

COMMISSIONING OF THE TPS CONTROL SYSTEM

C.Y. Liao[#], J. Chen, Y.S. Cheng, P.C. Chiu, C.Y. Wu, C.H. Huang, K.H. Hu, Y.T. Chang,
D. Lee, S.Y. Hsu, C.J. Wang, C.H. Kuo, K.T. Hsu
National Synchrotron Radiation Research Center, Hsinchu 30076, Taiwan

Abstract

Control system for the Taiwan Photon Source (TPS) has been completed in 2014. Commissioning of the accelerator system is in proceeding. Electron beam were stored at the storage ring and emit first light in December 31, 2014. TPS control system adopts EPICS toolkits as its frameworks. The subsystems control interfaces include event based timing system, Ethernet based power supply control, corrector power supply control, PLC-based pulse magnet power supply control and machine protection system, insertion devices motion control system, various diagnostics related control environment, and etc. The standard hardware components had been installed and integrated, and the various IOCs (Input Output Controller) had been implemented as various subsystems control platforms. Low level and high level hardware and software are tested intensively in 2014 and final revise to prepare for routine operation is under way. Efforts will be summarized at this paper.

INTRODUCTION

The TPS [1] is a latest generation of high brightness synchrotron light source which is constructed at the National Synchrotron Radiation Research Center (NSRRC) in Taiwan. TPS consists of a 150 MeV electron linac, a booster synchrotron, a 3 GeV storage ring, and experimental beam lines. Ground breaking for civil construction was held on February 2010. The construction works were completed in April 2013. Accelerator system installation and integration was proceeding in later 2013. The control system environment was ready in half of 2014 to support subsystem integration test and commissioning without beam. After 4 months of hardware testing and improvement, the TPS initiated the commissioning of the booster ring and storage ring on December 2014. On the last day of 2014, the TPS has delivered its first synchrotron light [2, 3].

Adequate and reliable functionality of control system is one of the key to the success of TPS commissioning. Control system for the TPS is based on the EPICS framework [4]. The EPICS toolkits provide standard tools for display creation, archiving data, alarm handling and etc. The EPICS is based on the definition of a standard IOC structure with an extensive library of driver and support a wide variety of I/O cards. The EPICS toolkits have various functionalities which are employed to monitor and to control accelerator system.

The TPS control system consists of more than a hundred of EPICS IOCs. The CompactPCI (cPCI) is

equipped with input/output modules to control subsystems as standard IOC. The other kinds of IOCs are also supported by the TPS control system, such as BPM IOC, PLC IOC, various soft-IOC and etc.

To achieve high availability of the control system, emphasis has been put on software engineering and relational database for system configurations. Data channels in the order of 10^5 will be serviced by the control system. Accessibility of all machine parameters through control system in a consistent and easy manner will contribute to the fast and successful commissioning of the machine. High reliability and availability of TPS control system with reasonable cost and performance are expected.

SYSTEM COMPONENTS

The system installation and integration with subsystems for the control system was done [5]. Details of the control system are summarized in the following paragraph.

General EIPCS IOC Interface

There are many different kinds of IOCs at equipment layer to satisfy various functionality requirements, convenience and cost consideration, shown in Table 1. Most of the devices and equipments are directly connected to cPCI IOCs with EPICS. The cPCI EPICS IOC is equipped with the cPCI-6510 CPU board. The cPCI-7452 128 bits DI/DO module is used for BI, BO solution. ADC and DAC modules in IP (Industry pack) module form-factor are used for smaller channel count application, such as insertion devices control. Event system modules are in 6U cPCI form-factor. Private Ethernet will be heavily used as field-bus to connect many devices. Power supplies of all magnets except for correctors are equipped with Ethernet to the EPICS IOC. Multi-axis motion controller with Ethernet interface is the standard for the control system.

Ethernet attached devices are connected to the EPICS IOC via private Ethernet. Devices support VXI-11, LXI, Raw ASCII and Modbus/TCP protocol are connect to EPICS IOC directly by TCP/IP interface. Devices of this category include power supply, temperature acquisition (RTD or thermocouple), digital multi-meters, oscilloscopes, signal generator, and other instruments.

