CONTROL SYSTEM DESIGN FOR FRONT END DEVICES OF IRFEL*

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Abstract

An Infrared Free Electron Laser Light (IRFEL) is being constructed at National Synchrotron Radiation Laboratory. IRFEL consists of e-gun, accelerating tube, microwave, klystron, power supply, vacuum, resonator, undulator, beam diagnosis, cooling water and other devices. The development of the control system for the front end devices of IRFEL is based on EPICS. This paper will introduce the hardware system design, Input Output Controller application, Operation Interface, data archiving and retrieval.

INTRODUCTION

Tunable Infrared Laser for Fundamental of Energy Chemistry (FELiChEM) is the significant scientific instrument, which is supported by the National Natural Science Foundation of China in 2013 [1]. Infrared Free Electron Lasers (IRFEL) is the core part of FELiChEM, which can accelerate beam to 60MeV and generate middle-infrared and far-infrared laser.

EPICS is a set of open source software tools, libraries and applications developed collaboratively and used worldwide to create distributed soft real-time control systems [2]. EPICS community provides a large number of software tools. When developing the control system for front end devices of IRFEL, ASYN, StreamDevice and iocStats are used in Input Output Controller (IOC) applications. Control System Studio (CSS)/Display Builder is adopted in Operation Interface (OPI) development. The EPICS Archiver Appliance (AA) is used as the data archiving tool for data acquisition, storage, migration and retrieval.

OVERALL ARCHITUCTURE

As shown in Fig. 1, the EPICS based control system follows a standard "three-layer" model, which contains management layer, LAN and front end control layer [3]. The management layer of the IRFEL control system consists of server system and OPI. The hardware of server system consists of several Dell PowerEdge servers and iSCSI SAN storage. Virtualization software VMware is adopted to create multiple virtual machines which are used as file server, web server, relational database and softIOC. The OPI runs on a Linux PC.

The controlled front end devices of IRFEL include e-gun, microwave, klystron, power supply, vacuum, resonator, undulator, beam diagnosis and cooling water. Among these devices, the IOC applications for e-gun, undulator, cooling water and beam diagnosis are provided by the manufacturers, only the OPI need to be developed. When developing the IOC applications for power supply, vacuum, microwave, klystron, resonator, Ethernet is used for the data communication. So the IOC applications can run on the virtual machines. For the front end devices with serial interface, serial device servers are used to connect serial devices to Ethernet. For example, the controlled devices of vacuum system consist of 6 TPG300 vacuum gauge controllers and 20 sputter ion pump controllers, which are all intelligent devices with serial interface and are connected to Ethernet via serial device servers. The power supply system consists of 48 power supplies with Ethernet interface, they are connected to the control LAN directly.

IOC APPLICATION

IOC application is mainly composed of the run-time database, device driver and sequencer as shown in Fig. 2. The run-time database consists of all kinds of records. The naming of records follows the hierarchy "System:Device:Channel:Parameter:Type" which facilitates the development of data archiving and retrieval.

Device driver is divided into three layers: record support, driver support and device support. StreamDevice is used as device support, and Asyn is used as driver support. StreamDevice is a generic EPICS device support for devices with a "byte stream" based communication interface [4]. It is used for multiple device types that support custom communication protocols. Asyn is a general purpose facility for interfacing device specific code to low level communication drivers [5]. It is a general-purpose driver module that supports serial, network, and other communication protocols.

The problem of communication timeout is occurred during tests. We use the State Notation Language (SNL) to write a communication management program to avoid excessive warning messages being written into the log file. Fig. 3 shows the flow chart of communication management program for a record which reads periodically the data from a front end device. A variable is defined to count the times of communication timeout. When the timeout continuously achieves 10 times, the program sets the scan field of the record to Passive in order to stop the data communication. In the same time, an alarm message is sent to the related staff via the alarm system to report the anomaly.

OPERATION INTERFACE

CSS is an Eclipse-based collection of tools to monitor and operate large scale control systems. Display Builder is an upgrade of Best OPI Yet (BOY). Compared with BOY, the design of Display Builder avoids thread delay and improves overall performance for complex widgets, such as scripts and action [6].
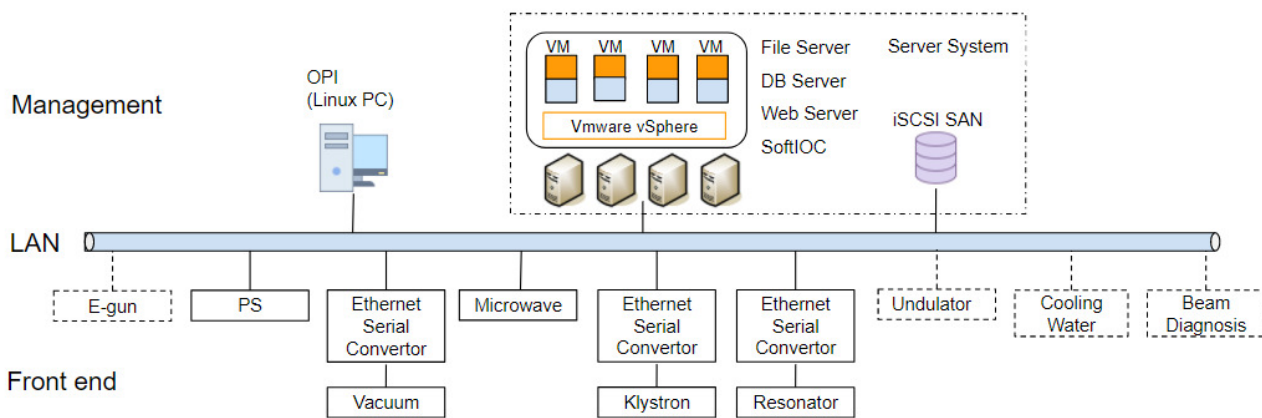
Figure 1: Control System Architecture of IRFEL Front End Devices. The IOC applications of the devices in dashed line box are provided by the manufacturers.
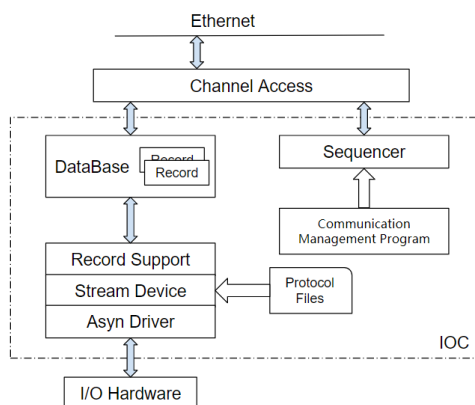

