POWER SUPPLY CONTROL INTERFACE FOR THE TAIWAN PHOTON SOURCE

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Abstract

The Taiwan Photon Source (TPS) is a latest generation synchrotron light source. Stringent power supply specification should be met to achieve design goals of the TPS. High precision power supply is equipped with 20, 18, and 16 bits DAC for the storage ring dipole, quadrupole, and sextupole magnets with Ethernet interface. Control interface include basic functionality and some advanced features which are useful for performance monitoring and transient diagnostics. These power supplies can be access by EPICS IOCs. Corrector power supplies control interface is a special design embedded interface module which will mount at the corrector power supply crate to achieve required performance. The setting reference of the corrector power supply is generated by 20 bits DAC and reading is done by 24 bits ADC. The interface module is embedded with EPICS IOC for slow control. Fast setting ports are also supported by the internal FPGA for orbit feedback.

INTRODUCTION

The TPS is a latest generation of high brightness synchrotron light source which has been under construction at the National Synchrotron Radiation Research Center (NSRRC) in Taiwan since 2010 [1]. It consists of a 150 MeV electron Linac, a 3 GeV booster synchrotron, and a 3 GeV storage ring. The magnets of TPS are important components around strong ring, booster ring and transport lines. These magnets are used to bend electron and keep electron orbit of storing ring and booster ring. In order to achieve these requirements, many types of power supplies will be used for different magnets. The TPS power supplies control interfaces include Ethernet and CPSC (Ethernet). The functionalities, operation interface and preliminary test of power supplies will be shown in this report.

The EPICS (Experimental Physics and Industrial Control System) is a set of open source software tools, libraries and applications developed collaboratively and used to create distributed soft real-time control systems for scientific instruments such as the particle accelerators [2]. Many resources and supports are available as well as numerous applications for accelerator have been developed.

As a result, the EPICS framework was also selected as control system infrastructure for the TPS project. The EPICS platform has been gradually built and tested to control and monitor the subsystems of TPS. Utilizing EPICS channel access mechanism with the specific toolkits, the data can be accessed between the IOCs and the clients.

STORAGE RING POWER SUPPLY CONTROL INTERFACE

TPS power supplies control interface are divided into four categories rather than a unified solution. These four kinds of power supplies will be provided by three different vendors. The reason of this choice is to meet the practical situation from manpower, budget and available vendors.

Table 1: TPS Storage Ring Power Supply Summary

Magnet	Type	Max Current	Stability ppm	Number of PS	Vendor	Control Interface
Dipole	Unipolar	750 A	±10	1	IE Power (Eaton)	Ethernet
Quadrupole	Unipolar	250 A	±10	240	Chroma ATE Inc.	Ethernet
Sextupole	Unipolar	250 A	±50	168	Chroma ATE Inc.	Ethernet
Corrector	Bipolar	± 10 A	±10	HC: 168 VC: 168 Fast HC: 96 Fast VC: 96	ITRI	CPSC Ethernet – EPICS CA SFP – Orbit Feedback
Skew Quadrupole	Bipolar	± 10 A	±10	96	ITRI	CPSC (Ethernet)

ITRI: Industrial Technology Research Institute of Taiwan, R.O.C.

Dipole Magnet Power Supply

The storage ring dipole DC power supply will be equipped with Ethernet interface. Control resolution will be 18 bits effective number, noise and drift will be better than 10 ppm and it had contracted to IE Power [3] (acquired by Eaton Corporation in 2011).

Quadrupole and Sextupole Magnet Power Supply

The intermediate power supply for storage ring quadrupole and sextupole magnet with current rating 250 Amp will be equipped with Ethernet interface as well. The quadrupole magnet power supply is 18bit with higher stability than sextupole magnet with 16 bits. The two kinds of power supplies are both contracted to a local company Chroma ATE Inc. [4] and would have internal data buffer for transient recording capability.

Corrector Power Supply and Skew Quadrupole Power Supply

The small power supply for corrector magnets in the range of ±10 Amp categories will be interfaced to analogue interface directly. The power supply is NSRRC home made and manufactured by Industrial Technology Research Institute of Taiwan, R.O.C. [5]. The controller

interface CPSC (Corrector Power Supply Controller) is dedicated to be designed for both EPICS control system and fast orbit feedback application. Table 1 summarizes the specifications of storage ring power supplies.

