CONTROL OF THE PULSE MAGNET POWER SUPPLY BY EPICS IOC EMBEDDED PLC

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Abstract

The EPICS embedded programmable logic controller (PLC) has been developed based on F3RP61-2L, a CPU module of a FA-M3R series PLC running Linux OS. The EPICS IOC resided in F3RP61-2L module can access the registers of sequence CPU modules and I/O modules of the PLC. The embedded EPICS PLC was applied to control the prototype of pulse magnet power supply and support functionality testing remotely. The system comprises various input/output modules and a CPU module with built-in Ethernet interface. The control information (status of the power supply, ON, OFF, warn up, reset, read/write voltage, etc.) can be accessed remotely using EPICS client tools. The EDM is selected to develop the GUI for itself. Efforts are summarized in this report.

INTRODUCTION

Taiwan Photon Source (TPS) is a 3 GeV synchrotron light source which is being in construction at NSRRC campus. The pulse magnets of the TPS consist of booster injection septum and kicker, booster extraction septum and kicker, storage ring injection septum and kickers, and storage ring diagnostic kickers (pingers). Table 1 lists main parameters of TPS kicker and septum pulse magnets. The EPICS IOC embedded PLC, F3RP61-2L IOC, was adopted for the prototype pulse magnet power supply control. The F3RP61-2L IOC is compact, easy troubleshooting, and cost effective for pulse magnet power supply control. The pulse magnet power supply (pulser) requires small amount of I/O ponits therefore the F3RP61-2L IOC is more suitable compared with the applications of the TPS standard 6U CompactPCI platform with high I/O density.

The EPICS toolkit [1] was adopted for the framework of the TPS control system. A typical PLC in control environment is supervised by a remote IOC through serial link or Ethernet connections. It needs more work for developing both side of control software compared with using F3RP61-2L IOC.

The EPICS IOC embedded F3RP61-2L [2] is devloped by KEK and RIKEN team which simplies the control framework of PLC. The sequencer of EPICS can replace the function of ladder programs. The F3RP61-2L CPU module can function as the EPICS base and access I/O modules. The way to access I/O module of the PLC is "VME-like" without ladder programming and a separated IOC. These are the benefits of F3RP61-2L IOC.

Table 1: Main parameters of TPS pulse magnets

Magnet type	Type	Operating current (A)	Pulse duration (μs)	Pulse shape	#
Booster Injection Kicker	PFN	500	1	Flat top	1
Booster Extraction Kicker	PFN	570	1	Flat top	1
Storage Ring Injection Kicker	Half-sine	4700	5.18	Half-sine	4
Storage Ring Pinger	Half-sine	-	~ 1.5	Half-sine	2
Booster Injection Septum	Half-sine	3500	500	Half-sine	1
Booster Extraction Septum	Half-sine	10000	500	Half-sine	1
Storage Ring Injection Septum	Half-sine	10000	300	Half-sine	1

CONTROL ENVIRONMENT FOR THE PROTOTYPE PULSE MAGNET POWER SUPPLY

The control environment for the prototype pulser control consists of two functional levels as shown in Fig. 1. The upper layer is the operation interface, a typical EPICS EDM page to operate the pulser running in Linux PC with EPICS base installed. The lower one is the F3RP61-2L IOC which monitors status and controls the pulser.

To support remote access of the current waveform, EPICS-scope or oscilloscope is managed by a soft-IOC. To capture waveform of current transformer at pulse magnet, there are two options in EPICS environment. First one: The LAN extension for Instrumentation (LXI) or Ethernet-base oscilloscope is connected to a soft IOC via Ethernet. Second option: Use an EPICS IOC embedded scope.

The timing IOC equipped with event receiver (EVR) will distribute trigger signal of the pulse magnet power supply to synchronize the operation of the accelerator system.

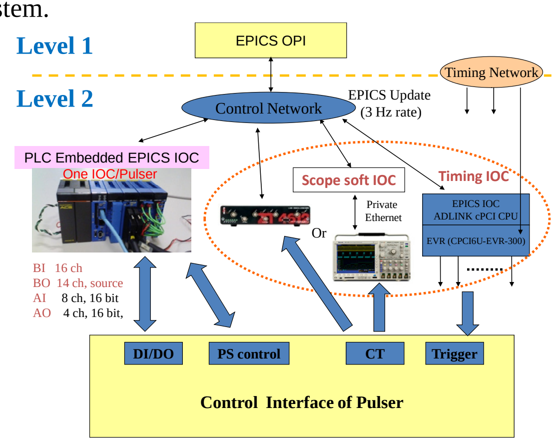


Figure 1: Control environment of the prototype pulse magnet power supply.

