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DATA ARCHIVE SYSTEM FOR SUPERCONDUCTING RIKEN LINEAR ACCELERATOR AT RIBF

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Abstract

Since 2009, the Radioactive Isotope Beam Factory (RIBF) project has utilized the RIBF control archive system (RIBFCAS). With the number of archived data points expected to increase dramatically after the initiation of the superconducting RIKEN Linear Accelerator (SRILAC), the Archiver Appliance was introduced to improve the data archiving performance. To realize a user-friendly system for data visualization, the data of RIBFCAS and the Archiver Appliance should be visualized on the same system. Therefore, we developed a system that implements a Web API to convert RIBFCAS data into the JSON format, thereby making it possible to unify the data format with the Archiver Appliance and display the data with the same viewer software. The maximum data-acquisition cycle was 10 Hz compared to a cycle of 1 to 20 s in conventional systems. In the SRILAC beam commissioning, our implemented system was useful for finding anomalies and understanding the behavior of superconducting cavities. The success of the proposed data archive system in SRILAC paved the way for it to be implemented in the entire RIBF control system.

INTRODUCTION

At the RIKEN Nishina Center, the RIKEN Radioactive Isotope Beam Factory (RIBF) accelerator facility consists of five cyclotrons and two linear accelerators. One of the linear accelerators, the RIKEN linear accelerator (RILAC), has been utilized for not only as an injector for cyclotrons, but also stand-alone heavy ion experiments. As an upgrade, to perform search experiments for super-heavy elements with atomic numbers of 119 and higher [1], the superconducting RIKEN Linear Accelerator (SRILAC) was newly installed downstream of the RILAC in 2019.

Since 2009, RIBF has been using the RIBF control archive system (RIBFCAS) developed by RIKEN Nishina Center as a data archive system for the data generated by the Experimental Physics and Industrial Control System (EPICS) [2]. For RIBFCAS, an Adobe AIR-based viewer software was developed to view the retrieved archive data. On the other hand, MyDAQ2 developed at SPring-8 as a data store, was introduced mainly for non-EPICS-based systems [3]. In the RIBF control system, MyDAQ2 is utilized not only as a data store, but also for the integration and handling of non-EPICS-based systems by EPICS Channel Access without the development of an EPICS device support [4]. The Adobe AIR-based viewer software developed for RIBFCAS was also compatible with the archive data of MyDAQ2. However, both sets of data storage in these conventional systems are performed in a cycle of 1 to 20 s; whereas the EPICS-based SRILAC control system requires a system with higher archiving performance than the conventional systems. Therefore, herein, we newly introduce the Archiver Appliance developed by a collaboration among SLAC, BNL, and MSU [5], which has been widely used for large experimental facilities adopting EPICS-based systems.

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IMPLEMENTATION METHODS

Deployment

In the case of the Archiver Appliance designed for SRILAC, the specifications of the server hardware are as follows: CPU Intel Xeon E-2124, 3.3 GHz, 4 cores; memory 64 GB; and storage SSD 1.2 TB and SAS 8 TB (4×2 TB, RAID5). The CentOS 7.7 is adopted as the operating system. As the Archiver Appliance accesses a large number of EPICS process variables (PVs) at one time,

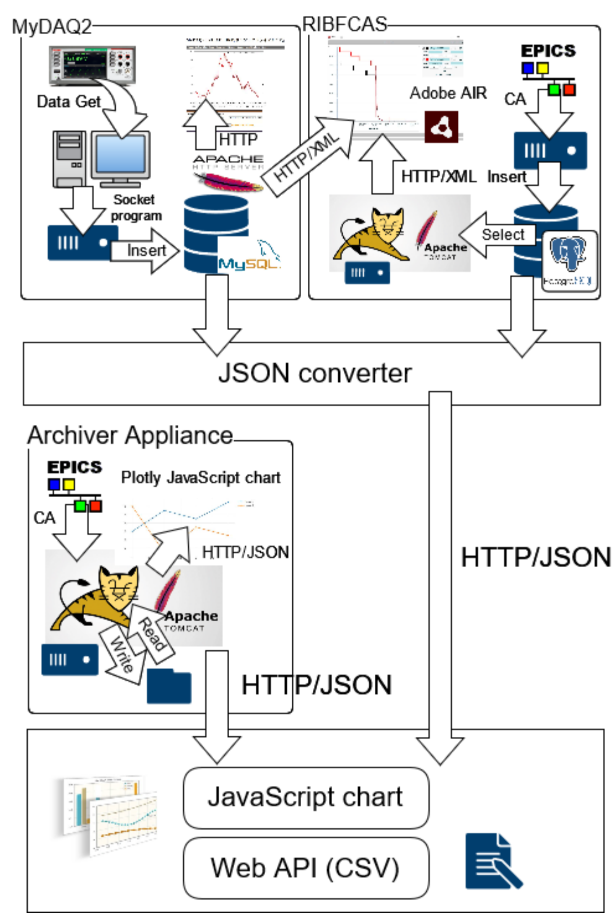

Figure 1: System chart of linkage methods with existing systems. The clients obtain the archived data through the JavaScript chart or Web API.

