STATUS OF CONTROL SYSTEM FOR THE TPS COMMISSIONING

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Abstract

Control system for the Taiwan Photon Source (TPS) project has been implemented. The accelerator system began to be commissioning from third quarter of 2014. Final integration test of each subsystem will be done. The EPICS was chosen as the TPS control system framework. 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, 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. Development and test of the high level and low level software systems are in final phase. The efforts will be summarized at this report.

INTRODUCTION

The TPS [1] is a latest generation of high brightness synchrotron light source which is being in construction at the National Synchrotron Radiation Research Center (NSRRC) in Taiwan. It consists of a 150 MeV electron linac, a booster synchrotron, a 3 GeV storage ring, and experimental beam lines. Civil construction had started from February 2010. The construction works are approximately finished in half of 2013. Accelerator system installation and integration was proceeding in later 2013. The control system environment was ready in half of 2014 to support subsystem final integration test and commissioning without beam. Commissioning with beam was started from August 2014.

Control system for the TPS is based on the EPICS framework [2]. The EPICS toolkit provides standard tools for display creation, archiving, alarm handling and etc. The big success of EPICS is based on the definition of a standard IOC structure together with an extensive library of driver software for a wide range of I/O cards. The EPICS toolkits which have various functionalities will be employed to monitor and to control accelerator system.

The control system consists of more than a hundred of EPICS IOCs. The CompactPCI (cPCI) IOC will be equipped with input/output modules to control subsystems as standard IOC or the TPS control system. The power supply and fan module of the cPCI crate will be hot-swapped. Adopting cPCI platform for EPICS IOCs provides us a chance to take advantages of local IT industry products with better supports and low cost. The other kinds of IOCs are also supported by the TPS control system, such as BPM IOC, PLC IOC, various soft-IOC and etc. The IOCs, control consoles and servers are also running Linux operation system.

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 contributes to the fast and successful commissioning of the machine. High reliability and availability of TPS control system with reasonable cost and performance are expected.

CURRENT STATUS

Installation for the control system is almost done. The system is ready to do final integration with subsystems. The software environment is ongoing final revision to connect various subsystems. Control related applications are on-going before subsystem ready in June/August 2014. The progress of the control system is summarized in following paragraphs.

Networking

Mixed of 1/10 Gbps switched Ethernet are deployed for the TPS control system [3]. The Gigabit Ethernet connection will be delivered at edge switches installed at control and instruments area (CIA). One CIA corresponding to one cell of the storage ring, there are 24 CIAs in total. 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 will 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 are focus in the design phase.

Equipment Interface Layer

There are several different kinds of IOC at equipment layer to satisfy various functionality requirements, convenience, and cost consideration. Most of the devices and equipments will be connected to cPCI IOCs with EPICS running directly. The 6U cPCI platform was chosen for the EPICS IOC. To simplify various developments at construction phase, only 6U modules are supported for the machine control system. The cPCI EPICS IOC equipped with the latest generation CPU board will be standardized as ADLINK cPCI-6510 CPU module [4]. The CPU module equipped with Intel Core i7

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CPU running Linux provides high performance to meet various applications.

The cPCI-7452 128 bits DI/DO module is used for BI, BO solution, this high density version in 6U form-factor satisfy most of applications. Industry pack (IP) carrier board in 6U cPCI form-factor can equip up to 4 IP modules. Various IP modules are adopted for required applications. ADC and DAC modules in IP module form factor will be 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 will be the standard for the control system.

Ethernet attached devices will connect to the EPICS IOC via private Ethernet. Some network attached devices might not work properly if the network traffic is high due to the simple TCP/IP stack implementation. Private network with lower traffic is to ensure the reliability and performance of the links. Devices support VXI-11, LXI, Raw ASCII and Modbus/TCP protocol are supported to connect to EPICS IOC directly via 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 supply will be driven by the corrector power supply controller (CPSC) module [5]. The CPSC equip with 20 bits DAC and 24 bits ADC. Two SFP ports supported by the on board FPGA (Spatan 6), these SFP ports will receive correction setting (Autora and Gigabit Ethernet by using UDP/IP protocol) from fast orbit feedback FPGAs to slow orbit feedback PC, feed-forward correction computer and IOC. Setting command sent to these SFP ports will be added with the slow setting from EPICS CA client.

