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CONTROL INTERFACE AND FUNCTIONALITY OF TPS BOOSTER POWER SUPPLY

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Abstract

The TPS booster is a synchrotron with injection energy at 150 MeV and extraction energy at 3 GeV in 3 Hz. Booster main power supplies consist of one dipole power supply with maximum current 1200 Ampere and four quadrupole family power supplies with maximum current of 120/150 Ampere. The small power supply for booster corrector and sextupole is a low noise switching power supply with +/- 10 Ampere current range. The TPS booster control environment is based on EPICS framework to support rich functionalities including power supply control, waveform management, operation supports, and so on. All power supplies support DC mode and 3 Hz ramping mode operation for TPS booster commissioning and operation. Efforts on control interface and functionality for TPS booster power supply will be summarized.

INTRODUCTION

The TPS [1] is a latest generation of high brightness synchrotron light source which had completed phase I commissioning in March, 2015 [2-3]. It consists of a 150 MeV electron Linac, a 3 GeV booster synchrotron, and a 3 GeV storage ring. The EPICS (Experimental Physics and Industrial Control System) was chosen for the TPS accelerator control.

The control interfaces of TPS booster power supplies have two major categories: one is for the large main power supply which could provide current up to 1200 and 120/150 amperes and used for dipole magnets and quadrupole magnets respectively; the other is small power supply which supports +/- 10 Amperes current output and used for sextupole magnets and correctors. Table 1 summarizes the specifications of booster ring power supplies [4-5].

Table 1: TPS Booster Ring Power Supply Summary

Magnet	Type	Max Current	Number of PS	PS Vendor	Control Interface
Dipole	Unipolar	1200 A	1	Eaton[4]	RS485 & Analog interface
Quadrupole	Unipolar	120/150 A	4~5	Eaton	RS485 & Analog interface
Sextupole	Bipolar	± 10 A	4	ITRI [5]	Analog interface
Corrector	Bipolar	± 10 A	HC: 60 VC: 36	ITRI	CPSC (Ethernet)

All of these power supplies should have features of waveform play with external trigger functionalities to enable electron beams ramp from 150 MeV to 3 GeV in 3 Hz. The large power supply provides RS-485 control interface for ON/OFF and status reading and analog input for current setting. One dedicated EPICS IOC is used to

serve its control and monitor. The small power supplies have 12 special designed corrector power supply controllers (CPSC) with embedded EPICS IOCs allocated at power supply rack for its control. The control environment of these power supplies will be summarized in this report. Fig. 1 shows the pictures of dipole and quadrupole power supply for booster synchrotron which had been installed in the site.



Figure 1: Large and small power supplies for the dipole, quadrupole, sextupole and correctors of TPS booster synchrotron respectively.

CONTROL INTERFACE OF BOOSTER MAIN POWER SUPPLY

The booster main power supplies are composed of one dipole power supply with maximum current 1200 Amperes and four family quadrupole power supplies with maximum current of 120/150 Amperes. These power supplies support analog input for power supply current setting (DC and AC). Serial to Ethernet adapter are used to interface between the booster main power supplies and EPICS IOC.

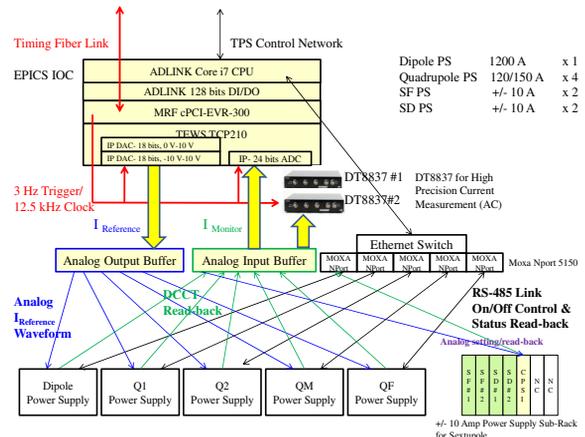


Figure 2: Control infrastructure of TPS booster ring dipole, quadrupole and sextupole power supplies.

Fig. 2 shows the overall booster ring dipole, quadrupole and sextupole power supplies control interface. One cPCI crate equipped with one CPU blade, one EVR, one 128 bits DI/DO and ADC/DAC modules will serve to control booster main power supply and synchronous precision monitor. There are small power supply will drive four power supplies for two sextupole family. Besides, the DT8837 equipped 24 bits ADC provides extra high more precision monitoring than ADC modules.

