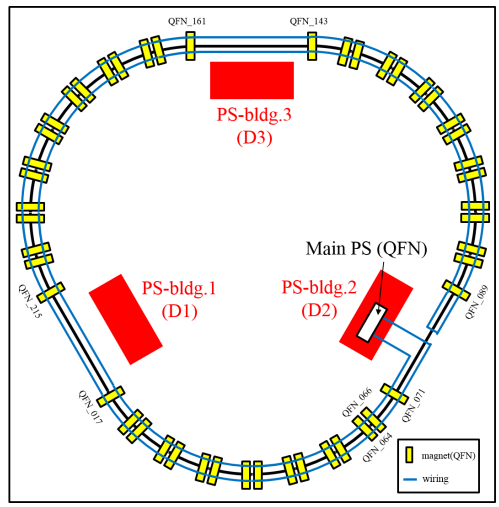

Figure 1: The layout of QFN power supply cabling.

- "Flux" - as magnetic flux monitors.
- "Short" - to make a short-circuit to reduce ripples of magnetic field [2].

In 2014-2015, we have developed the relay-selector system. Before the relay-selector system is installed, we have to switch connections between a trim-coil and a corresponding equipment by hands. All trim-coil connectors are placed in MR three power-supply buildings. So we need a lot of time to change connections. This relay-selectors system can reduce these overhead time since need not to switch the connection by hands.

By the way, the relay-selector system is applies to trim-coils of QM and SM. Since the BM trim-coils are used only for the "Short" purpose, it is independent from the system.

TRIM-COIL RELAY-SERECTORS SYSTEM

Each trim-coil need 4 relays. As shown in Figure 2 and 3, a relay-unit has 8 relays for 2 trim-coils. An aggregation-unit gathers cables from 8 relay-units. A control panel with buttons and fault indications is mounted in a rack. A relay-selector system, which consists of three rack, has 6 aggregation-units. Thus, a relay-selector system has to control 384 relays. J-PARC MR have three power-supply buildings, and each building has one relay-selector system. In total, this control system need to switch 1152 relays (equal to 288 trim-coils x4).

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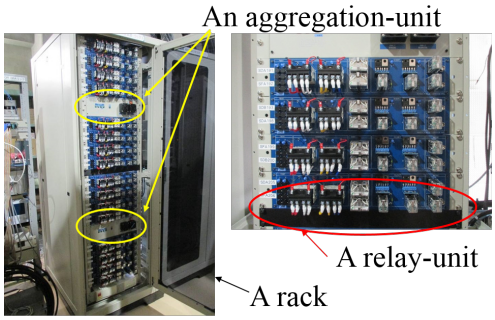

Figure 2: The photo of a relay-selector rack and a relay-unit.

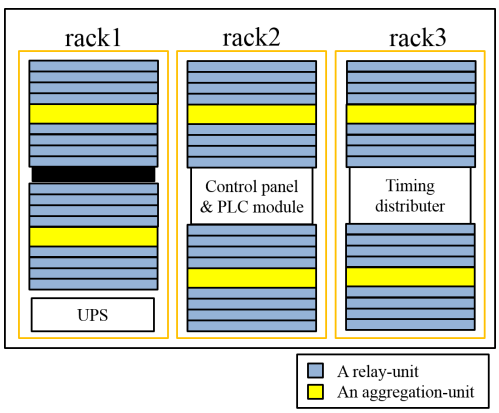

Figure 3: The layout of relay-selector.

EPICS PV CONFIGURATION

PLC Controller and I/O Modules

In J-PARC, we have been using an EPICS-based control system for the accelerator equipment [3] [4]. In J-PARC MR, a PLC-type CPU module running embedded Linux and PLC I/O modules (Yokogawa FA-M3 series) [5] [6] are standard for general I/O purposes. Relay-selectors are connected to PLC I/O via their aggregation-units. The buttons and fault indications of a panel are connected also to PLC I/O modules. Module cabling layout is shown in Figure 4.

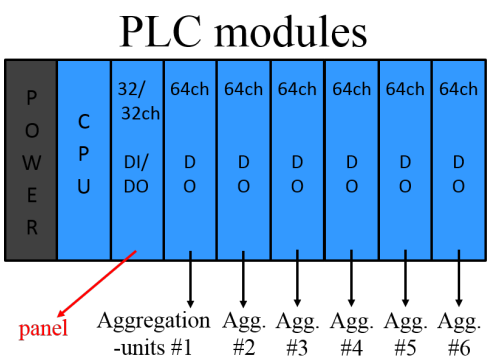

Figure 4: The layout of PLC modules and cabling.

