UPGRADE OF THE CONTROL AND INTERLOCK SYSTEMS FOR THE MAGNET POWER SUPPLIES IN T2K PRIMARY BEAMLINE

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Abstract

T2K is a long-baseline neutrino oscillation experiment at J-PARC in Japan. High intensity neutrino/antineutrino beam is generated and propagates 295 km to Super-Kamiokande. High intensity proton beam, 350 kW in May 2015, is extracted from Main Ring synchrotron, guided through a primary proton beamline to a graphite target us- ing normal-conducting (NC) magnets and super-conducting combined-function magnets. In October 2014, we replaced all the power supplies (PSs) for NC magnets with newly de- veloped PSs. We also developed new control system based on EPICS and PLCs, putting emphasis on the safe operation of power supplies, and integrated it into the existing inter- lock system. Consequently the latency time for the interlock system was improved. We report the actual implementation and operation results of these developments.

INTRODUCTION

The T2K (Tokai-to-Kamioka) experiment [1] is a long-baseline neutrino oscillation experiment at J-PARC (Japan Proton Accelerator Research Complex) in Japan. A high intensity neutrinos/anti-neutrino beam is produced, and propagates 295 km from J-PARC to Super-Kamiokande.

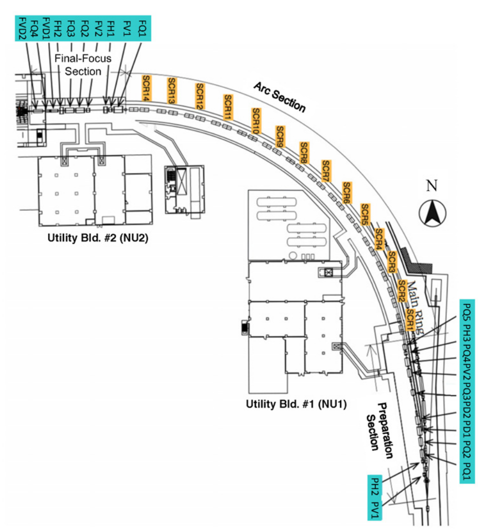

Figure 1: T2K primary beamline.

The T2K neutrino experimental facility is composed of primary/secondary beamlines and a near detector (ND280). The high intensity proton beam, 350 kW in May 2015, is extracted from the Main Ring synchrotron (MR), guided through the neutrino primary beamline to a graphite target.

Figure 1 shows the T2K primary beamline, consisting of the preparation (PREP), arc and the final focusing (FF) sections. In the arc section, 14 doublets of super-conducting combined function magnets [2] are located and bend the beam toward Kamioka direction. In the PREP section, the extracted proton beam is tuned with a series of 11 normal-conducting (NC) magnets. Ten NC magnets in the FF section guide and focus the beam onto the target. The power supplies (PSs) for PREP are located at the utility building-1 (NU1) and those of FF are located at the utility building-2 (NU2).

Critical problems we had on the primary beamline are as follows:

- A single failure shot, caused by trip of NC PSs for example, results in a serious damage of beamline equipments.
- The power supplies of NC magnets were made mostly in 80's and needed increasing effort for maintenance.

In order to solve these problems we developed new power supplies for NC magnets with a power supplies company and replaced in summer 2014.

NEW POWER SUPPLIES

The requirements for new PSs for NC magnets are (1) improvement of safety interlock, (2) precise and stable operation, (3) improvement of maintenancebility, (4) upgrade of control system and (5) downsizing. We report each requirement and actual implementation.

Table 1 shows the types of PS corresponding to the magnet, rated current and unit count. Figure 2 shows frontal new PSs' pictures.

Figure 2: The pictures of a new part of power supplies for normal-conducting magnets. The left is power supply for dipole magnet and the right is four steerings installed in a rack.

