EMBEDDED EPICS CONTROLLER IN INSERTING DEVICES OF SSRF

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Abstract

Shanghai Synchrotron Radiation Facility is the first homemade third-generation of synchrotron radiation light source in China. To satisfy the requirements of scientists who use synchrotron radiation light sources doing various kinds of research, about more than 60 beamlines and hundreds experimental station will be set up. In the first stage of SSRF, 7 beamlines have been built. Among of them, 5 beamlines have used inserting devices(IDs) including both of wigglers and undulators. To support stable and long life beam, the control part of these IDs must focus on high stability and high precision. Thus, Simens PLC, which has been widely used in industrial control fields, was used as local device controllers to control the motors. About upper layer control, we adopted a kind of embedded EPICS controller to implement the control of correction coil power supplies and PLC. This embedded EPICS controller is based on a commercial Ethernet/Serial converter which running MontaVista linux as its operation system. Beyond this, Experimental Physics and Industrial Control System(EPICS) IOC Core program and several kinds of device control drivers were integrated to it. After several months using, the whole system works stably. Details of the necessary integration work and operation performance will be discussed in this paper.

INTRODUCTION

The Shanghai Synchrotron Radiation Facility (SSRF), which is comprised of a 3.5GeV electron storage ring, a full energy booster, a 150 MeV linac, and seven beamlines in Phase I, is a third generation light source built in China. Beginning at the end of 2004 with a groundbreaking ceremony, the accelerators were installed in ten months from November 2006. On Dec., 2007, storing electron beams in the storage ring were realized, and the first synchrotron radiations were observed three days later on the front-end of Beamline BL16B of the facility. Now, the accelerator machine runs 3 GeV 100 mA beams with a lifetime of 810 hours. Meanwhile, construction of the first seven beamlines (five ID beamlines and two bending magnet beamlines) has been progressed on schedule. Up till now, all five sets of inserting devices (IDs), including two In-Vac undulators (IVU25), one EPU (EPU10) and two wigglers (W80 and W140) have been assembled and commissioned. Their main parameters are listed in table 1[1].

Table 1: Parameters of Ids in SSRF

Parameter	IVU25	EPU10	W80	W140
Period length(λμ)	25	100	80	140
Number of periods	80	42	19	8
Peak field(T)	0.94	0.6	1.2	1.9
Minimum gap	6	30	13	13

OVERVIEW

Usually, the insertion devices are inserted in a free straight section of the storage ring of the synchrotron for spatially concentrating radiation for research purposes, which typically consists of two arrays of permanent magnets positioned symmetrically above and below the electron beam. The magnets force the electrons into a snake-like path, so that the light from all the curves adds together. Wigglers are similar to undulators but have fewer magnetic poles. The magnetic forces are changeable as each magnet array which is supported by a large and stiff girder can be moved updown, parallel or taper changed with gird based on physical design requirement. Usually, each girder or shifter is controlled by two actuators, one at each end of the beam. This configuration ensures that the parallelism of the magnet arrays can be set and maintained irrespective of the precision of the ball-screw assemblies and also allows the beams to be intentionally tapered relative to each other. However, this configuration also causes considerable added complexity, as an over taper of one or both beams can mechanically damage the linear bearings, the overall structure or in the worst case allow the magnet arrays to come in to contact with each other. Thus, switches and encoder are used to monitor or avoid damage. Additionally, each insertion device is fitted with two correction coils per end, for vertical and horizontal corrections. Finally, the ID control system consists of the motion control, protection system, coil control human interface. Although these insertion devices are about several meters long and weigh about several tons, the insertion devices have to be built to extreme precision. Many of the design tolerances are approximately 50 microns, less than the width of a human hair. To achieve this and support stable and long life commission, the control part of these IDs must focus on high stability and high precision. Thus, Simens PLC, which has been widely used in industrial control fields, was used as local device controllers to control the motors. To combine the local device controller melting into SSRF's distributed control system based on EPICS and interface with power supply controller of coil by serial, linux soft IOC and

Ethernet/serial box are used to accomplish the whole ID control system. The control scheme is as Figuere 1:

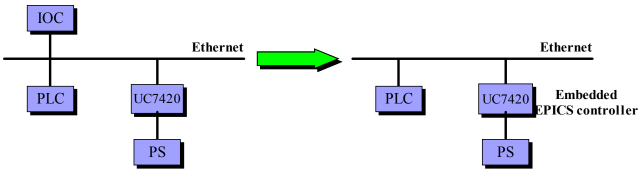

Figure 1: IDs control system architecture.

