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APPLICATION OF EPICS SOFTWARE IN LINEAR ACCELERATOR

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Abstract

The institute of modern physics (IMP) has two sets of linear accelerator facilities, they are CAFe (China ADS front-end demo linac) and LEAF (Low Energy Accelerator Facility). The Main equipment of LEAF facility consists of ion source, LEBT (Low Energy Beam Transport), RFQ (Radio Frequency Quadrupole) and some experiment terminals. Compare with LEAF, CAFe equipment has more and adds MEBT (Medium Energy Beam Transport) and four sets of superconducting cavity strings at the back end of RFQ. In the process of commissioning and running linac equipment, The EPICS Archiver application and Alarm system are used. According to the refined control requirements of the facility sites, we have completed the software upgrade and deployment of the archiver and alarm systems. The upgraded software system have made the operation of linac machines more effective in term of monitoring, fault-diagnostic and system recovery, and becomes more user-friendly as well.

INTRODUCTION

The CAFe is a prototype of ADS proton superconducting linear accelerator. It mainly includes a compact ECR (Electron Cyclotron Resonance) ion source, a low energy beam transport LEBT section, a radio frequency quadrupole acceleration system RFQ , a MEBT, 4 sets of CM superconducting cavity strings, a HEBT (High Energy Beam Transport) and a beam dump with the function of measuring current intensity and absorbing the energy from ion beam [1,2]. The layout of CAFe facility is shown in Fig. 1.

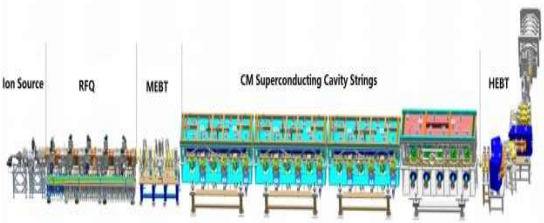

Figure 1: The layout of the CAFe facility.

The CAFe facility can provide a high power beam with the beam intensity of several mA. At the same time, CAFe, as a new research device, needs to do some research on the operation mode of the machine.

The LEAF contains a 45 GHz fourth-generation superconducting high-charge state ECR ion source, a 300 kV high-voltage platform, an advanced RFQ heavy ion accelerator capable of accelerating a variety of ions, and a DTL energy regulator. LEAF is a research facility of the low-energy, high-current and high-charged heavy ion [3]. The layout of the LEAF is shown in Fig. 2.

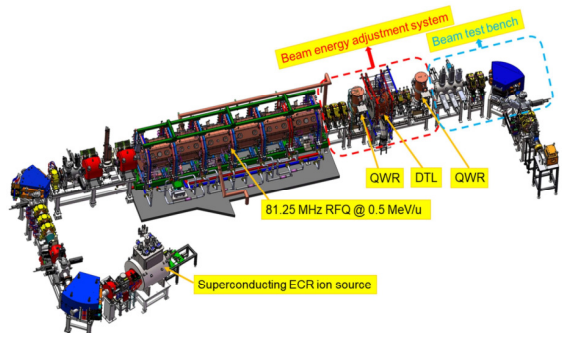

Figure 2: The layout of the LEAF facility.

LEAF can provide pulse (beam energy range of 0.1-20 MeV) and continuous beam with high beam intensity, high charge state and many kinds of ions. The core parts of the LEAF are superconducting high charge ECR ion source and RFQ accelerator. They are the most key equipment of the front-end injector for the next generation large heavy ion accelerator. Therefore, the development of the LEAF will build a good foundation for the development of the next generation high-power high current heavy ion accelerator.

During the commissioning and operation of the LEAF and CAFE accelerator systems, the upper-level applications have a similar requirement for both systems. For example, the alarm system needs to monitor whether values of the defined PV variables exceed their safety threshold ranges, and the data archiving system needs to store the historical relevant PV data from the systems for fault location diagnosis and error analysis.

For the alarm system, the BEAST software package is used for the LEAF, which is mainly composed of Alarm-ConfigTool, Alarm Server, JMS (Java Message Server) and Alarm Client GUI. In the control system of the CAFe facility, we use the alarm module from the EPICS Phoebus software to upgrade the BEAST-based alarm system. Compared with ActiveMQ message publishing technology, Kafka with its own alarm message publishing technology has much higher data throughput and is more suitable for processing large-scale real-time data streams.

For the data archiving system, we used the Channel Archiver and Archiver Appliance software packages in the EPICS software tool to build two data archiving systems with redundant functions. The Channel Archiver software package was released earlier, and its client software is relatively rich. The Archiver Appliance is a new data archiving system and adopts a multi-level storage method. It also provides a Web front-end management interface, allowing

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users to directly archive, query and mange PV variables through web pages.

OVERALL STRUCTURE OF THE SOFTWARE SYSTEM

As the types of field equipment of linear accelerator are varied and the installation positions are relatively scattered, we use a network-based distributed software structure to construct the upper-level application software system. The software structure is shown in Fig. 3.