Control system for the TPS is based upon EPICS toolkit framework. The EPICS toolkit provides standard tools for display creation, archiving, alarm handling and etc. These toolkits which have various functionalities will be employed to monitor and to control accelerator system.

There are 24 of dedicated cPCI EPICS IOCs are built individually at the 24 cells of storage ring to operate the power supplies respectively. Each IOC is used to control 10 quadrupole magnet power supplies and 7 sextupole magnet power supplies, and one of IOC is appended to control only one dipole magnet power supply.

The cPCI EPICS IOC equipped with the latest generation CPU board will be standardized as ADLINK cPCI-6510 CPU module [6]. The 6U cPCI platform was chosen for the EPICS IOC platform. Local company manufactured crate and CPU module which could provide an economic solution is the major reason. StreamDevice is a feasible tool to build connection between EPICS IOC and power supplies.

The small power supplies applied for both slow/fast correctors and skew quadrupole magnets. There will be 8 power supply modules in one crate and the first slot will be plugged in one CPSC. Besides general control, monitor and configuration, the fast correctors will be also applied for the fast orbit feedback. The CPSC with EPICS IOC is therefore dedicatedly designed and the embedded FPGA will handle fast setting application. Synchronization mechanism and built-in waveform are also supported. Figure 1 shows the overall control of power supplies for each cell of the storage ring.

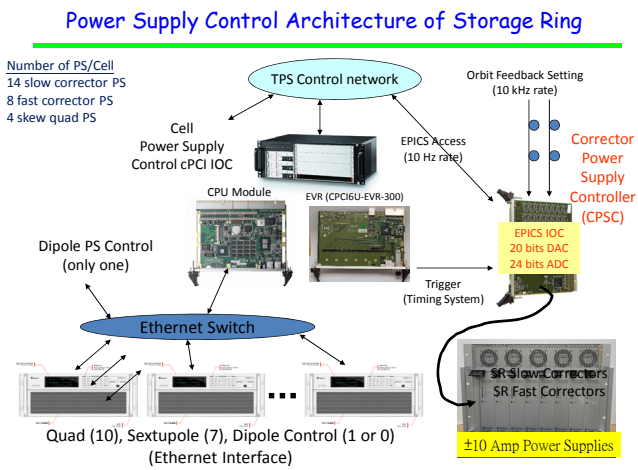

Figure 1: Control infrastructure in one cell of TPS storage ring power supplies.

BOOSTER RING POWER SUPPLY CONTROL INTERFACE

The booster power supplies are composed of one dipole power supply with maximum current 1200 Ampere and four family quadrupole power supplies with maximum current of 130 Ampere. These power supplies will be equipped with the same controller with serial control interface internally. Serial to Ethernet adapter will interface with control system. These power supplies will support external reference input or internal waveform generator for booster power supply ramping. The overall booster ring power supplies control interface is shown in Fig. 2. The most probably booster ramping waveform is sinusoidal wave. Two family of sextupole are driven by two small power supplies. There are 60 horizontal corrector and 36 vertical correctors. Corrector power supplies of the booster will adopt CPSC also. If corrector ramping is necessary, the CPSC has built-in waveform generator which can fulfil this functionality. Table 2 summarizes the specifications of booster ring power supplies.

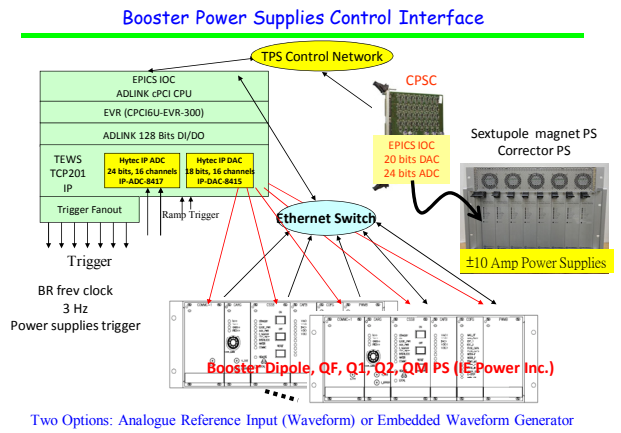

Figure 2: Control infrastructure of TPS booster ring power supplies.