EMBEDDED EPICS CONTROLLER

In the left side of Figure 1, EPICS can be seen as a SCADA package as EPICS is a toolkit of pre-built components from which an accelerator control system can be constructed. The Linux soft IOC running EPICS IOC core will take response of the control logic of communicating with PLC, implementing the complement logic of PLC, driving the coil power supply and offer a common standard EPICS interface (so call CA protocol) to GUIs and beam line control users. uc7420, which is a commercial Ethernet/serial box made by Moxa company, will take the only role of protocol converter. It's composed of an intel xscale CPU of 266Mhz, 128MB SDRAM of main memory, 32MB flash memory, 8/16 serial ports, buttons, CF storage slot, a lcd panel and with Monta vista linux as it realtime OS. Users are allowed to modify its IP address and serial port parameters basically through telent/http or on the panel. Since UC7400 using a 266Mhz CPU which is more powerful than those old VME CPU boards such as VME2302, we started to consider about the possibility to combine the linux soft IOC and this Ethernet/serial box to one embedded EPICS controller which means running EPICS iocCore on it instead of using it as only an Ethernet serial protocol converter. Then the control architecture will be simplified as showed in right side of Figure 1.

Porting

MontaVista Linux is sufficiently like redhat Linux makes porting it a feasible thing to do. The porting of IOC core was done by following steps[2]:

- Creating 3 new makefiles for new architecture Linux-xscale by using Linux-x86 makefiles as template and doing some modifications of compiler switches.
- Trivial modifications of several EPICS base source codes such as ipAddrToAsciiAsynchronous.cpp.

With the new added cross compile architecture, we can use a Linux PC as the host machine and cross-complied the source code of EPICS base3.14.8.2 on host. Since the UC7400 supports NFS protocol, during debuging, we utilized NFS to mount EPICS base and user application files which exported by host machine, environment variables such as LD_LIBRARY_PATH were set automatically in bash shell of client machine to be pointed to right place. After setting up the cross compile environment, nearly all the EPICS application which originally can run on standard linux will be able to be cross compiled by just trivial modification and run on the new target machine. When utilization, all EPICS programs will be stored on a CF card instead of NFS. These programs can be started up automatically as separated threads by elaborately modifying the linux startup file. All these threads can be monitored by separate log files. Developers can interact with UC7400 from a remote computer through telnet/ssh and modify all developments comfortably. For user who is not interesting in the details about this "black box", the only thing to maintain it is just rebooting it.

Protocol Converter Program

As the important purpose of using this Ethernet/serial box to interface serial devices, a linux driver is needed to implement the function of converting Ethernet protocol at certain port to its serial ports and we call it "proxy". This proxy program would supply three parts of functions:

- Nonblock socket recv/send.
- Multi threads for managing multi serial ports.
- Can be managed separately by modifying configure file of each serial port from file system and save logs.

We implemented these three parts of functions separately in three c files named as socket.c, readcfg.c and proxy.c. Encapsulating all the socket related functions in one file and use it as a library gives the feasibility of developing other network program on UC7400 in future. proxy.c main program uses pthread library to manage the multi threads which respect to serial ports operations. Hence, our new embedded EPICS controller based on Ethernet/serial box is as follows Figure 2.

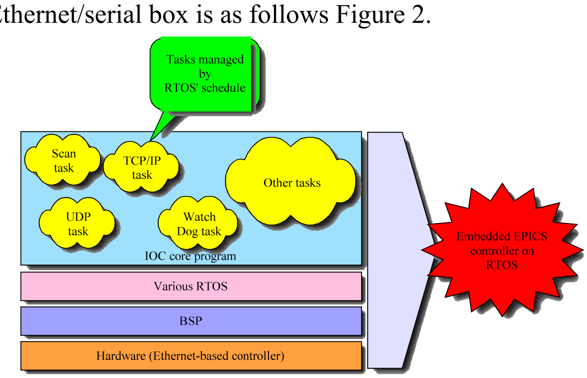

Figure 2. Embedded EPICS controller.

