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DESIGN AND IMPLEMENT OF WEB BASED SCADA SYSTEM FOR HUST FIELD-REVERSED CONFIGURATION DEVICE

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Abstract

As a large complex fusion research device for studying field reversed configuration (FRC) plasma, HUST FRC (HFRC) is composed of many subsystems. In order to coordinate all systems and ensure the correct, orderly and stable operation of the whole experimental device, it is very important to have a unified and powerful control system.

HFRC SCADA (Supervisory Control And Data Acquisition) system has selected the in-house developed CFET (Control system Framework for Experimental Devices Toolkit)as the control framework, with advantages of strong abstraction, simplified framework, transparent protocol and flexible extension due to Web technology.

Introduction

Growing worldwide demand for energy, and problems of scarcity and environmental impact associated with conventional sources are the challenges facing humanity [1]. The energy industry is facing decades of transformation. On a longer scale, nuclear fusion will be part of a catalog of more sustainable energy sources [2].

Field-reversed Configuration (FRC) has the advantages of complete axis symmetry, relatively simple structure, β~1 and so on [3]. Therefore, it is of great significance for the research of new fusion configuration, and the future exploration of miniaturization and economization of the fusion reactors [4, 5]. HUST Field-Reversed Configuration (HFRC) is a pre-research platform for field-reversed configuration research device based on plasma's colliding and merging, which is under development.

HFRC is composed of many subsystems such as magnets, vacuum, power, and diagnostics. It's important to have a unified control system considering the diversity and complexity of the subsystems. This paper describes the design and implementation of control system specially designed for HFRC.

HFRC SCADA (Supervisory Control And Data Acquisition) system includes the global control system, which coordinate all subsystems, and control systems in various subsystems such as the pulse power supply control system. It also offers a customizable and pluggable web based HMI for better operation. Users can design the HMI by simply dragging and dropping widgets in the browser.

At present, HFRC SCADA has been initially deployed in daily experiments of HFRC, which will provide valuable experiences for future control system design of large experimental device.

Design of HFRC SCADA

Micro Service HFRC SCADA adopted the decentralized model on the whole, and it can mainly be divided into two parts: central control system and subsystems. The main function of central control system is to coordinate the run of whole experimental device, and all subsystems need access plant operate network and accept the monitoring and the dispatch from central control system. The main subsystems are charger control system, pulse power control system, central timing control system, distributed timing control system and data acquisition system. Each subsystem offers different service to others. Fig.1 shows the overall structure of the whole system.

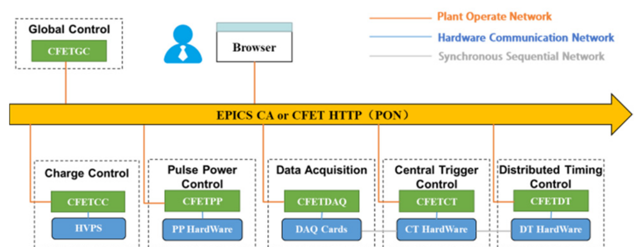

Figure 1: Overall structure of the whole system.

HFRC SCADA builds the whole system as a suite of small services, each running in its own process and are independently deployable. Adopting micro services makes HFRC SCADA simpler to deploy and understand, and minimizing the risk of change.

FSM (Finite State Machine) Pattern The discharge process of HFRC can be seen as a sequential transitions of states. HFRC SCADA uses FSM mode to control the flow of discharging and handle exceptions.

FSM is reliable, easy to understand, predictable and safe. There is only one state active at any one time, which drastically reduces the chance of unforeseen errors or unexpected behavior in the system.

Observer Pattern In observer pattern, any other object can be registered on an observed object, which will function as an observer. The first object, also called the subject, informs registered observers each time it is modified [6].

As HFRC SCADA is a distributed event handling system, observer pattern works well in implementing coordination of subsystems. Each subsystem can act as both an observer and a subject.

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CFET HFRC SCADA selects the in-house developed CFET (Control system Framework for Experimental Devices Toolkit) as the control framework. CFET is a general software framework for fusion device integrated control system development based on Web technology, and can be used as supervisory control and data acquisition (SCADA) software.

