EPICS integration of BACnet-based monitoring system for secondary water-cooling in LIPAc

N. Kaneko†, M. Kojima, K. Kondo, T. Nakayama, H. Sakamoto, M. Sugimoto, H. Usami, QST, Rokkasho, Japan
Y. Carin, IFMIF/EVEDA Project Team, Rokkasho, Japan
IFMIF/EVEDA Integrated Project Team

Abstract

Control systems of Linear IFMIF Prototype Accelerator (LIPAc) are built mostly based on EPICS. However, some of them are constructed with non-EPICS system. One of the examples is the secondary water-cooling facility that is monitored and controlled through commercial software. It handles measurement data such as temperature and flow rate over an industrial network protocol called BACnet. Due to this reason, it was impossible to compare or analyze the correlation and impact of an event for the primary and secondary cooling water on the same timeline. This had been making it difficult to understand the phenomenon and to identify the cause of it. In order to tackle this problem, we have realized a solution that collects and analyzes BACnet data packets on the network and integrates it into the EPICS environment. In this paper, the details of the implementation method will be discussed.

INTRODUCTION

The International Fusion Materials Irradiation Facility (IFMIF) is an accelerator-based neutron source aiming to test materials for future fusion reactors. The Linear IFMIF Prototype Accelerator (LIPAc) is under construction in Rokkasho, Japan in order to validate the feasibility of the low energy section of the IFMIF accelerator by producing a 9 MeV deuteron beam at 125 mA [1]. The data acquisition and control of LIPAc is based on Experimental Physics and Industrial Control System (EPICS) 3.14 [2]. Nevertheless, there are some exceptions, and one of them was the secondary water-cooling facility.

SECONDARY WATER-COOLING SYSTEM OF LIPAC

The LIPAc has a primary and secondary water-cooling line as depicted in Fig. 1. The system was developed as part of a bigger system whose main role is radiation management and ventilation control system. Since this system was designed together with the building before the technical specification of the accelerator was settled, controlling it through EPICS was out of the consideration. Due to this historical reason, the system had been monitored and controlled using third party commercial software which did not have a direct compatibility with EPICS.

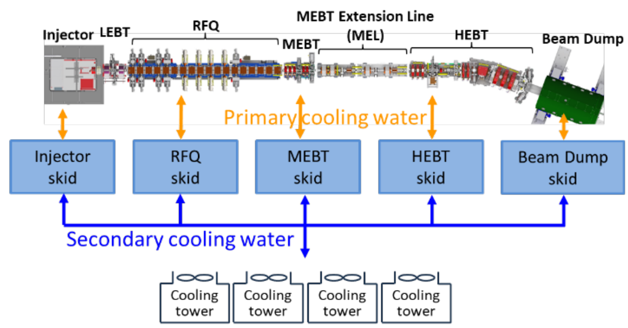

Figure 1: Overview of the cooling system of LIPAc.

MOTIVATION

Problems of Original System

The original control system of the secondary water-cooling had the following drawbacks:

1. The trend data of primary and secondary water-cooling system could not be displayed in the same timeline, which made it difficult to compare and analyze their correlation and their impact of each other.
2. Monitoring and control of the system was only possible from a single workstation with proprietary software in one of the control rooms (see Fig. 2).

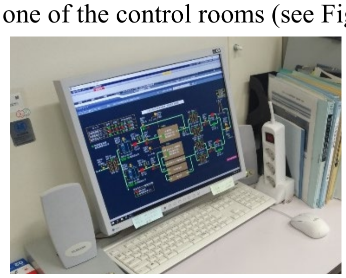

Figure 2: Proprietary workstation in the control room.

   Although most of our accelerator status information is available from any buildings in the facility and even from off-site with SSL-VPN connection, it did not apply to the secondary water-cooling system, and there was no means of remotely accessing its values.
3. Archiving the measurement data was not possible. To be precise, the data could not be stored for more than 48 hours, which impedes root cause analysis after incidents.

For a high current and power accelerator like LIPAc, removal of heat is vital. Moreover, since variations of cooling water temperature can directly impact the characteristics of the devices, understanding the system's behavior is

† kaneko.naomi@qst.go.jp

a key for successful operation. As the commissioning phase of the accelerator progresses and the duty cycle increases, its importance will increase even more.

Objective

Due to these reasons, integrating the secondary water-cooling system into EPICS had been a long-standing request. The aim of the integration was to overcome the aforementioned drawbacks to enhance its capability and flexibility.

Scope of EPICS Integration

There were approximately 100 Input/Output (I/O) data points that were targeted to be integrated into EPICS. Some variables in the original system were both readable and writable on its operator interface. However, in the scope of new EPICS system, it was agreed to make all variables read-only based on the principle that controlling them should be possible only from the proprietary workstation located in the control room or by manually manipulating the actuators in the field such as valves.

