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Development of local control system for ITER gyrotron

ITERジャイロトロン用ローカル制御系の開発

Katsumi Ohshima[1], Yasuhisa Oda[1], Yasunori Hashimoto[2], Kazuo Hayashi[3], Ryosuke Ikeda[1], Ken Kajiwara[1], Koji Takahashi[1] and Keishi Sakamoto[1]

大島克己，小田靖久，橋本慰登，林一生，池田亮介，梶原健，高橋幸司，坂本慶司

[1] *Japan Atomic Energy Agency*

801-1, Mukoyama, Naka, Ibaraki 311-0193, Japan

日本原子力研究開発機構　〒311-0193　茨城県那珂市向山801-1

[2] *Japan Expert Clone Corp.,* [3] *Nippon Advanced Technology Corp Co.Ltd.*

日本エクス・クロン株式会社，日本アドバンストテクノロジー株式会社

A prototype of local control system for ITER EC H&CD system was developed as ITER relevant control system. The prototype was developed based on technology defined in ITER Plant Control Design Handbook and ITER CODAC Core System and ITER relevant hardware were utilized. The functions of state machine management, timing control of high voltage power supply system for gyrotorn, and waveform recording were implemented on the system and high power RF oscillation was demonstrated using 170 GHz gyrotron.　For validation of control architecture for ITER EC H&CD system, coordinative operation of gyrotron and transmission line was demonstrated. Since both subsystems are procured by different countries, coordination of independent controllers with interface over network communication is required. For demonstration of launcher switching during plasma experiment, waveguide switch in transmission line changed its direction during gyrotron pulse with synchronous control of RF power suspend and switch.

1. Introduction

ITER ECH&CD system is designed to inject 170 GHz RF up to 20MW into plasma with 24 gyrotrons as RF power source. Japan procures 8 gyrotrons and an equatorial port launcher (EL).[1-3] Fig.1 shows major components of ITER EC H&CD system and its control architecture. It consists of RF sources, launchers, HVPS for gyrotrons and transmission line(TL) and each subsystem is procured by different domestic agencies(DAs). Therefore inter-subsystem interface is key issue for integration of the system. In ITER, the control interface between different subsystems is designed to utilized network based communication with coordination of EC main controller. [4]

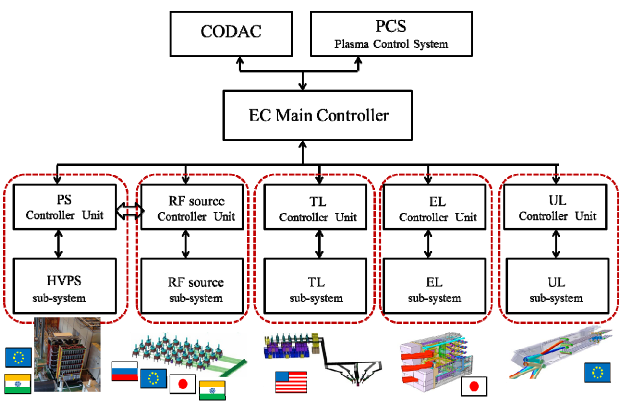

Fig.1. Control architecture of ITER EC system

For control interface, ITER defined standard documents for control namely Plant Control Design Handbook (PCDH) which includes catalogue of hardware and software to be used for ITER control system (ITER CODAC) [5,6]. ITER CODAC utilize Experimental Physics and Industrial Control System（EPICS）　as a standard control technology and EPICS tools such as Control System Studio (CSS) are defined a software for human-machine interface (HMI) and other functions.

In JAEA, the ITER relevant TL and a full size mockup of EL are connected to high power gyrotorn test stand and examined with high power operation. This configuration of integrated major EC components is suitable for validation of ITER EC operation as "ITER EC system prototype". In this presentation, the issue for coordinative operation of multi subsystem controllers and the experiment of synchronous operation of gyrotron and TL is reported.

2. Gyrotorn local controller

In JAEA, ITER relevant gyrotron local controller was developed based on PCDH standard technology for ITER EC system development. Figure 2 shows the architecture for gyrotron local controller. The local controller is consist of a slow controller and a fast controller.