OPERATION SUPPORTS OF BOOSTER MAIN POWER SUPPLY

To support electron beams ramping from 150 MeV to 3 GeV, Extensible Display Manager (EDM) is used for general power supply on/off control and status display and MATLAB-based Graphic User Interface (GUI) is developed to generate and download waveform via EPICS channel access interface. Fig. 3 shows the EDM page for booster main power supply control. Power supply could be operated at DC/AC mode. Fig. 4 shows the MATLAB GUI for ramping waveform generation and download of booster ring dipole, quadrupole and sextupole power supplies. The injection time (T_{inj}), extraction time (T_{ext}), injection and extraction energy could be adjusted. Then according to the energy as time, current waveforms of dipole and quadrupoles are mapped from the measured energy-current mapping tables.

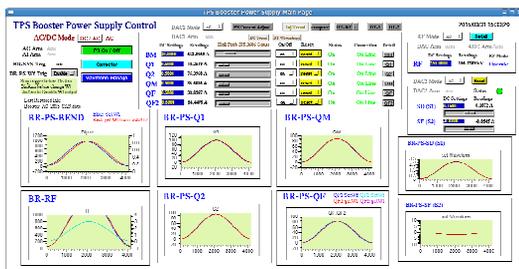


Figure 3: EDM page for booster main power supply control.

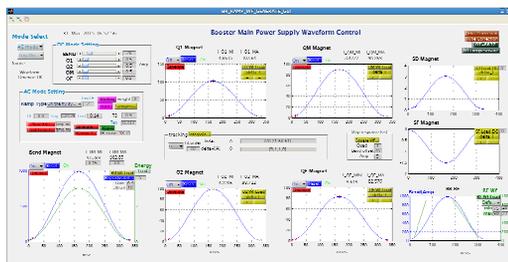


Figure 4: MATLAB GUI for ramping waveform generation and download of booster ring dipole, quadrupole and sextupole power supplies.

Power supply for booster dipole and quadrupoles were contracted and delivered by Eaton. System test at final installation site with real magnet loads are in July 2014 [6]. Fig. 5 shows the difference between target waveform and reading waveform of dipole and quadrupole power supplies. It exhibits a phase delay which would result in

10%~30% error at low current between setting/reading. However, due to the limited bandwidth of power supplies regulation loop, different magnet loading will lead to different phase delay for dipole and quadrupole power supplies.

To improve the relative error between the output reading and reference of dipole and quadrupole power supplies, several strategies are developed [7]. Fig. 6 shows the error between power supply output current and reference is decreased to 0.2 % after 4 iteratively modification. Besides, the reproducibility (stability) of power supply itself is less than 0.2% and normalized quadrupole power supplies tracking error to dipole power supply at injection point for every shot as shown in Fig. 7.

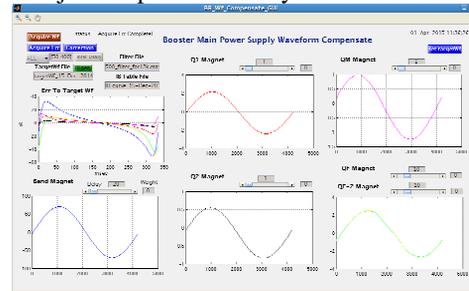


Figure 5: MATLAB GUI for booster main power supply current waveform compensate. The error between power supply output current and reference is 10%~30%.

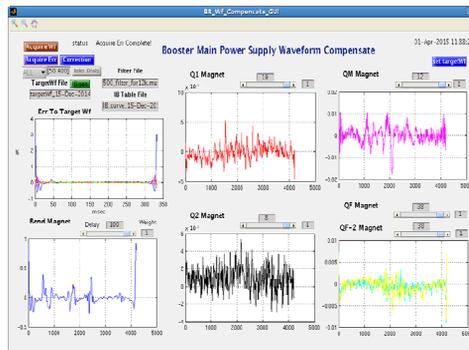


Figure 6: The error between power supply output current and reference is decreased to 0.2 % at low current after 4 iteratively modification.