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broadcasting during "ca_search" can consume considerable network resources. To solve the broadcast issue caused by "ca_search," we can set "EPICS_CA_AUTO_ADDR_LIST = NO" in the Archiver Appliance and specify the hostname of PV gateway [6] in the environment variables "EPICS_CA_ADDR_LIST". This will prevent the broadcast from flowing into all hosts on the subnet. The advantage of having a PV gateway between the Archiver Appliance and the EPICS Input/Output Controllers (IOCs) is that it reduces the load on the IOCs. Moreover, an increase in the number of EPICS IOCs can be handled by adding the hostname of the IOC to the PV gateway without shutting down the Archiver Appliance process.

In the case of the Archiver Appliance for SRILAC, the maximum data-acquisition cycle was 10 Hz, and the default data acquisition setting was set at 1 Hz, which is stored when the PV value changes ("Monitored?" and "sampling period 1.0").

Linkage with Existing Systems

With the introduction of the Archiver Appliance to the SRILAC control system, the Archiver Appliance, RIBFCAS, and MyDAQ2 should be able to visualize each other's archived data in the same system. As RIBFCAS stores data in relational databases using PostgreSQL and MyDAQ2 uses MySQL, it is not difficult to directly access and retrieve data from either database. In addition, the Archiver Appliance has a "data retrieval URL" for data retrieval; the data can be retrieved in various formats such as JSON and CSV [7]. Therefore, to realize a linkage among the different systems, a method to directly access the relational database for RIBFCAS and MyDAQ2 was established, and the data of RIBFCAS and MyDAQ2 were converted into JSON, which is the same format as that used by Archiver Appliance, and handled. Using the data with a common format by the developed JSON converter, a visualization software was realized for the retrieved archive data. The system chart is shown in Fig. 1.

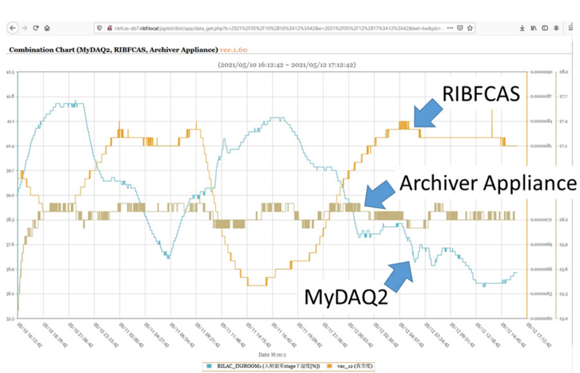

Figure 2: Example of accessing data using Firefox and displaying Archiver Appliance, MyDAQ2, and RIBFCAS archived data on jqPlot-based chart at the same time.

Visualizing Archived Data

A web application was developed to visualize the archived data from RIBFCAS, MyDAQ2 and Archiver Appliance using the same viewer software (see Fig. 2). The acquired data are passed as an argument to jqPlot [8], a JavaScript plug-in for charting, and the chart is displayed as a web application. The advantage of using jqPlot as a charting function is that it automatically adjusts the minimum and maximum values of the Y-axis to optimize the gridline of the chart when visualizing the correlation of the data.

Archiving from Other Networks

The development of superconducting cavities in the SRILAC project was conducted in a separate building (called the Research and Development Building: R&D building) away from the RILAC room [9]. This building is equipped with clean rooms and test rooms, where various parameters such as radiation, vacuum, and liquid helium level are monitored. Although the accelerator room is not in the R&D building, it is required that the test equipment be able to compare experimental data with the RIBF archived data, because the test equipment could be affected by the magnetic field of the cyclotrons. However, the RIBF control system network is a closed system, and it is not installed in the R&D building. Moreover, for extending the RIBF control system network to the R&D building, man power is required. To realize a data store from the RIKEN local area network (LAN) to MyDAQ2 in the RIBF control system network, we developed a program to insert data into the MyDAQ2 system using the HTTP method. As a result, approximately 100 data points of the system in the R&D building were successfully archived into the MyDAQ2 system by HTTP access via a reverse proxy system [10] since 2018 and merged with the existing RIBF archive data. A system chart is shown in Fig. 3.