Based on the technology of Web, CFET adopts HTTP protocol and RESTful design principle as the general communication protocol of the system. Under the CFET framework, the object realizing the same business function logic is called as a Thing. As is shown in Fig. 2, all resources in CFET system can be accessed by an URL through the internet. It is just the same as the URL we meet in the browser and someplace else. The head of the under UDA is the address of the CFET Host and in the end is the query string. One URL can locate anresource of a CFET Thing in a CFET Host of a CFET CODAC system [7].

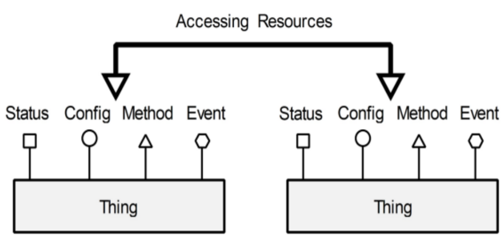

Figure 2: CFET abstract model.

Under the CFET framework, each subsystem can access plant operate network and realize the function of coordination and monitoring.

Hardware Module

The most commonly used field-reversed plasma formation method is based on the Field-Reversed Theta-Pinch (FRTP) formation [8]. HFRC device is mainly divided into plasma formation area, collision fusion and compression area. The FRTP is located in the formation area and is mainly used for the formation and injection of FRC plasma. The control system controls the discharge process mainly by orchestrating the power supply in the formation area.

In order to obtain the desired results, HFRC has strict requirements on the discharge timing. If the trigger timing deviates more than expected, the obtained current waveform will not match the expected one, and the result will be unsatisfactory. Considering the adaptability to the CFET framework and the problem of generating the trigger timing signal with high accuracy, the formation area power controller is developed independently.

As is shown in Fig. 3, formation area power controller hardware mainly includes MCU real-time slow control board, FPGA trigger board, AC-220V to DC-12V power supply, three-terminal interface and 1U Standard Chassis.

MCU real-time slow control board is responsible for the generation of slow control signals, such as heating signals, temperature signals. FPGA trigger board generates high-precision trigger signals.

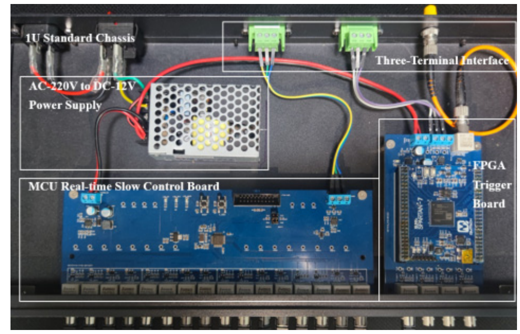

Figure 3: The formation area power controller.

Data Acquisition, Archive and Access

Data acquisition subsystem adopts CFET as framework. CFET's high robustness and low coupling performance allow the subsystem to be deployed in HFRC and other systems with data acquisition requirements.

Data acquisition subsystem is compatible with common formats of data storage and provides full support for files in formats such as HDF5. Both data file and MDSplus are supported to upload experimental data. The MongoDB database is used as the underlying software for the experimental file data access.

HFRC data acquisition subsystem offers different ways of accessing data with full functionality, simplicity and high performance.

HMI

HFRC SCADA implements HMI based on Web technology. Users only need a browser to supervise control and acquire experimental data. HMI also supports UI customization, which means users are able to design their own interfaces. Figure 4 shows the current global control interface.

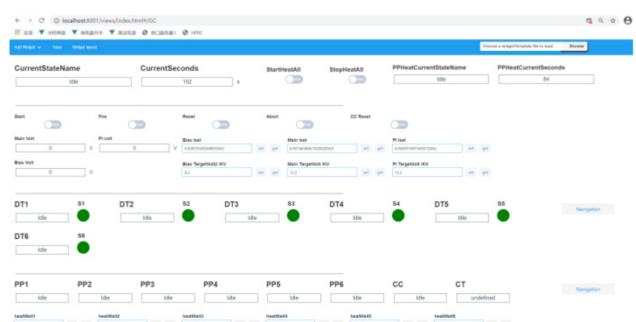

Figure 4: The global control interface.

CONCLUSION

This paper introduces the design and implement of Web Based SCADA System for HFRC in terms of the overall design of the system, hardware module, data acquisition and HMI. HFRC SCADA is able to orchestrate all the instruments and devices to conduct a successful experiment, as well as collect and archive the scientific data generated during the experiments. It also offers a customizable and pluggable web based HMI for better operation.

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