All corrector power supplies are driven by the corrector power supply controller (CPSC) module [6]. The CPSC equips with 20 bits DAC and 24 bits ADC. Two SFP ports supported by the on board FPGA (Spatan 6), these SFP ports are receive correction setting (Aurora and Gigabit Ethernet by using UDP/IP protocol) from fast orbit feedback FPGAs to slow orbit feedback PC, feed-

[#]liao.cy@nsrrc.org.tw

forward correction computer and IOC. Setting command sent to these SFP ports will be added with the slow setting from EPICS CA client.

Table 1: Type of EPICS IOCs

Type	Quantity	Applications
6U CompactPCI	~40	CIA IOCs, Timing, RF, ID, etc.
COM Express Embedded	72 (Atom) + 13 (xScale)	BPMs
EPICS IOC Embedded PLC	13	Pulse Power Supply, MPS
Embedded w PCI/PCIe	10~20	Gateways and Beam-line Timing
Embedded w POE	~5	Image IOCs
Embedded IOP	~122	Corrector PSs
Miscellaneous	~20	Software IOCs, Bunch-by-Bunch Feedbacks, LabVIEW IOCs, etc.

Power Supply Control

TPS power supplies control interface are divided into three categories due to it provides by three different vendors. The small power supplies for corrector magnets, skew quadrupoles are in the range of ± 10 Amp categories. This category power supply will be in module form-factor. Each power supply sub-rack can accommodate up to 8 power supply modules. A custom designed CPSC module was installed at control slot of the sub-rack. The CPSC will be embedded with EPICS IOC and provide fast setting SFP ports to support orbit feedback functionality. Power supply modules installed at the same sub-rack will interface to this CPSC module.

The intermediate power supply with current rating 250 Amp is equipped with Ethernet interface. Power supplies are expected to have internal data buffer with post-mortem capability. There are two versions of power supply in this category, sextupole power supply with 16 bits resolution and quadrupole power supply with 18 bits resolution DAC.

Storage ring dipole DC power supply and power supplies for the dipoles and quadrupoles of the booster synchrotron are contracted to Eaton. Each power supply equips with RS-485 serial interface. MOXA serial to Ethernet adapters enable directly interface with the EPICS IOCs. The storage ring dipole will be control via this link. Booster dipole and quadruple power supplies will interface by precision analogue interface as shown in Fig. 1. The DACs and ADCs operated synchronize by the same clock and trigger to achieve better reproducibility. Waveform generate form the DAC on IOC will drive these booster power supplies. This functionality is essential for energy ramping of the booster synchrotron [7]. Control resolution of these power supplies has 18 effective bits.

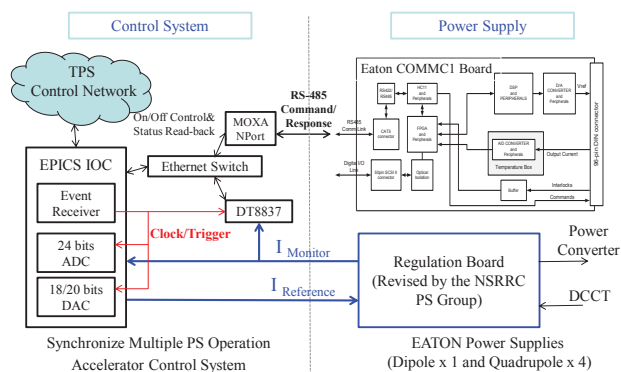


Figure 1: Booster synchrotron AC power supply control interface.

Networking and Timing System

Mixed of 1/10 Gbps switched Ethernet are deployed for the TPS control system [8]. The Gigabit Ethernet connection was delivered at edge switches installed at control and instruments area (CIA). The control network backbone is a 10 Gigabit link to the control system computer room. Private Ethernet is used for Ethernet based devices access which support fast Ethernet and GbE. Adequate isolation and routing topology will balance between network security and needed flexibility. The file and database servers are connected to the control and intranet network, allowing the exchange of data among them. Availability, reliability and cyber security, and network management will continue to strengthen.