PLC CONTROL

The PLC controls itself is consisted of velocity and position Control, encoder processing and protection controls. But to the different IDs, there is a small difference[3]:

- IVU: 4 step motor are controlled and BERGERLAHR encoder.
- Wiggler: 1 serv motor is controlled by 1 Simens simovert masterdrives MC and HEIDENHAIN encoder.
- EPU: 6 serv motors are controlled by 2 Simens simovert masterdrives MC.

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Additionally, several tens of thermal sensors are installed in in-vacuum undulator which signals are monitored and feedback to protection system.

From the side of embedded EPICS controller, since the PLC takes the same CPU module and same network module, the control methods are same. An existed EPICS driver for S7-plc which was developed by PSI is adopted. This driver is intended to exchange blocks of data which can have arbitrary length and layout over TCP/IP between Siemens S7 PLCs and EPICS IOC. PLC and/or IOC send periodically or when values change. Control signal can be send to PLC in the format as "SR-ID:H17IVU27:CmdGap" and monitor signal can be read back in the format as "SR-ID:H17IVU27:DnEn_Water_Temp" obeying the naming rule of EPICS CA protocol[4].

Need to be mentioned, we connect the PLCs to the uc7400 on a separate physical network using a second network interface to avoid connection problems and decrease network jam in control subnet.

COIL POWERSUPPLY CONTROL

Each insertion device is fitted with two correction coils per end, for vertical and horizontal corrections. Each pair of coils is driven from a 10 Amp bipolar high accuracy DSP based power supply. These power supply units are directly controllable from EPICS. The required correction current applied to the electron beam is a function of insertion device gap. To achieve these two control requirements: An EPICS StreamDevice driver has been modified and cross-compiled to implemented generating a current demand, readback current as well as other power supply controls functions.

About the function of dynamically changing current based on insertion device gap, For example, IVU25 demands the current changing when gap changes. Thus a two dimensional table has been implemented and used by EPICS State Notation Language (SNL). The SNL has also been cross-compiled for this embedded EPICS controller. The trim table was obtained during the insertion device commissioning procedure.

PERFORMANCE

Finally with this power supply controller, we did a simple CPU loading test of UC7400. When no EPICS applications running on it the CPU status was 0.8-1.4% using. With connecting 16 ports serial devices to UC7400 and iocCore running on it at the same time, the values increased to around 35%. Also we have checked the memory usage, about 40M memory was used for MontaVista Linux itself among 128M memory, there was enough free memory left for EPICS applications. Figure 3. shows the cpu health and memory usage of it.

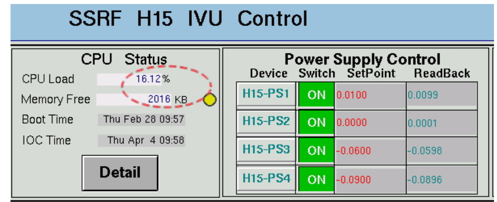

Figure 3. Status of Embedded EPICS controller.

CONCLUSION

We have completed extensive testing and evaluation of this embedded EPICS controller based on MontaVista Linux in these 5 IDs' control system. The reliability and performance of them have been proved good and well suited to our requirements. Practically, the Ethernet/serial box UC7400 is convenient for the quick setting, and considerably enhances the degree of freedom of the installations with the compact controller size and full function characteristic. Since we can monitor the controller status and operate the controller remotely, it also keeps the possibility to be extended or enhanced in future application.

REFERENCES

[1] Q. Zhou et al., "SSRF Phase-I insertion devices", IEEE Trans. Applied Superconductivity, vol.20, no.3, Jun.

[2] Martin R. Kraimer, et al., EPICS Input/Output Controller (IOC) Application Developer's Guide, Release 3.14.8, Argonne National Laboratory, 02-DEC-2005.

[3] J. Zhang, et al., "Local Control System of the Elliptically Polarized Undulator at SSRF", IEEE TRANSACTIONS ON APPLIED SUPERCONDUCTIVITY, VOL. 20, NO. 3, JUNE 2010.

[4] Philip Stanley, et al., EPICS Record Reference Manual, EPICS Release 3.13.