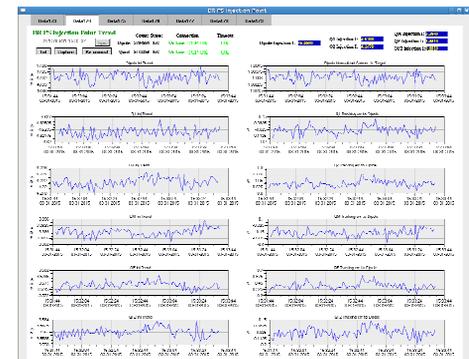


Figure 7: The EDM page shows the reproducibility (stability) of power supply itself and normalized quadrupole power supplies tracking error to dipole power supply at injection point for every shot.

CONTROL INTERFACE OF BOOSTER CORRECTOR POWER SUPPLY

The small power supply for booster sextupole and corrector is a sophisticated switching power supply with analog regulator. Each power supply sub-rack accommodates up to eight power supply modules. The center slot is allocated to install a CPSC for control eight power supply modules. CPSC is embedded with Xilinx Spartan-6 FPGA and was contracted to D-TACQ [8]. The CPSC embedded EPICS IOC to access via EPICS CA clients. The functional block diagram of CPSC module is shown in Fig. 8.

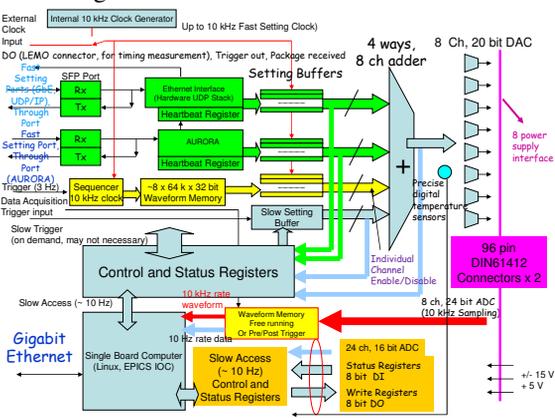


Figure 8: Functional block diagram of the corrector power supply controller (CPSC) module.

There are 60 horizontal correctors and 36 vertical correctors are controlled via 12 CPSCs. The CPSC has built-in waveform generator which can be fulfilled corrector current ramping functionality. EDM control pages of booster corrector power supplies had been developed and provided as shown in Fig. 9.

Figure 9: TPS booster corrector power supply control summary EDM page.

Fig. 10 shows each power supply control page which includes output current trend, ramping waveform display, status indicate, synchronization mode settings and etc. Furthermore, the CPSC can provide output current waveform capture with free running or pre/post trigger. This function can be helpful to diagnostic power supply performance and adjust PID factor of power supply for different magnet load. Fig. 11 shows MATLAB script which is used to check booster corrector power performance. It was quite obvious that which power supply has trouble or oscillation.

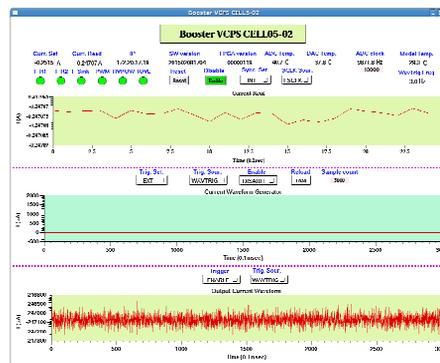


Figure 10: EDM page of corrector power supply for detail information.

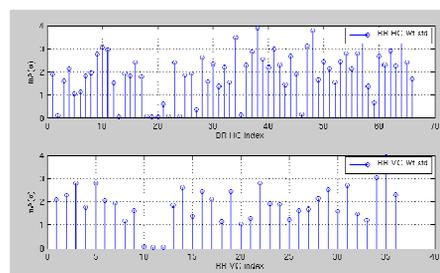


Figure 11: Simple MATLAB script for the corrector power supply performance check.

SUMMARY

Control interface, EDM GUI, MATLAB-based GUI and operation procedures of booster power supply are presented in this report. After power supplies installation, the power supply control environment was set up for TPS booster ring commissioning and operation. The operation applications including the operation interface, power supplies on/off/current setting and checking, ramping waveform download and etc. had been delivered. Functionality and performance of the booster power supply control have been proofed and satisfied the TPS booster ring commissioning requirement.

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