Table 2: TPS booster ring power supply summary

Magnet	Type	Max Current	Stability ppm	Number of PS	Vendor	Control Interface
Dipole	Unipolar	1200 A	±10	1	IE Power (Eaton)	Ethernet*
Quadrupole	Unipolar	130 A	±10	4	IE Power (Eaton)	Ethernet*
Sextupole	Bipolar	± 10 A	±10	2	ITRI	CPSC (Ethernet) with Waveform support in CPSC
Corrector	Bipolar	± 10 A	±10	HC: 60 VC: 36	ITRI	CPSC (Ethernet) with Waveform support in CPSC

TRANSPORT LINES POWER SUPPLY CONTROL INTERFACE

Power supplies for the transport lines includes linac to the booster transport line (LTB) and booster to the storage ring (BTS) dipole magnets, quadrupole magnets and correctors, and DC septa are summarized in Table 3 and Table 4. It was decided that the transport line dipole and quadrupole power supply will adopt the same type power supply as the sextupole power supply of the storage ring to minimize the types of power supply. The rating of the sextupole power supply is 250 Ampere that need parallel two and three sets for the BTS dipole (484 Amp) and DC septa (608 Amp) applications. The power supplies have

the same Ethernet interface with the storage ring sextupole. Despite the corrector for the transport line is much relaxed in the noise specification, the power supply same as the storage ring corrector will be used for this applications to simplify the types of power supply. The corrector power supply for transport line will be controlled by the CPSC module also.

There are two DC septa serve for the booster extraction and storage ring injection to relax the single long pulse septum required due to limited space available for these pulse septa.

Table 3: TPS LTB power supply summary

Magnet	Type	Max Current	Stability ppm	Number of PS	Vendor	Control Interface
Bending	Unipolar	250 A	±10	1	Chroma ATE Inc.	Ethernet
Quadrupole	Unipolar	250 A	±10	10	Chroma ATE Inc.	Ethernet
Corrector	Bipolar	± 10 A	±10	HC: 5 VC: 7	ITRI	CPSC (Ethernet)

Table 4: TPS BTS power supply summary

Magnet	Type	Max Current	Stability ppm	Number of PS	Vendor	Control Interface
Bending	Unipolar	500 A	±50	2 (parallel)	Chroma ATE Inc.	Ethernet
Quadrupole	Unipolar	250 A	±50	7	Chroma ATE Inc.	Ethernet
Corrector	Bipolar	± 10 A	±10	HC: 6 VC: 6	ITRI	CPSC (Ethernet)
BR extraction DC Septum	Unipolar	750 A	±10	3 (parallel)	Chroma ATE Inc.	Ethernet
SR extraction DC Septum	Unipolar	750 A	±50	3 (parallel)	Chroma ATE Inc.	Ethernet

POWER SUPPLY CONTROL ENVIRONMENT

To control and monitor power supplies based on EPICS environment via Ethernet, the clients should be installed the specific EPICS base and the graphical OPI (Operation Interface) toolkits, such as EDM (Extensible Display Manager) and MATLAB (channel access via the labCA module) for EPICS channel access.

STORAGE RING POWER SUPPLY OPERATION INTERFACE

The EDM toolkit was chosen to develop the operation interface. The client console can use the specific EDM page to access the data via PV channel access. The preliminary GUI page of storage ring dipole, quadrupole and sextupole magnet power supplies controls should be shown in Fig. 3. Figure 4 shows the GUI page of storage ring vertical corrector, horizontal corrector and skew quadrupole magnet power supplies controls. The macro name method was regularly used to switch each display page. The main control page was shown critical information for observing status easily, and the main operation process functions are also executed from the panel.

The MATLAB toolkit with labCA is adopted to develop the high level application program for commissioning and diverse operation procedures. The application includes the specific overall power on/off control, degauss process, checking power supply status, operation performance analysis, operation statistics and etc. The various operation processes will be developed and tested according to the various operation modes. The detail control page of power supplies with the trend plot for observing is shown in Fig. 5. It shows the current variation during the degauss process executed. The degauss application is also developed with the specific function of batch process to reduce the peak of power consumption for saving energy.