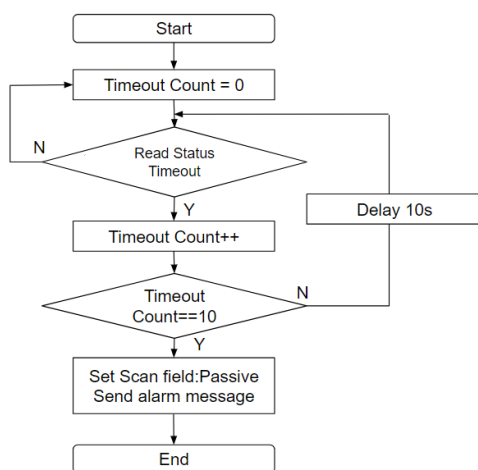Figure 2: Diagram of IOC Application.

Figure 3: Communication Management Program Flow Chart for A Record.

Display Builder is used in the development of OPI. Fig. 4 shows the IRFEL power supply control panel in edit mode, which contains the info of 48 power supplies. Name, communication status, scan period, switch status, setting value,

read back value and error status of each power supply is displayed in the panel.

Figure 4: IRFEL Power Supply Control Panel.

There are three action buttons at the top left of the IRFEL power supply control panel. These buttons act on all power supplies concurrently. The PS On/Off button can turn on/off all power supplies. The Scan Period button can set scan period for all power supplies to passive, 1 second, 2 second or 10 second. The Save/Restore button is used to save and restore the setting value of all power supplies. The Save/Restore action is implemented with python scripts. If "save" option is clicked, a dialog box will pop up to set the name of saved data file and the saved location. If "restore" option is clicked, the historical data file stored before can be selected through the dialog box for recovery.

Click the action button with the power supply name, the corresponding sub-interface will be opened in new tab. Fig. 5 shows the sub-interface that can monitor more detailed status and reset the error state for one power supply.

DATA ARCHIVING AND RETRIEVAL

The EPICS Archiver Appliance(AA) is a data archiving tool released in the EPICS community and provides the functions of data acquisition, storage, migration, retrieval and management in the IRFEL facility [7]. AA divides the data into three types: short term store (in RAM disk), medium term store (in local SSD disk) and long term store (in NFS).This mechanism makes AA have high data retrieval
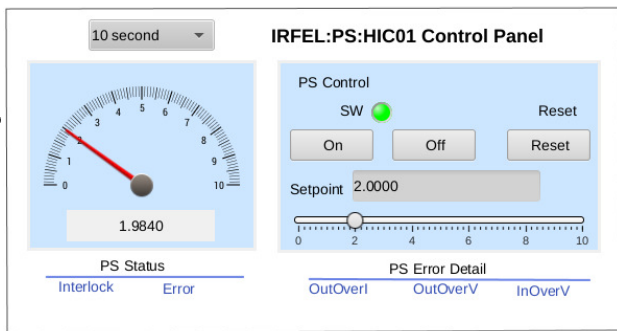
Figure 5: OPI of A Power Supply.

performance, which is helpful to machine status analysis and fault diagnosis.

A Single-Page Application is developed to provide run-time data display and historical data query as a Web-Based GUI based on the HTTP interface. The Web-Based GUI directly obtains the list of all archived records from AA, constructs the hierarchical structure according to the name of record and generates a tree structure. The operator can select the record by clicking the check box in front of the tree node. Then, the chart component based on Highcharts JavaScirpt library on the right shows the curve during the last 24 hours by default, as shown in Fig. 6.
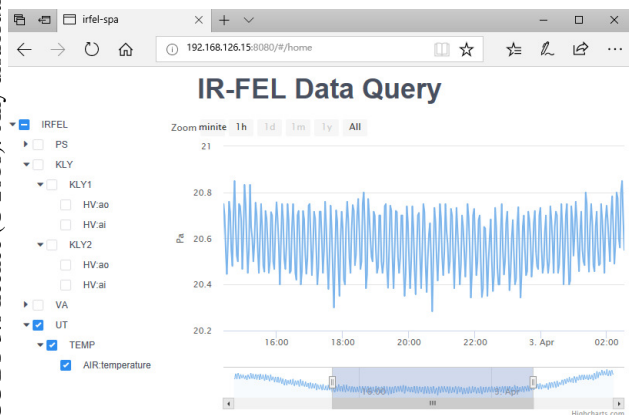

Figure 6: Historical Data Query for IRFEL.

CONCLUSION

EPICS community provides various tools that greatly facilitate the control system development for front end devices of IRFEL. The communication management program written in SNL is useful to avoid excessive warning messages. The well-designed actions in OPIs is much helpful to operate the front end devices. The hierarchy of records naming convention is essential to construct the tree structure of data query. The tests show that the control system offers the advantages of efficiency, stability and convenient operation.

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