The slow controller is consist of SIEMENS S7-300 PLC system and plant system host which provides EPICS communication for PLC. The slow controller manages state machine of gyrotron system and protection action for gyrotron and auxiliary devices. The slow controller also acquires the temperature and flow rate of cooling water lines for gyrotron and status information of auxiliary devices.

The fast controller is developed on ITER CCS computer with PXIe system. Timing control of gyrotron PS system and recording waveform of gyrotron parameters is defined for function of the fast controller.

The high power RF oscillation of 170 GHz gyrotron was successfully demonstrated using the ITER relevant control system.

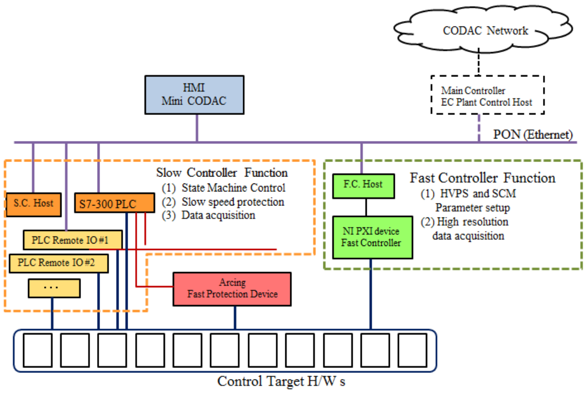

Fig.2. Architecture of Gyrotron Local Controller

3. Transmission line local controller

JAEA TL test stand consist of short TL and long TL sections and a waveguide switches (WGSW) WGSW connects short line and long line.

ITER relevant TL local controller was developed and it consist of slow controller. The controller remotely changes WGSW directions and in-line gate valves according to selected operation mode. Vacuum level in waveguides, cooling water flow rate, water pressure, and temperature are monitored. The operator can access all operation commands and present status at remote HMI.

The inter-subsystem communication is utilized for synchronous operation of TL and gyrotron. ITER requires to switch launchers during the plasma operation within 3 s. To change WGSW direction, it is mandatory to interrupt RF power during gyrotron pulse and quick recovery after switch operation. For this purpose, status of RF power and TL switch direction are shared with both controllers using S7 connection over Profinet. The sequential control of both system is implemented.

Figure 3 shows the sequence of the experiment. 1) Once gyrotron controller receives RF pause request, the controller stops gyrotron output RF power. 2) TL controller received the status of RF stop and start operation of waveguide switch. 3) After termination of switch operation, TL controller send the TL ready status. 4) When the gyrotron controller receives TL ready status, the controller resumes RF output.

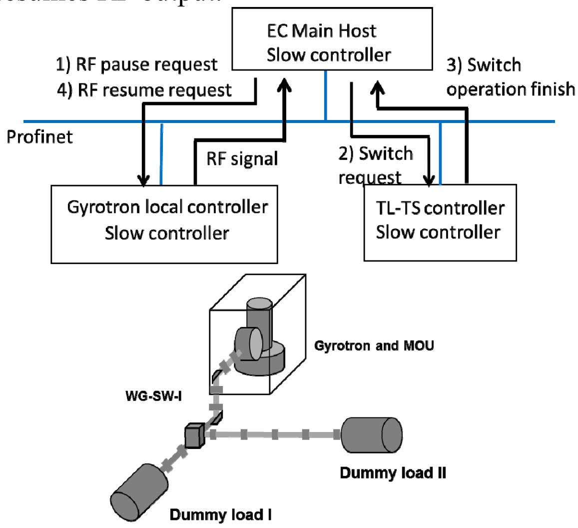

Fig.3. Schematic of TL test stand and control sequence.

The sequence operation of in-pulse switch operation was successfully demonstrated at 400 kW RF power and direction change took 1.5 s which achieved ITER requirement.

4. Summary

ITER relevant gyrotron local controller was developed and high power RF oscillation control using 170 GHz gyrotron was demonstrated. To validate the integrated control architecture of ITER EC H&CD system, ITER relevant TL controller was developed and TL switch operation during gyrotron pulse as coordinative operation of gyrotron and TL system was demonstrated and switch operation with synchronized RF power on/off control was achieved. The direction change during gyortron pulse took 1.5 s which achieved ITER requirement for switch operation during the plasma operation.

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