ISBN 978-3-95450-148-9

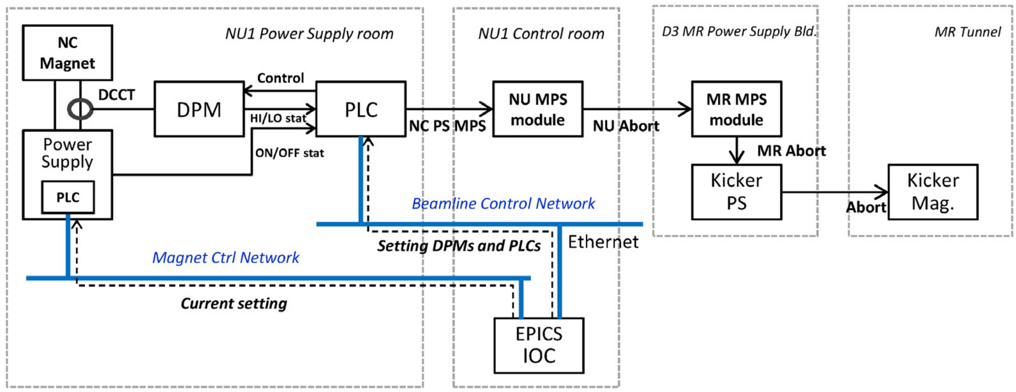

Figure 3: Schematic of control system for new power supplies for normal-conducting magnets.

Table 1: New Power Supplies for Normal Conducting Magnets at T2K Primary Beamline

Magnet type	DC OUT (A) / (V)	Converter type	Current stability(A)	Unit
Dipole	1500 / 100	chopper	0.1	4
Quadrupole	1000 / 100	chopper	0.1	9
Steering I	± 400 / ± 40	chopper	0.05	1
Steering II	± 200 / ± 20	switching	0.05	2
Steering III	± 100 / ± 10	switching	0.05	5

The output current stability is 0.1 A for PSs for dipole and quadrupole magnets and 0.05 A for steering magnets. It is superior to old ones and the ripple of output current is reduced. There are two DCCTs in each PS, one is for feedback control and the other is for interlock using current monitoring. Each PS has a LCD touch panel on the front for local operation. For safer operation, control of the PS is password-protected. We succeed in saving-space (about -67%) by installing four PSs of steering magnets to a rack (see Figure 2)

IMPROVEMENT OF THE CONTROL SYSTEM

The control system for the old PSs was not designed to support EPICS [3]. Therefore we chose relational databases as interface between the old control system and EPICS. The relational databases (MySQL) that represent the status of each magnet were prepared. We could access to the magnet data via tables of MySQL. In the new PSs, we changed the framework of control system less complex configuration which means that we got rid of a unique control system and adopted standard Programmable Logic Controller(PLCs) with EPICS. We built the two EPICS IOCs, one is for PSs at NU1, and the other is for those at NU2. Figure 3 shows a schematic of control system for new PSs at NU1. The IOC is communicate with the PLC which is built-in each PS over Ethernet. We separated the new PS's control network with the existing beamline control network in order to separate from EPICS broadcasts. The new NC PS's output current is monitored by the existing interlock system for current fluctuation as described in next section.

IMPROVEMENT OF THE INTERLOCK LATENCY TIME

We have developed current-fluctuation interlock system for old NC PSs using digital panel meter (DPM) in 2012 [4]. The DPMs continuously sample and digitize the DCCT output voltage of the PSs, and they determine whether it stays within a preset range. HI/LO status outputs of DPM are connected to PLC input-modules. The input-modules aggregate the HI/LO status from all DPMs and the output-module outputs MPS signals. The MPS is an interlock to stop MR beam and protect beamline equipment from high intensity beams or cascade of equipment failures. TheDPM is able to change the number of moving average times for input voltage to remove the fast component of electric noise.