PRELIMINARY STUDY

As a first step, we consulted the domestic company, who was outsourced to develop the original system, whether they can upgrade the system so that it will periodically output the measurement data in a CSV file. Unfortunately, their answer was that it is not possible because this function was not considered at the design phase and adding it may make the system's behavior unstable according to their view. Therefore, a preliminary study was conducted to examine the feasibility of in-house development. From the network of the secondary water-cooling system, the packets were collected by port mirroring on a switch, and the traffic was analyzed using a protocol analyzer application, namely Wireshark [3].

Investigation Result

As a result of the investigation, the following facts were discovered:

- Secondary water-cooling system is operated in a closed network that is independent from the accelerator network that hosts the communication of EPICS Channel Access (CA).
- Measurements from sensors are collected by programmable logic controllers (PLC) and sent to the data acquisition server every 10 minutes as illustrated in Fig. 3.
- Data queries and responses between the server and client are transmitted over a network protocol called Building Automation and Control Networking Protocol (BACnet) [4].

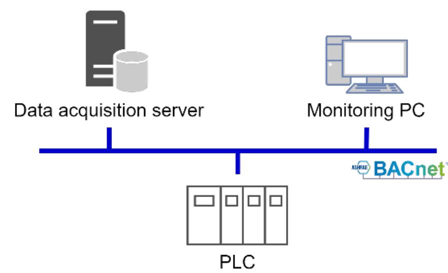

Figure 3: System architecture.

BACnet Communication Protocol

BACnet is an open industrial standard protocol that was developed to make components of different vendors interoperable, especially for controlling infrastructure of buildings. Typical applications include control of Heating, Ventilation, and Air Conditioning (HVAC), lighting, power consumption, fire detection, and so forth. The BACnet language is structured as a hierarchy of "devices", "objects" and "properties", and its schema is similar to EPICS records. Typically used properties of BACnet objects are given in Table 1. An example of a BACnet packet collected with Wireshark is shown in Fig. 4.

Table 1: BACnet Properties

Property	**Description**	**Example**
Object type	Corresponds to Record Type (RTYP) in EPICS records.	Analog Input, Analog Output, Binary Input, Binary Output
Object ID	Identification number unique for each data point.	142
Object name	Corresponds to NAME field in EPICS records.	Cooling tower outlet temperature
Present value	Current value of the object. Corresponds to Value (VAL) field in EPICS records.	16.2
Unit	Corresponds to Engineering Unit (EGU) field in EPICS records.	degC

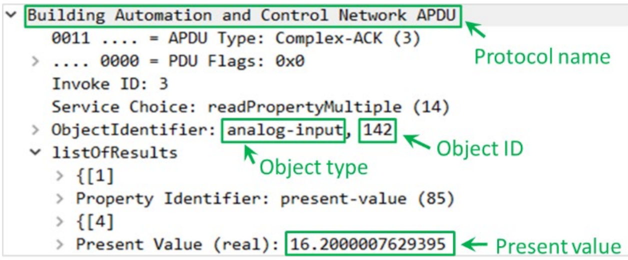

Figure 4: Example of packet captured by Wireshark.

IMPLEMENTATION METHOD

Strategy

Based on the result of the preliminary study, the following two solutions were considered for realizing the integration into EPICS.

A. Using an EPICS driver for BACnet that has already been supported [5], develop a client program that sends queries of the target I/O data to the server, and shares the received data to the EPICS CA network.

B. Using port mirroring, capture the BACnet packets that are periodically distributed in the network with TShark, which is a command line version of Wireshark. From the captured packets, extract the target I/O data, and share it to the EPICS CA network.

Initially, the plan was to proceed with the above-mentioned solution A, yet the negotiation to apply this change was unsuccessful. The reason was because it requires modification to the original system, that is to add a new client to the network, and there is a risk that the system will not be supported any further by the company who developed the original system. Therefore, solution B was selected in the end, although it is less straightforward.

Software Scheme

The adopted software scheme is illustrated in Fig. 5. The following processes are executed in loop in a Linux environment (CentOS7), where an EPICS software Input/Output Controller (soft IOC) is also running:

1. Collect BACnet packets from the secondary water-cooling network for a certain period of time using TShark.
2. Save the captured packets in a CSV file.
3. From the saved file, extract the value of the target I/O data points.
4. Publish the extracted data to EPICS CA network with *caput* command.

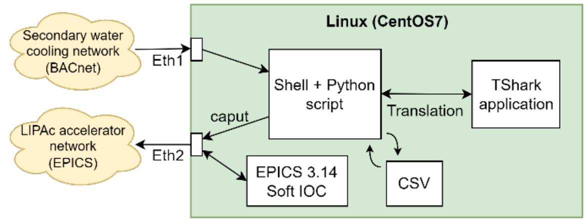

Figure 5: Software scheme.