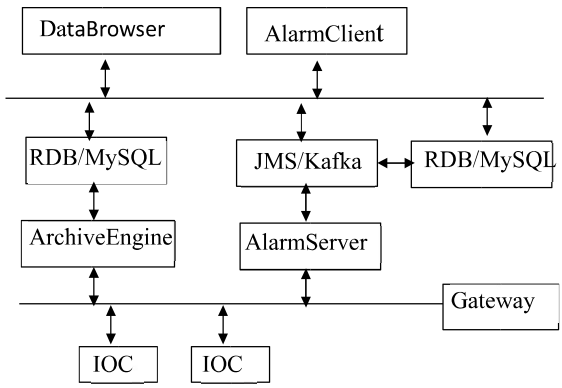

Figure 3: Software structure of data archiving and alarm system.

The CSS-based DataBrowser and AlarmClient tools are used for our operation interface which provides the functionalities of querying the operating status of the equipment and displaying the alarm information. For the alarm system and archiver system, they have been very well integrated in CSS. By relatively simple parameter configurations, Users can easily query and display required operation data.

ArchiverEngine is mainly responsible for reading the real-time data from listed PVs from all IOCs, and then saving it to the historical database; AlarmServer is the core of the alarm system and communicates with the IOC through the CA (Channel Access) protocol to monitor the alarm status of PV values and publish the alarm messages.

In order to improve the reliability of the data link connection when reading a large number of PV variables, and at the same time to classify and manage these data, the EPCIS gateway tool is used between IOCs and the upper data processing engine to achieve the security control of data access and data classification.

ALARM SYSTEM

When the operating status of the field equipment changes, especially when a fault occurs, the alarm system will issue alarm information to the accelerator commissioning, operation and maintenance personnel or equipment maintenance personnel through software user interface, voice, SMS(text messages) or other methods. The alarm system should not be used to replace the equipment protection functions of the Interlock system. It provides data for equipment operators to analyze the causes of equipment failures, but sometimes it also increases the burden of data analysis for operation and maintenance personnel. During accelerator beam commissioning, the physical personnel can use the electronic log software to realize the recording function of the alarmed equipment and the processing methods of the operation and maintenance personnel. Clog electronic log is used in CAFE facility, which is provided by CSNS.

The alarm system based on the BEAST software package can import the database configuration file into the relational database through the AlarmConfigTool tool. The Alarm Server is used to read the configuration information from the relational database, monitor the alarm information of the PV channels in the IOCs, and pass the alarm information to the client through the JMS; JMS acts as a communication channel between alarm client and server to transmit alarm messages, receive log information of other applications etc. The Alarm Client GUI is used to display alarm information in real time. The demand statistics of some alarm equipment of LEAF system is shown in Table 1.

Table 1: Main Alarm Device Information Statistics of LEAF Facility

Device name or system	Threshold Value	Alarm message is displayed
RFQ cooling water system	Water temperature 36°	RFQ water temperature alarm
	Water flow 20L/min	RFQ water flow alarm
	Water pressure 0.3Pa	RFQ water pressure alarm
Vacuum system	LEBT 10-5mbar	LEBT vacuum alarm
	RFQ 1.1x10-5mbar	RFQ vacuum alarm
Water quality monitoring	Water resistance 9 MΩ	Water resistance alarm
	Level of water tank 1.5m	Water level alarm of tank
	Supply-water pressure 4 bar	Water pressure alarm of water

The data source monitored by the Alarm system can come from the device IOC or the PV variables published by the soft IOC. For example, the Alarm system of CAFe can monitor the change of the PV values published by using the pcaspy software package to realize the alarm of the soft protection logic value in the MPS system. The operation interface of the alarm system is shown in Fig. 4.

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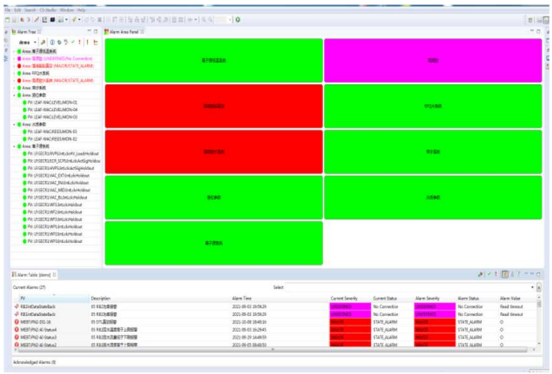

Figure 4: Operation interface of the Alarm system.

As shown in Fig. 4, the alarm system of LEAF includes 9 alarm modules, which are ion source cryogenic system, vacuum system of energy increasing and decreasing section, radio -frequency cavity water temperature system, liquid level parameters, ion source system, radio-frequency cavity, RFQ Water system, beam diagnosis system and water quality system.

In the construction of the alarm system of the CAFe facility, we adopt the Phoebus-based CSS software system for interface development and deployment. Phoebus is the current variant of Control System Studio [4]. Compared to the environment of the early CSS software, it no longer depends on EclipseRCP. Instead, it offers software tools such as Display Builder, Data Browser, Probe, PV Tree, Alarm, Scan and so on. The Phoebus software architecture is simpler, and the development environment is easy to set up, all of which help greatly improve the user experience. It is a very suitable for the development of control system operation interface.