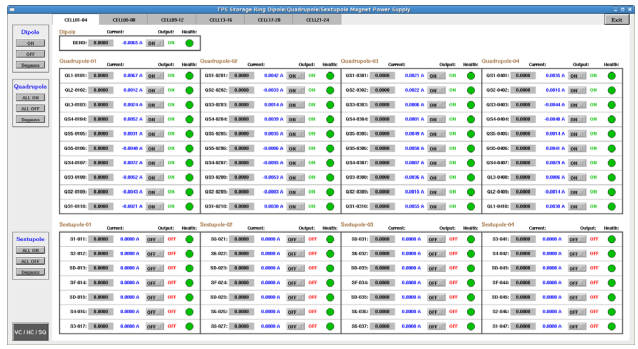

Figure 3: The operation interface of storage ring dipole, quadrupole and sextupole magnet power supplies.

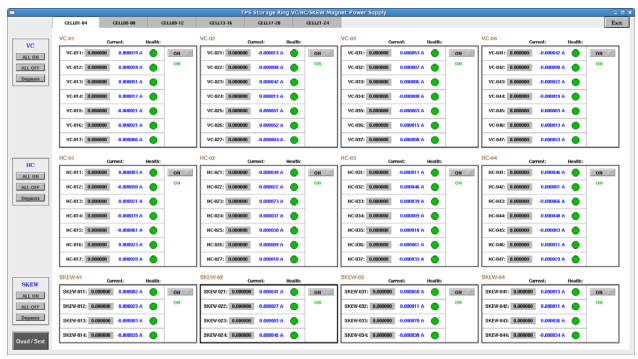

Figure 4: The operation interface of storage ring vertical corrector, horizontal corrector and skew quadrupole magnet power supplies.

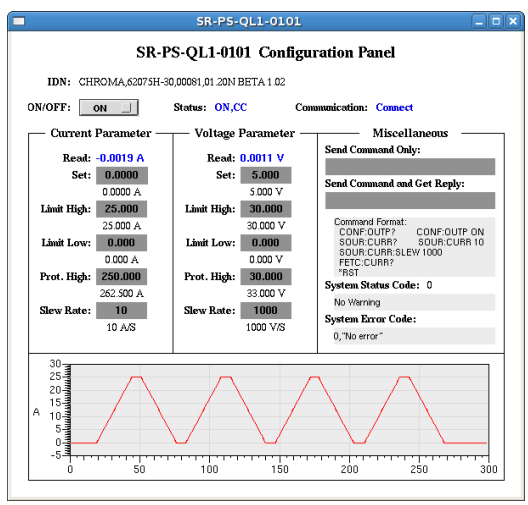

Figure 5: The trend shows current variation of the quadrupole magnet power supply during the simulated degauss process.

PRELIMINARY TEST OF INTERMEDIATE POWER SUPPLY

The several prototype intermediate power supplies for storage ring quadrupole magnet and sextupole magnet have been delivered in NSRRC. These power supplies including 18 bit resolution is used to control quadrupole magnet and 16 bit resolution for sextupole magnet. These power supplies have internal data buffer for transient waveform recorder. The maximum recorder time is 10 seconds with 1k samples/sec and 10000 recorder points. The transient waveform recorder is helpful to analyse behaviours of power supply.

The quadrupole magnet power supply provides sinusoidal wave generator in output DC current of power supply. The frequency and amplitude of sinusoidal wave are adjustable. The sinusoidal wave generator will be used to diagnose power supply and beam physics applications. Figures 6-7 show functionality tests include transient waveform recorder and sinusoidal wave generator for sextupole magnet and quadrupole power supplies. Figure 8 displays current setting resolution test of the prototype sextupole magnet power supply. The resolution is 10 mA with magnet load. The current setting resolution is 5 mA with magnet load for quadrupole magnet power supply is shown in Fig. 9.