PLC I/O Configuration

The I/O modules configuration of Yokogawa F3RP61-2L IOC is shown in Fig. 2. It includes power supply module, 16 bit digital input module, 16 bit digital output module, 8 channel analog input module (16 bit ADC) and 8 channel analog output module (16 bit DAC). The I/O modules are mastered by F3RP61-2L CPU module. The interlock function of pulse magnet power supply is handled by local hardware circuits. It uses relay and timer relay to implement interlock logic and warm up procedure.

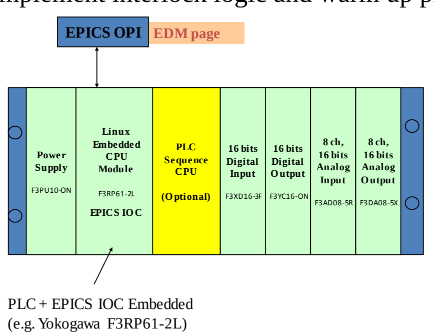


Figure 2: Configuration of EPICS PLC IOC for pulse magnet control.

F3RP61-2L IOC

The F3RP61-based IOCs were adopted for the control systems of KEKB, J-PARC and RIKEN RI Beam Factory [2-5] successfully. The Yokogawa F3RP61-2L CPU complies with FA-M3R form factor and EPICS installed. I/O modules could be accessed by the F3RP61-2L CPU module running Linux as well as the PLC sequence-CPU module. It behaves like multiprocessor environment on the PLC. However, the sequence-CPU module is an option and inessential part.

The Yokogawa Company provides Embedded Linux Development Kit (ELDK) and Board Support Package (BSP) for F3RP61-2L module. A host PC running Red Hat Enterprise Linux is used to develop the embedded EPICS IOC. In order to "make" a new target, F3RP61-2L IOC, few existing configuration files provided by KEK should be modified. Then a set of IOC core program is produced and runs on F3RP61-2L without difficulty.

The Linux system is installed on the CF card in the CPU module. The cross-compile binaries of EPICS programs are placed on the host PC for ease of application development and IOC version control. The Linux on the CF was configured to mount the file system of the host PC so that the F3RP61-2L IOC would download the executable file of iocCore after the boot up. The cross-compile development environment of EPICS Applications is shown in Fig. 3.

KEK has implemented driver/device support for the EPICS records including ai/ao, bi/bo, longin/longout, stringin/stringout and mbbi.

The EPICS sequencer can perform any kinds of logic operations as well as the ladder program runs in PLC sequence-CPU. Both can perform data read-write I/O and registers. The EPICS sequence program with comments is more understandable compared with ladder program. And the work of implementing ladder program may be omitted. EPICS sequencer helps to develop the applications more efficiently.

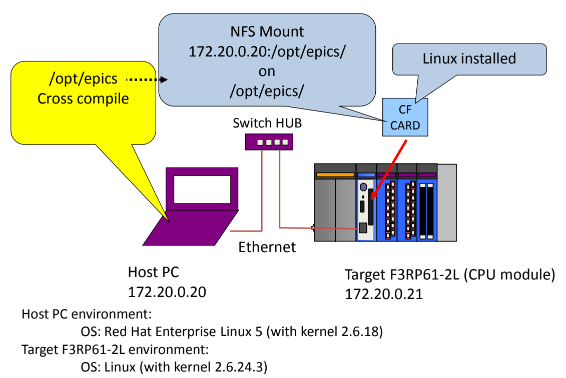


Figure 3: The cross-compile development environment of EPICS Applications.

EPICS Waveform Support of Pulse Magnet

To explore the functionality of remote waveform access, two options were tested. One solution is to build EPICS soft-IOC and use ASYN modules to communicate with LXI or Ethernet-based oscilloscope through Ethernet interface. The ASYN module supports several communication protocols, TCP or VXI-11 is selected to connect oscilloscopes. The system architecture is shown as Fig. 4.