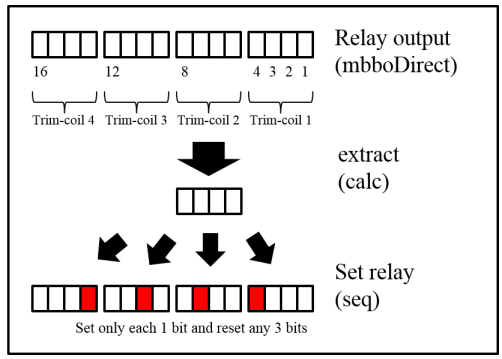

Figure 5: The footnote about PVs of relay output.

Design of EPICS PVs

Created PVs (Process Variables, a signal unit defined in EPICS) and numbers of them per one relay-selector system are shown in Table 1. The lower part of Table 1 concerns bit-oriented relay-output controls. Relationships of control PVs are shown in Figure 5.

Table 1: The Number of EPICS PVs of a Relay-Selector System

PVs	EPICS-type	number	explanation
Status	bi	5	system power, trigger
Interlock	bi	12	temperature, fan
Operation	bo	6	power and remote
Test switch	bo	7	test sw, trigger disable
Relay output	mbboDirect	24	see Figure 5
Extract	calc	96	see Figure 5
Set relay	seq	384	see Figure 5
Reset relay	seq	96	clear all

One “relay-output” PV, which is a 16-bit signal, contains 4 purpose of 4 trim-coils. The 4-bits are extracted as the “extract” PV, corresponds to one of four trim-coils. This PV shows the status of the selected purpose of the trim-coil. Before changing a trim-coil purpose, four relays are cleared by the “reset relay” PV. The reason is to avoid multi-bit-on status. Then, one of four relays, corresponds to the target purpose, are set by “set relay” PV.

GUI DEVELOPMENT

The total system, consists of three relay-selector systems, has 1152 relays. We have developed a top screen and four screens correspond to four purposes.

Figure 6 shows a top screen for total control. Using this screen, main power-switches are controllable. The status of remote-enable switches and fault indicators (temperature

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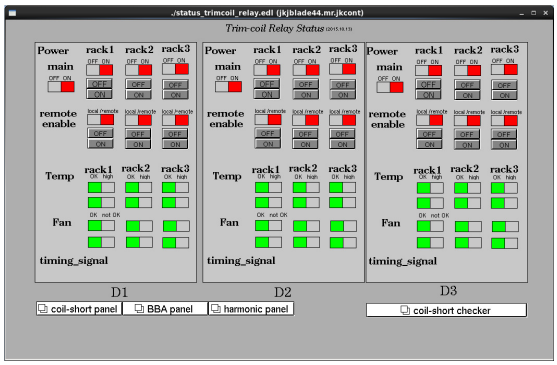

Figure 6: Top screen for the total control.

and fan) can be checked. Moreover, the screen has "open-new display" buttons.

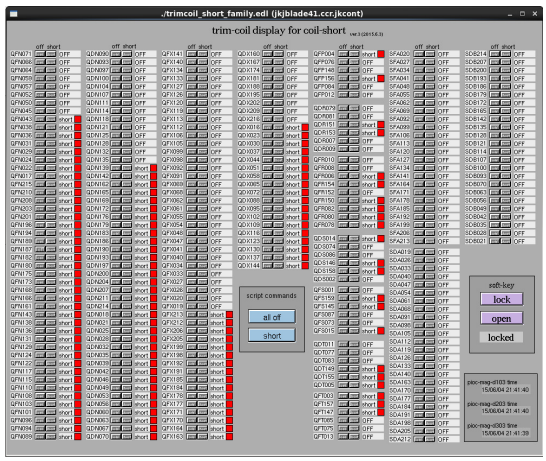

Figure 7: The control screen for switching to "short".

In the following, two screens of four purposes are shown. Figure 7 is the "Short" screen. As the distance from the power supply increases, ripples of magnetic field also increase. Thus, the trim-coils far from the power-supply are often set "Short". As shown in Figure 7, we can select any combination of "Short" trim-coils using this screen. The red indication in Figure 7 means that "Short" is selected.

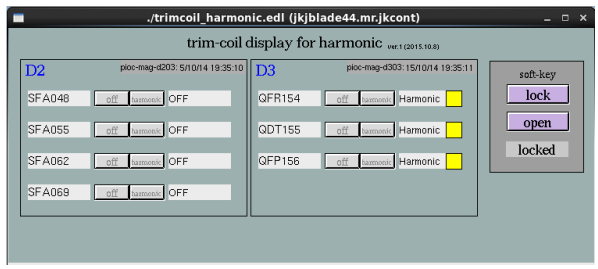

Figure 8: The control screen for switching to "harmonic".

Figure 8 is the "Harmonic" screen. The "Harmonic" purpose needs only 7 trim-coils. Set and reset of each trim-coil is possible. The yellow indication in the Figure 8 means that "Harmonic" is selected.

CONCLUSION

The three setups of the control system for the trim-coil relay-selector were developed. Operation started in April 2015. By using the system, we reduce the overhead time to change relay connections considerably than before.

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