Alarms in Phoebus are composed of server and client modules [5]. The server sends alarm messages to the Kafka middle message plug-in by monitoring the changes in the alarm status of the PV variables issued by each IOC. The alarm interfaces that can be displayed on the Phoebus software are Alarm Tree, Alarm Table and Alarm Area Panel.

The alarm module in Phoebus software is used to deploy the alarm system, which can provide users with a concise, manageable and operable alarm interface, realize the visualization of alarm data and improve the real-time performance of fault handling.

DATA ARCHIVER SYSTEM

In the process of accelerator commissioning and operation, the equipment fault location and fault analysis based on the data archiving system is very important. When equipment failures or beam current accidents occur, accelerator physics personnel need the data archiving system to provide historical data of related equipment to facilitate post-accident handling and cause analysis.

Previous archive systems were built based on the EPICS Channel Archiver tool, using MySQL for data storage and running a database server on Linux, and mounting the IBM DS3512 disk array for data storage as well. KeepAlived is used to achieve high availability of the database server [6]. The archive system communicates with the front-end IOC using the ArchiveEngine tool, and the browsing and query of archived data is realized by the DataBrower tool in the CS-Studio software.

As the scale of data in the archive database becomes larger and larger, the speed of reading and retrieving the data stored in the MySQL database becomes slower and slower. At the same time, the BEAUTY-based archive system does not provide friendly interfaces of information query and management. Therefore, we upgraded the archive system of these two facilities (LEAF and CAFe) with Archiver Appliance.

The new archiving system includes IOC data collection, data archiving engine (Archiver Appliance) and data query and information management tools. Its software system structure is shown as in Fig. 5.

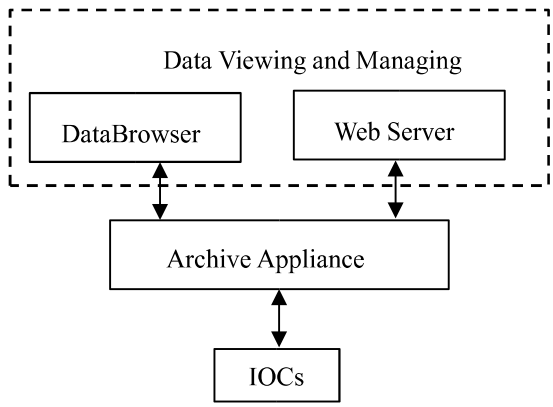

Figure 5: The structure diagram of Archiver Appliance.

The Archiver Appliance reads PV data according to the PV variable name, data sampling mode and frequency in the configuration file, and stores the collected data in a structured file in PB format. The DataBrowser supports Archiver Appliance's PB/HTTP protocol and accesses it through the pbraw interface. Users can directly access and query the Archiver Appliance data system through a browser and receive Web response of user filing to their query requests. The web operation interface of the Archiver Appliance system is shown in Fig. 6.

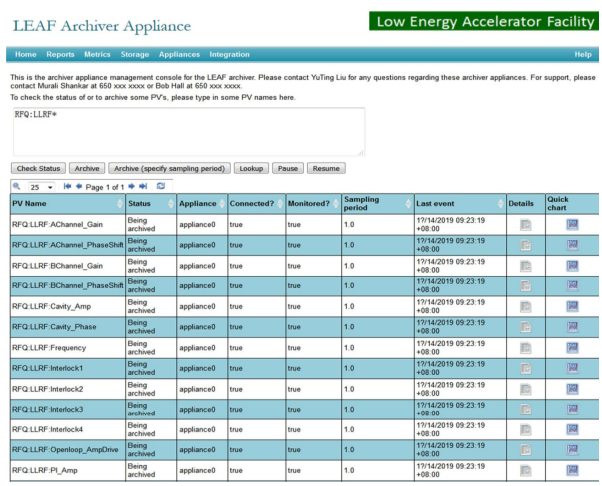

Figure 6: The Web operation interface of Archiver Appliance.

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The data archiving system based on the Archiver Appliance solves the problems of low data index efficiency and inconvenient background management in the past. At the same time, the upper human-computer interaction interface is designed by using CSS software system based on Phoebus, which provides convenience for physical personnel to access experimental data and fault diagnosis and analysis.

CONCLUSION

Compared with the alarm system of ActiveMQ message mechanism, the accelerator alarm system based on Kafka streaming data platform can effectively improve the data throughput of the system and the real-time performance of alarm information release.

The archive system software of Channel Archiver was released earlier, and its client software is relatively rich. The new Archiver Appliance software uses a multi-level storage method, which can retrieve 1 Hz double-precision data for one day within 0.5 seconds. It also provides a Web front-end management interface, which has more advantages in system information management and fast data retrieval.

After the upgrade and redeployment of the above application software, the usability of the data service in the control systems of the two facilities is improved, and better user-friendly interfaces are provided for data query and operations. The upgraded software systems run more stable, and the user interfaces are more friendly, which improves the maintainability of the accelerator device for long-term operation.

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