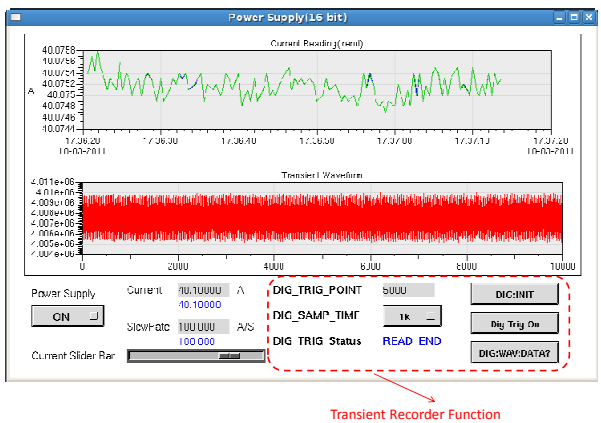

Figure 6: The engineer test EDM screen for functionality of the sextupole magnet power supply.

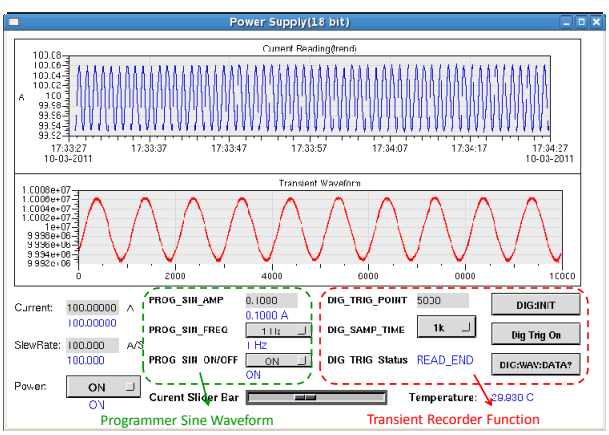

Figure 7: The engineer test EDM screen for functionality of the quadrupole magnet power supply.

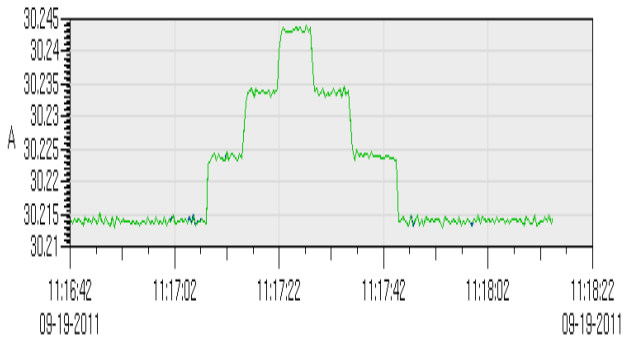

Figure 8: The current setting resolution test of the sextupole magnet power supply.

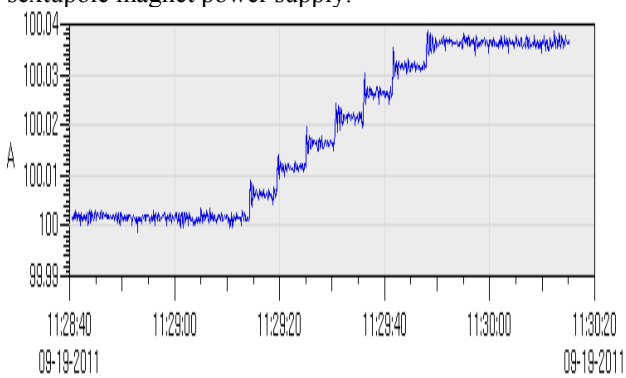

Figure 9: The current setting resolution test of the quadrupole magnet power supply.

SUMMARY

The power supply system of TPS is still in the acquisition phase. Most of power supplies will arrive in 2012. Preparation of the power supply control interface is on going. Prototyping of EPICS support for intermediate power supply of the storage ring, booster ring and transport lines are in proceeding. Plan of the power supply control for main power supply of the storage ring and booster ring is on the way. The CPSC module was contracted to the vendor, detailed design is in proceeding.

Preliminary user interfaces and operation procedures are presented in this report. Before power supplies delivered, the virtual power supply control environment was constantly established for developing the operation applications in advance. The operation applications include the operation interface, power on/off setting and checking, degauss process and etc. The various operation processes will be developed and tested according to the various operation modes. The performance and high level applications of power supplies of TPS will be demonstrated other reports in the future.

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