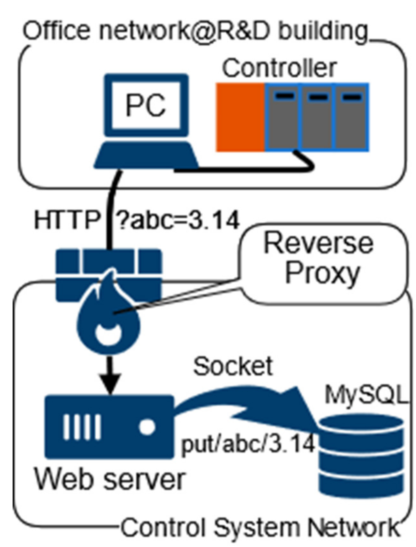

Figure 3: System chart of sending archiving data from the R&D building to MyDAQ2 through a reverse proxy.

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ACTUAL CLIENT SYSTEM USAGE

The Archiver Appliance for SRILAC operates within a closed RIBF control network and retrieves data from approximately 50 IOCs via the PV gateway. The archived data acquired in the network can be accessed by client PCs for operations. Conversely, users from offices where the accelerator control network is not installed can reach the data via HTTP reverse proxy. Concerning system management and ease of system construction, web communication is suitable for providing information stored in the control system network to many people. To meet these requirements, a combined system with reverse proxy servers for web communication and a firewall was constructed to provide accelerator information to the RIKEN office network while ensuring secure access. Installation of reverse proxy servers in front of real web servers is a widely used prescription for security and caching [10].

In this system, a Web API developed to interface the Archiver Appliance, RIBFCAS, and MyDAQ2 is used for client access. Users can retrieve data in jqPlot-based charts and CSV format via HTTP without being aware of the Archiver Appliance and the existing system. Therefore, by using this Web API, users can not only display data charts from the office via a reverse proxy but can also easily use it for analysis by programs written in various languages such as Mathematica and Python. The archived data can also be accessed from users' homes via VPN.

In recent years, RIKEN has been using Slack [11] as a communication tool instead of E-mail. To share information for discussion on Slack, we added the URL of the jqPlot-based chart on the Slack channel. Figure 4 shows an actual discussion on Slack in SRILAC beam commissioning.

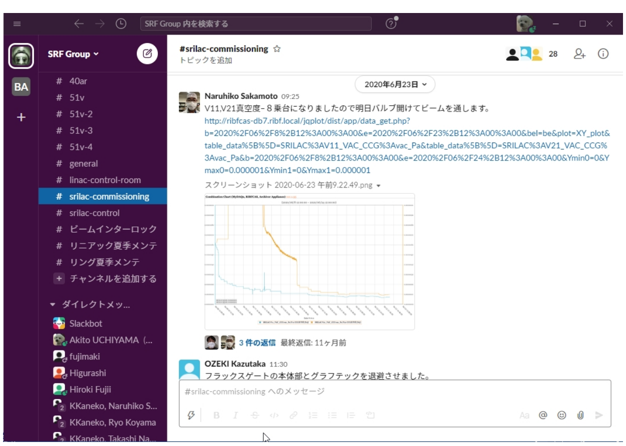

Figure 4: Example of discussion on SRILAC beam commissioning on Slack (in Japanese). We used the data displayed on the chart and pasted the URL on the channel.

OPERATION RESULT

During SRILAC beam commissioning in 2020, the Archiver Appliance was very useful for clarifying the behavior of the superconducting cavities and problems with the vacuum. It is currently an essential tool for SRILAC beam tuning. Based on the successful introduction of the Archiver Appliance in the SRILAC control system, the Archiver Appliance is currently being deployed in the entire RIBF control system. As of May 2021, the Archiver Appliance has collected approximately 15,000 data points from 1 Hz to 10 Hz, such as vacuum values and magnet power supply current values, for the entire RIBF including SRILAC. Additionally, the number of IOCs connected to retrieve archived data has also increased from 50 to 110. As a data rate for the storage, the disk consumption is approximately 3.7 GB per day. The real capacity of the main storage is 6 TB, which will be sufficient to store data for four years.

CONCLUSION

To improve the performance of the archive system for the efficient operation of SRILAC, the Archiver Appliance was introduced. It is useful for SRILAC beam commissioning and will be used as an essential tool across the entire RIBF control system in the future. Via visualization software using data exchange in the JSON format, the Archiver Appliance is linked with the existing system. As of 2021, the Archiver Appliance is being deployed not only in the SRILAC control system but also in the entire RIBF control system.

To facilitate future research, we have begun utilizing a system to archive all EPICS PVs utilized in RIBF operation for machine learning. The system is implemented using different hardware (CPU Xeon® Silver 4110, 2.10 GHz, 8 cores; memory 256 GB; all flash storage; 10GBASE-T network interfaces) than the system in SRILAC. Approximately 200,000 data points are acquired in a 10 Hz data cycle, which will be archived continuously for five years.

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