The event system consists of event generator (EVG), event receivers (EVRs) and a timing distribution fiber network [9, 10]. The EVG and EVRs can be installed with various universal I/O mezzanine modules to meet different input/output requirements. The mechanical form-factor of EVG and EVRs is in 6U cPCI module. The 125 MHz event rate will deliver 8 nsec coarse timing resolution. Fine delay is supported by the EVRTG which generates gun trigger signal. Its high resolution and low timing jitter provide accurate synchronization of hardware and software across the TPS control system.

Insertion Devices and Front-end

Insertion devices (ID) control for the phase I project include one set of EPU46, two sets of EPU48 [11] and seven sets of in-vacuum insertion devices (two sets of 2 meter long IU22-2m, three sets of 3 meter long IU22-3m, and one set of 3 meter long IUT22-3m with taper functionality). Motion control was done by the Galil DMC-40x0 motion controller. In-house EPICS device support for this motion controller was developed. A cPCI EPICS IOC equips with AI/AO/BI/BO I/O modules were used. All parameters of motion controller will be created as EPICS PVs. Update rate can be up to 200 Hz. This would be useful for feed-forward compensation process. The user interface of insertion device with front-end layout is shown in Fig. 2.

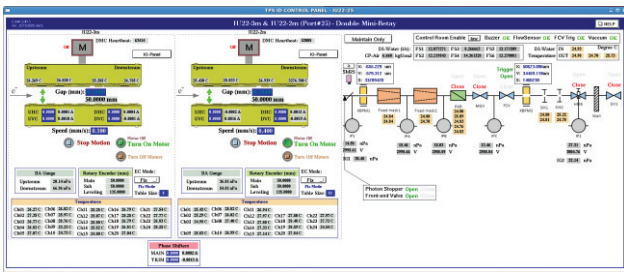


Figure 2: Graph user interface of two insertion devices (IU22-3m + IU22-2m) with front-end.

Diagnostic System

New generation digital BPM electronics is equipped with Ethernet interface for configuration and served as EPICS CA server with 10 Hz data rate. Another multi-gigabit interface will deliver beam position for fast orbit feedback purpose at rate up to 10 kHz. The BPM electronics will also provide post-mortem buffer for orbit analysis during specific event happened like beam loss.

High precision beam current reading and lifetime calculation was done at a dedicated IOC. This IOC will install EVR to received booster cycle timing signals and high resolution IP ADC modules to digitize the DCCT signal and perform beam lifetime calculation.

The GigE Vision digital cameras support for screen monitor [12], synchrotron radiation monitor, X-ray pinhole camera [13] and other applications. Counting type and integrating type beam loss monitors was connected to the control system by counter or ADC modules installed at IOCs.

PLC and Interlock

The PLC was used for most of control system related interlock system [14]. FM3R with embedded EPICS IOC is also used for some applications, such as pulse magnet power supply control and machine protection system (MPS). The MPS collects various interlock signals from local interlock subsystem of orbit, vacuums, front-ends, and etc. The beam disable commands to trip beam or inhibit injection can be distributed to the specific devices or subsystem by the global machine interlock system or uplink functionality of the event system. The summarize control page is shown in Fig. 3.

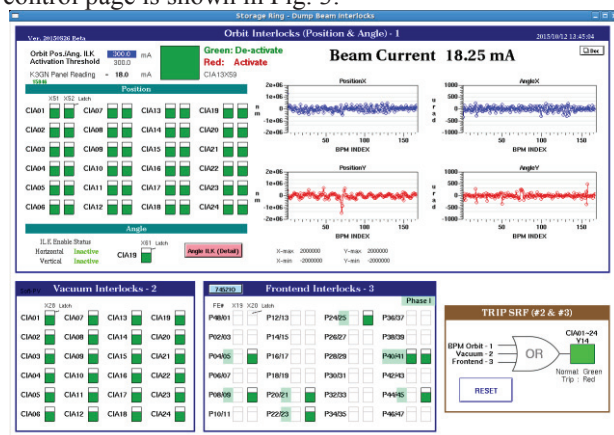


Figure 3: The machine protection system control page.

