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A MAJOR UPDATE OF WEB BASED DEVELOPMENT TOOLKIT FOR CONTROL SYSTEM OF LARGESCALE PHYSICS EXPERIMENT DEVICE

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Abstract

The deployment of the control system called CODAC (Control, Data Access and Communications) is necessary for the operation of large-scale experimental facilities. CFET (Control system framework for experimental devices toolkit) is a flexible SCADA (supervisory control and data acquisition) software tool, which is used for the construction of a CODAC. CFET is fully based on open web technologies, it is easy to integrate all kinds of systems and devices into CFET. This paper has undergone a major iteration of CFET. HMI has been redesigned and implemented. The control engineer can use a web based WYSIWYG HMI editor to compose the HMI. In CFET, InfluxDB has been integrated. It is used to store the engineering data, and also visualize the data on the website. Docker based microservices architecture has been designed, putting CFET and dependent packages into a lightweight container. At present, CFET has been used in the CODAC system of J-TEXT tokamak and HUST Field-Reversed Configuration facility.

INTRODUCTION

For a long time, Experimental physics and industrial control system (EPICS) have been used to build large-scale experimental equipment control systems in the accelerator field. So far, the community has been very mature, and EPICS has very strong support for hardware equipment in the accelerator field [1-2]. ITER (as the world's largest tokamak) chose EPICS as the core framework of their control system [3-6], and chose EPICS Channel Access protocol as the communication protocol for the control network. Therefore, many other equipment in fusion field have chosen EPICS to build their own control systems. However, due to the differences in equipment and control requirements, EPICS has not demonstrated its advantages in the fusion community, and EPICS Channel Access protocol also has the problem of opacity and operability. Control system Framework for Experimental Devices Toolkit (CFET) framework is implemented as .NET standard libraries. It bases on Web technologies and uses HTTP as the control system communication protocol [7-8]. Web technology almost supported by all the devices. Countless web APIs have been published and consumed by all kinds of devices. It's also easy to integrate various new devices via the network, and provides flexible control system solutions for users in different scenarios. CFET is an efficient development tools with transparent protocol, and provides stronger support for new devices, also has the characteristics of easy integration and strong interoperability between subsystems.

This paper first briefly talked about the basic concepts of CFET. The third section will introduce the support of new communication protocol. Section 4 will introduce the redesigned HMI. The engineering data storage and management system will be described in the fifth section. CFET also uses docker to realize the cross-platform deployment of the user side rapidly. In the end, the application of CFET on HFRC will be briefly demonstrated.

BASIC CONCEPTS OF CFET

As mentioned before, CFET is a Web-based SCADA. Web plays a big role from websites (online services), online games, to smart sensor and IoT application. So CFET has good adaptability to a variety of different large-scale equipment, and can also meet new development models and new operating environments. HTTP is the most common communication protocol in web applications. The main communication module of CFET (CFET HTTP CM) uses the HTTP protocol of the RESTful architecture as the basic transmission protocol. The format of the RESTful framework is to use URI to locate resources and add verbs (intended action) in front of the resources. For example, if you need to know the switch status of light bulb A in the laboratory, the corresponding resource request should be "get + /lab/lightA/status". In HTTP CM, the client actions are mapped to HTTP verbs. There are three resource access actions, namely Get, Set and Invoke, mapping to HTTP Verb GET, PUT and POST. To different types of resources, HTTP verbs are different, otherwise an error that does not conform to the design principles will be reported.

The basis of interoperability is that every client in this system can understand each other conceptually, so we have to encapsulate the equipment in control system into a common model with consistent interfaces. The model has 5 types of resources: Thing, Status, Configuration, Method and event. Status, Configuration and Method are the property of Thing. A Thing can be either physical or logical. Event is a property based on publish/subscribe pattern. The subscriber can subscribe a resource and get notified on a certain condition.

NEW CFET COMMUNICATION MODULE

A CFET application, in principle, is allowed mount multiple Communication Modules. Each Communication

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Module corresponds to a protocol. When accessing resources, you can choose Communication Module via the protocol header, such as http://.

Due to increasing control requirements, CFET has developed some new communication modules: MQTT CM and WebSocket CM.

The HTTP protocol has a problem that only the client can send a request to the server, and the server return the query result. The HTTP protocol cannot enable the server to actively push information to the client. We can only use polling to get the current message if the server has continuous state changes. The biggest feature of WebSocket protocol is that the server can actively push information to the client, and the client can also actively send information to the server. CFET use WebSocket protocol to support remote events. WebSocket CM is integrated into HTTP CM, you don't need to change the protocol header, HTTP CM will automatically add 1 to its HTTP port number as the port number of WebSocket.

The MQTT (Message Queuing Telemetry transport) protocol is a protocol designed for communication between a large number of remote sensors and control devices that have limited computing power and work on a low-bandwidth, unreliable network. Provide one-to-many message publishing, uncoupling subscriber from publisher. MQTT has a wide range of applications in the Internet of Things, small devices, mobile applications, etc. CFET MQTT CM still uses RESTful architecture. The only difference from HTTP CM is that you need to replace "http://" in URL with "mqtt://" to select MQTT CM.

HUMAN MACHINE INTERFACE

Human machine interface (HMI) are developed separately and deployed on the operator's console in traditional control systems and always be a fixed interface on a limited platform. In web based control system, all HMI is a web site running on web servers. CFET provides a component called "WidgetUI". It is a WYSIWYG HMI editor, and the application developer can compose their own HMI via dragging and editing Widget. The component library of WidgetUI provide many widget: Label, Configurator, Gauge, Video player, Switch, Status light and so on. The following Fig. 1. Shows a simple HMI.