The other solution of the EPICS waveform support adopts commercial EPICS oscilloscope from ZTEC [6]. EPICS-base is built in the ZT4612 scope as an IOC. The client host can utilize the EDM to observe waveform and control oscilloscope without building another IOC to manage. Functionality and performance tests are still ongoing.

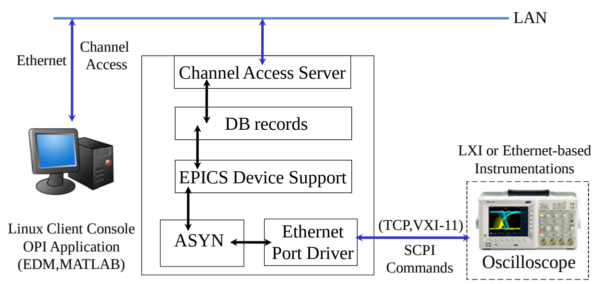


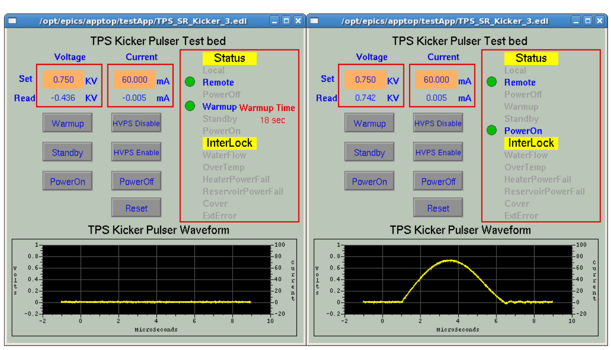
Figure 4: System architecture of building EPICS waveform support of LXI/Ethernet-based oscilloscope.

USER INTERFACE

Fig. 5 shows EDM page to control a current and a voltage of the high voltage power supply of kicker. The functions are "Power ON", "Power OFF", "Warm up", "Standby", "HVPS Enable", "HVPS Disable" and "Reset". Status and interlock information is shown on right part of EDM page. The high voltage of the pulser can be set in range of 0 – 40 kV.

Fig. 5 (a) shows filament of thyratron tube is in warm up program. A count down timer displayed on EDM page shows the warm up progress. Fig. 5 (b) shows the kicker charged to 0.75 kV. The kicker is trigger at 3 Hz which is the repetition rate of the TPS.

The Ethernet-based oscilloscope (Tektronix TDS3054B) is employed to observe waveform by EPICS CA tools.



(a) (b)

Figure 5: The control pages of pulse magnet power supply. (a) The thyratron tube warm up process in proceed. (b) High voltage power supply of kicker turn on and voltage sets 0.75 kV. The lower part of EDM page will display current waveform of kicker when trigger is active.

Figure 6: The F3RP61-2L (the second left module) serving as an EPICS IOC to control a pulse magnet power supply.

The lower part of Fig. 5 (b) shows the waveform measured by current transformer of kicker. The left vertical scale, voltage, is acquired from oscilloscope. The right vertical scale is converted to current. The current waveform of kicker shown on control page helps operators to easily observe working status of kicker. The picture of EPICS IOC embedded PLC installed at the top of the pulser is shown in Fig. 6. The PLC equips with five modules.

FUTURE PLANS

Since the pulse magnet current only exists for a few microseconds for kickers and a few hundred microseconds for septums. To observe the transient waveform, beside the oscilloscope, a peak detector will be implemented to provide control system a quasi-DC reading for the peak current of the pulse magnet in 3 Hz.

Purpose of the test bed for the pulser control is to explore the capability and applicability of the EPICS IOC embedded PLC for the TPS applications. This solution provides a low cost alternative besides a TPS standard cPCI EPICS IOC. Possible applications of the system for TPS are low I/O density system and interlock protection system.

CONCLUSIONS

The embedded EPICS IOC was realized on F3RP61-2L, a PLC-module-type CPU running Linux. The F3RP61-2L simplifies the control of pulse magnet power supply. It helps to develop EPICS IOC more efficiently than using other PLC system. Test bed of controlling pulser prototype by the F3RP61-2L EPICS IOC was set up. The basic operating functionality was tested and EDM page of pulser prototype was developed. Fruitful results were achieved. Efforts and experiences are very helpful for the TPS control system development.

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