The Old PSs and Latency Time

We measured the latency time of DPM and PLC for old PSs with changing the moving average number. Figure 4 shows the results of measurement. The latency of PLC was measured to be 14 msec, which was nearly constant as expected. The total latency of DPM increases in proportion to the number of moving average times. The ripple of output current of old PSs was large. Therefore we increased the number of moving average for DCCT signal in DPM for digital filter. For the number of moving average of one hundred, about one hundred mili-second latency time was expected at the DPM. In order to reduce the latency time, small number of moving average were required.

The New PSs and Latency Time

In new PS, we use one of two DCCTs in each PS for the interlock. The ripple of output current of new PSs was small, then the number of moving average in DPM was one at all new PSs. We measured the interlock latency time of DPM and PLC with changing the threshold current value of DPM for the PS for PD1, one of dipole magnets.

ISBN 978-3-95450-148-9

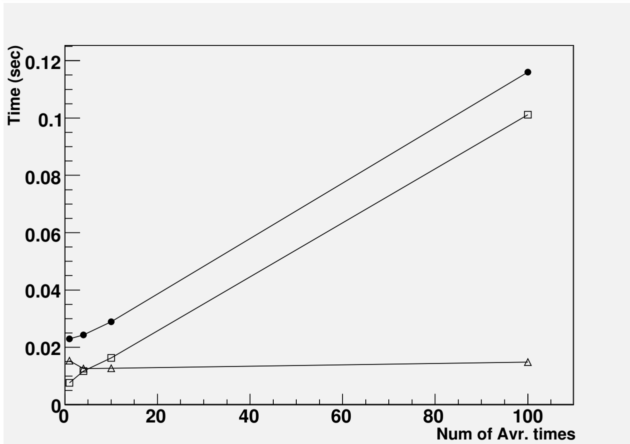

Figure 4: The interlock latency time vs. averaging times on a digital panel meter (DPM). The open triangle shows the latency time of PLC. The open square shows the latency time of a DPM. The closed circle shows the sum of the PLC and the DPM.

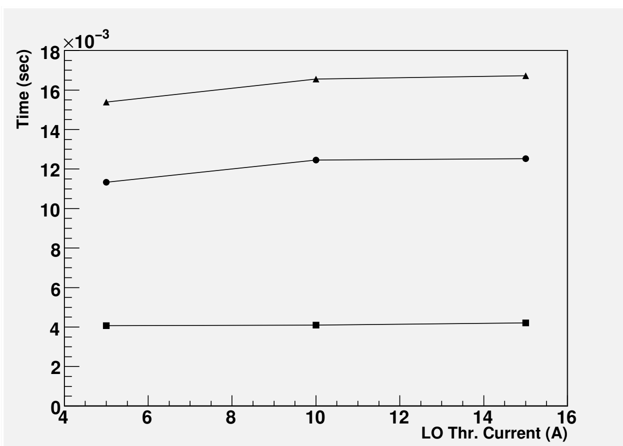

Figure 5: The interlock latency time vs. LO threshold current on a digital panel meter (DPM). The closed square shows the latency time of a DPM. The closed circle shows the latency time of PLC. The closed triangle shows the sum of the PLC and the DPM.

Figure 5 shows the results of measurement. The results shows that the latency time of PLC is almost same as the previous measurement. The latency time of the DPM was about 4 ms due to no averaging at the DPM.

The total latency time of the DPM and PLC is about 16 ms with ±5 A threshold window, which are used at beam operation. Additional latency time from PLC to the fast extraction kicker magnet in MR was 0.07ms. It is negligible small compared with the latency of DPM and PLC. We drastically reduced latency time of the interlock system of NC PSs. It reduces the risk for damage of beamline equipments by high intensity beams.

SUMMARY

We have developed the new NC PSs with the power supply campany and upgraded the control system for safety and stable operation of the high intensity proton beams. We integrated new NC PSs to the existing interlock system for NC PS current fluctuation. The latency time of the interlock system was drastically reduced. We developed EPICS based control system for new NC PSs. The control system is simpler and less complicated than old one.

ACKNOWLEDGMENT

The authors would like to acknowledge the member of J-PARC neutrino facility.

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ISBN 978-3-95450-148-9