Graphic User Interface (GUI) Implementation

The Operator Interface (OPI) panels were developed on the platform of Control System Studio (CSS) V4.5 based on Eclipse. Their designs mimic the interfaces of the proprietary software, but some adjustments were made to harmonize with the LIPAc guidelines, such as the color-coding, icon, and display language. An example of the GUI of the proprietary software and newly developed GUI are shown in Fig. 6 and Fig. 7 respectively.

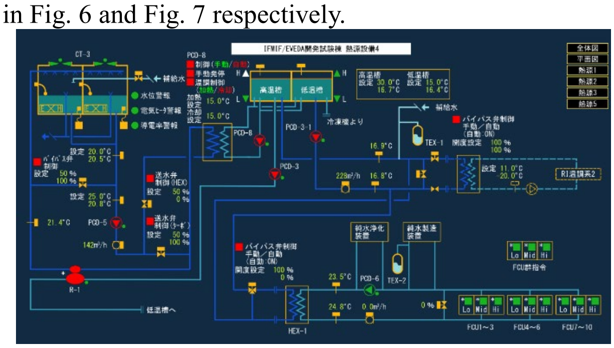

Figure 6: GUI of the proprietary software.

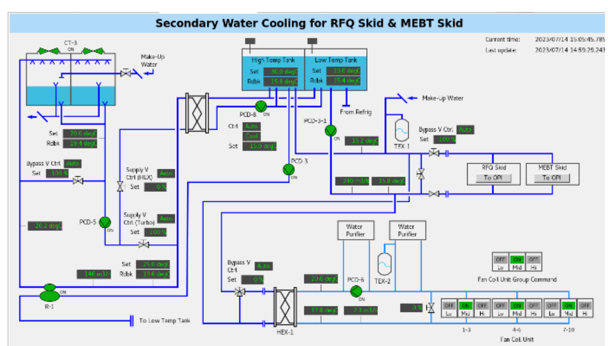

Figure 7: GUI developed with CSS.

CHALLENGES DURING DEVELOPMENT

One of the challenges during this development was that there were few design documentations available such as the software specification, network structure, and schematics. Some of them were incomplete or obsolete as the system was developed already ca. 15 years ago and the system configuration has changed over time. Thus, necessary information had to be revealed through reverse engineering.

Besides, since the accelerator group is the user of the secondary water-cooling system but not the owner of it, there was some effort required to get approvals to investigate and deploy the changes to the original system. A greenlight was given eventually by thorough explanation of the point demonstrating that this implementation does not degrade the functionalities or performance of the system (e.g., network overload, unintended operation of devices, security risks).

RESULT AND CONCLUSION

The status of secondary water-cooling system can now be monitored through EPICS. This improvement allowed operators to remotely access its status from anywhere onsite and off-site. It also allowed us to obtain historical data, which was not possible before the deployment. Figure 8 is an example of a trend graph from EPICS which was taken when a bug of flow rate control was discovered, and it greatly contributed to identifying the root cause. The overall development enabled fast and accurate event analysis and troubleshooting as well as contributed to enhance the flexibility and reliability of the system.

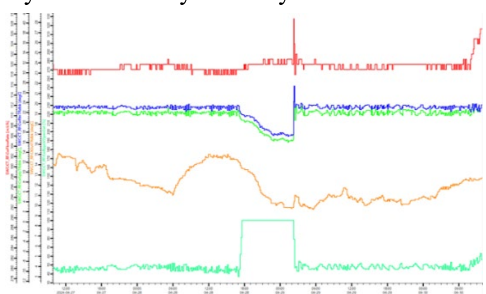

Figure 8: Example of a trend graph from EPICS.

However, it must be noted that with the current method, the client just passively waits for the data that is distributed periodically every 10 minutes. This 10-minute interval comes from the design of the original system. Hence, if retrieving data with shorter intervals is required, another implementation method must be chosen to send a data request to the server.

ACKNOWLEDGEMENTS

This work was undertaken under the Broader Approach Agreement between the European Atomic Energy Community and the Government of Japan. The views and opinions expressed herein do not necessarily state or reflect those of the Parties to this Agreement.

REFERENCES

[1] H. Dzitko *et al.,* "Status and future developments of the Linear IFMIF Prototype Accelerator (LIPAc)", Fusion Eng. Des., vol. 168, p. 112621, Jul. 2021. doi:10.1016/j.fusengdes.2021.112621[1]

[2] EPICS, https://epics.anl.gov/

[3] Wireshark, https://www.wireshark.org/

[4] BACnet, https://bacnet.org/

[5] BACnet Driver, https://controlssoftware.sns.ornl.gov/bacnet/index.html