Power Supply System Control

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

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 design CPSC module will be 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 CPSC installed 20 bit DAC and 24 bit ADC to ensure necessary performance for the orbit control especially in vertical plane of the storage ring. To simplify the type of power supply, this category power supply will be used for the corrector of LTB/BTS/Booster Synchrotron, and storage ring as well as skew quadrupole magnet power supply. The CPSC modules support waveform capability which can support corrector ramping for the booster synchrotron if necessary.

The intermediate power supply with current rating 250 Amp will be equipped with Ethernet interface. Power-supplies are expected to have internal data buffer with post-mortem capability. Output current of the power supply will output at rear plane BNC connector, which can connect to the cPCI ADC module also. 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. Both kinds of power supply can meet the 50 ppm and 10 ppm performance specifications for long-term drift. Noise level in the 10 ppm range was achived.

Storage ring dipole DC power supply and power supplies for the dipoles and quadrupoles of the booster synchrotron were contracted to Eaton. Each power supply equip with RS-485 serial interface. MOXA serial to Ethernet adapters enable directly All of these power supplies will interface with the EPICS IOCs directly. The storage ring dipole will be control via this link. Booster dipole and quadruple power supplies will interface by precision analogue interface; 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 [6]. Control resolution of these power supplies has 18 effective bits.

Timing System

The event system consists of event generator (EVG), event receivers (EVRs) and a timing distribution fiber network [7, 8]. 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. This mechanism simplifies the operation of the machine and allows complex sequences of events to be carried out by changing few parameters. The system is ready for system integration test and commissioning.

Insertion Devices Control Interface

Insertion devices (ID) control for the phase I project include one set of EPU46, two sets of EPU48 [9] 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). The motion mechanism of EPU46 and EPU48 are driven by servo motors. Undulator IU22-2m are driven by stepping motors, IU22-3m and IUT22-3m are drive by servo motors. Motion control is done by the

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Galil DMC-404x motion controller. In-house developed EPICS devices supports for this motion controller is in use. A cPCI EPICS IOC equips with AI/AO/BI/BO I/O modules will serve an ID. The SSI optical encoder is selected for all IDs. The encoders are connected to the motion controller directly. All parameters of motion controller will be created as EPICS PV. Update rate may be up to 200 Hz. This would be useful for feed-forward compensation process.

Diagnostic System Interface

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. Post-mortem analysis can help to find the weakest point and provide information to improve system reliability.

High precision beam current reading and lifetime calculation will be 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 will capture images for diagnostic purposes and other applications.

Counting type and integrating type beam loss monitors will be connected to the control system by counter or ADC modules installed at IOCs.

PLC and Interlock Solution

The Yokogawa FM3R PLC will be used for most of control system related interlock system [10]. FM3R with embedded EPICS IOC is also used for some applications, such as pulse magnet power supply control. Each subsystem is responsible to build their own interlock and protection system based on their requirement and preference. The global machine interlock system will collect various interlock signals from local interlock subsystem of orbit, vacuums, front-ends, radiation dosage monitors 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.

Operator Interface

The operator interface level consists of Linux PCs for consoles and servers for various purposes. OPI is implemented by EDM, MATLAB and CS-Studio. Consoles in the control room have multiple LCD screens as shown in Fig. 1. These OPI consoles will be installed at the equipment area of control room with optical PCIe extension to remote display unit at control room. This option provides better cooling for the computer, reduce loudness at control room and provide clean control consoles. Large screen format displays hang on the roof at control room will be available for display of important parameters likes beam current, lifetime, vacuum distribution, synchrotron radiation image and etc.

Figure 1: Console in the TPS control room includes multiple LCD screens and ready for use.

Control Applications

Generic applications provided by the EPICS toolkit will be used for all kinds of applications. 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.

SUMMARY

The TPS control system take advantages of the latest hardware and software developments to deliver high performance and rich functionality, and to be economical. The TPS control system environment is ready in June/July 2014 to support various subsystems final integration test. Commissioning of the TPS booster ring is in progress, and commissioning of the TPS storage ring is scheduled in later 2014.

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