CONTROL APPLICATIONS

Generic applications provided by the EPICS toolkit will be used for all kinds of applications [15]. Standard tools such as the archive system, alarm handler and save/restore tools are supported. Channel Access (CA) is used as an interface for process variables (PVs) access. Simple tasks such as monitoring, alarm handling, display and setting of PVs are performed using EDM panels and strip tools. Cold start, warm up and shutdown process are done by MATLAB scripts.

Operator Interface

The operator interface level consists of Linux PCs for consoles and servers for various purposes. Operation user interface (OPI) is implemented by EDM, MATLAB and CSS (Control System Studio). The top-layer control page is built by the EDM toolkit shown as the Fig. 4. All control pages can be launched from this page. All control components are located at the foreground of the TPS accelerator illustration.

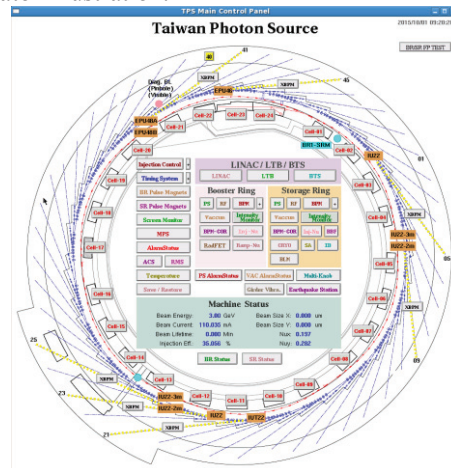


Figure 4: The TPS main control page made by EDM tool.

Save and Restore

To readily restore a set of the machine parameters for subsystems during operation as well as to optimize and record working points for different machine conditions, the mechanism of save and restore is developed. The save and restore function is established by using the MATLAB with the labCA. The various files of grouped PVs (Process Variables) list are created for saving the respective parameter values of each subsystem. The file with PVs and saved parameters is also selectable for resume the settings.

Archive and Logbook

The archive system of CSS (Control System Studio) named BEAUTY (Best Ever Archive Toolset, yet) was built to be used as the TPS data archive system [16]. An archive engine takes PV data from EPICS IOCs via channel access, and stores them in the data storage. The PostgreSQL RDB (Relational Database) was adopted as the data storage for the BEAUTY. Both the historic PVs data and the archive engine configuration are saved into

the same RDB. The archived data can be retrieved in a form of graphical representation using the CSS-based data browser. Taking the performance and redundancy into considerations, the storage servers and RDB table structures are tuned relative.

The “Olog” [17] solution is selected for the TPS electronic logbook. The TPS logbook is recorded the progress about commissioning information by the commissioning team and operators, and supports print function to copy data into the logbook for logging.

Alarm Handler

The “BEAST” (Best Ever Alarm System Toolkit) of CS-Studio with the MySQL RDB is adopted as the alarm handler for the TPS, as shown in Fig. 5. A distributed alarm system monitors the alarms in a control system and helps operators to make right decisions and actions in the shortest time. In the CS-Studio alarm system, each alarm is supposed to be meaningful, requiring an operator action. An alarm is no status display that operators may ignore. Each alarm requires an operator to react because the control system cannot automatically resolve an issue.

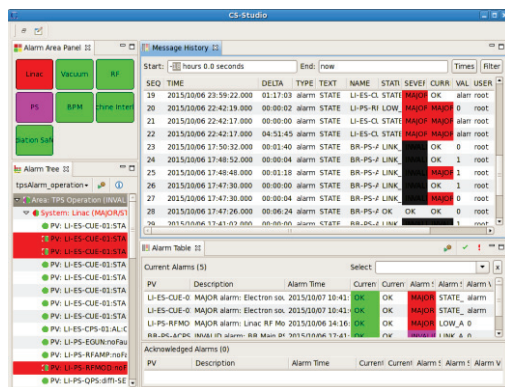


Figure 5: The CS-Studio alarm handler interface.

SUMMARY

The TPS take advantages of the latest hardware and software developments to deliver high performance, rich functionality, and economically control system. TPS control system revised continually during the commissioning and help successful completion the Phase I commissioning. The Phase II commissioning is starting with two superconducting RF cavities and insertion devices. Rich control related applications are developed on going and ready for routine operation.

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