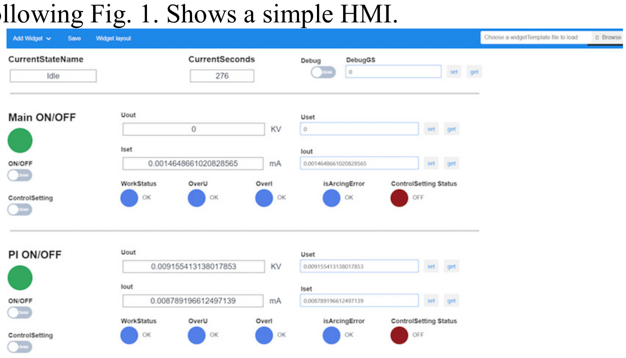

Figure 1: The HMI of high voltage power supply.

The completed interface can be directly saved as a Json file, which can be saved locally or in n a specified file path of CFET. The website can restore HMIs by parsing the Json file. And the website can also be accessed as a RESTful API. When a request come from a browser, the server would know that and return a web page to visualize the resource instead of a JSON object.

It is worth noting that, in addition to supporting access to CFET resources through the HTTP protocol, the website also supports subscribe a remote events through WebSocket protocol, which can be done by simply clicking on the website.

THE ENGINEERING DATA STORAGE AND MANAGEMENT SYSTEM

Engineering data refers to the non-experimental data generated during the experiment, such as sensor data, the voltage of the power and the temperature of the instrument, etc. Most of them have strong timing characteristics. Influxdb is purpose-built to handle the massive volumes and countless sources of time-stamped data produced by sensors, applications and infrastructure. CFET uses influxdb to store and monitor engineering data, which is capable of ingesting millions of data points per second. In CFET, we still write the control of Influxdb as a Thing with I/O interface exposed. Influxdb thing can be used with CFET Event to conveniently record any required engineering data.

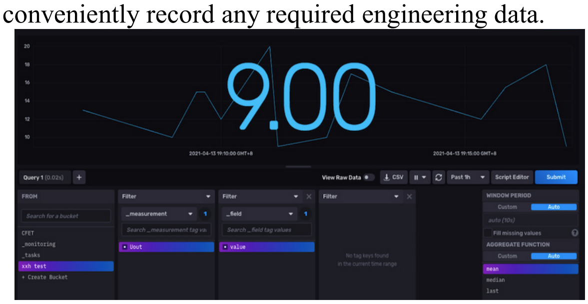

Figure 2: The interface of engineering data.

In addition to this, a dashboard interface (shown in Fig. 2.) and monitoring alarm interface built with Grafana are also used by CFET to visualize the engineering data.

APPLICATION ON HFRC

The Field-Reversed Configuration (FRC) device is a complex magnetic confinement fusion research device and is also a new type of fusion research device proposed in recent years [9]. The position and structure of this device are quite different from those of previous fusion devices such as tokamak, and can generate high-parameter plasma. HFRC is a FRC device being researched by Huazhong University of Science and Technology. HFRC contains multiple complex subsystems such as vacuum, power supply, and diagnosis. It is particularly important whether the control system can have the coordinated control capability of these complex and diverse subsystems, the real-time control capability of the discharge pulse, and the ability to provide flexible control functions to complete specific experimental content. Due to the flexibility and compatibility of CFET, HFRC chose CFET to build his control system. With the CFET framework, each subsystem can know any message from each other, and the central control system

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can coordinate and monitor by obtaining the status of each subsystem.

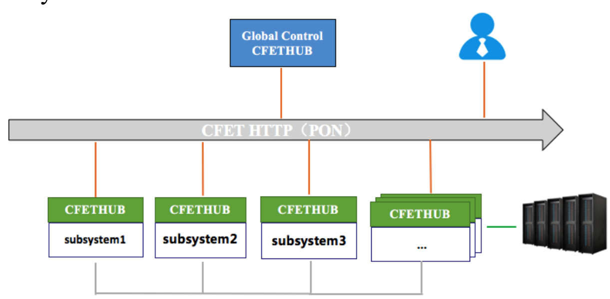

Figure 3:The Architecture of the control system of HFRC.

The HFRC control system is divided into two parts: the global control system and the sub-control system. The global control system coordinate subsystem to meet the control requirements of the overall operation of the device. The sub-control system consume these services by accessing CFET control system networks while exposing its own status API. The control system adopts a dynamic state machine mode to realize the process control of the discharge. Each subsystem can observe the state of the central control, execute its own actions and change its state according to the instructions of the central.

CONCLUSION

This work is aim for update web based development toolkit CFET. CFET bases on Web technologies and uses HTTP as the control system communication protocol to improve the interoperability of control systems. Although CFET has begun to take shape, there are still many functions that need to be improved. First this work added two new communication protocol module (WebSocket CM and MQTT CM) in CFET. Then the HMI was redesigned, and the component library was added. Users can access the control interface without restriction in any scene through the browser. CFET also be able to access Influxdb, integrates the storage and management system of engineering data, and users can also use the dashboard to monitor engineering data. Finally, the updated CFET has been applied to the HFRC control system, which meets the control requirements of HFRC daily experiments more flexibly and comprehensively, and also allows developers to develop the HFRC control system more efficiently.

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