2.8 Recent progress in computer and control division

Computer & Control Division

Abstract: In 2010, the division has made many progresses in the HL-2A experiment, ITER participation and HL-2M design. The progresses lie in the application of large-scale tokamak-plasma numerical simulation code for HL-2A and HL-2M, the extensions of measurement and control system, the upgrade of the plasma control system of HL-2A, the construction of HL-2M plasma control system.

Key words: Acquisition and measurement; Numerical simulation; Plasma control

There are three main research and development activities in 2010. The first is research and development of data acquisition and measurement system. A series of devices and system have been updated for HL-2A experiment and ITER probe diagnostic project. The second is the verification of the relative design for HL-2M. The last is the upgrade of HL-2A control system and the development for HL-2M such as the density feedback control, the ECRH assisted startup experiment, the real-time network based on the reflective memory cards.

1 Improvements on acquisition and measurement system

1.1 Construction of time communication network

At present, the measurement and control system of HL-2A experiments, relying on the timing control system to trigger the start of the subsystem. These subsystems use their own internal clock to drive the the sampling or controlling. With the development of the experiment, it is becoming more and more necessary to use the new technologies to meet the ever-increasing demand for synchronization of measurement and control.

Therefore in 2010, the construction of time communication network (TCN) began. With ITER CODAC TCN standard, synchronous clock source program has been developed for the timing controller in HL-2A experiment. By adopting a unified central clock and control timing device, the accuracy of the subsystem and overall reliability have been ensured.

1.2 Research and design for ITER Langmuir probes M&C

After three years of research and design, some progress and experiences have been obtained for ITER Langmuir probes measurement and control, including design concepts and technological choices. After preliminary R & D, comprehensive system architecture has been developed and a series of feasibility tests and experiments have been passed.

These solutions and applications are detailed; (a) The circuit board of analog isolation amplifier, protection and interface have been designed and made for ITER probe measurement and control. Now it is in circuit commissioning. (b) With special framework and open interface, data acquisition system can meet the demand of Langmuir probes diagnostic enhancement. (c) It has been realized in data interface and code conversion based on Linux and EPICS, and data formats of application layer based on CAN protocol. (d) Using CSS or other GUI toolset on server to realize parameters configuration, state monitoring, command dispatching, data flow, and Communicate with CODAC System through Plant System Host.

2 Progress in the implementation of large-scale numerical simulation codes

2.1 Application in HL-2M design

According to physical target of the pre-plan of HL-2M project, the physical design of the basic configuration and the ohmic field coils for the schemes of $R = 1.90/\alpha = 0.68$ and $R = 1.78/\alpha = 0.65$ have been completed; the basic configuration for large triangularity and highly elongation, which with toroidal magnetic field is 2.2 T and the plasma current up to 2.5 MA, has been accomplished in the scheme of $R = 1.78/\alpha = 0.65$. Further more, the ohmic coils can provide 14 V and the average stray field during the plasma region lower to 20 G. The Triangle variable ability (DN, $k = 0.8$, SN, $k = 0.6$), the influence of betap, internal induction ($l_i$) or ohmic coils current on the basic configuration have been explored. We have participated in formulating and completing the dimension chain of the scheme of $R = 1.78/\alpha = 0.65$, which include the position, group numbers and the ampere-turns of poloidal coils.

2.2 Program development and application

Application of TSC; TSC simulation of HL-2M has been completed to verify the design PF coils system, and to analysis the consumption of Volt-seconds. The threshold of auxiliary heating power for high betap discharge has been studied, and
obtained time evolution of high plasma parameters with the auxiliary heating power about 12 MW.

The result and error analysis for the different calculation models of EFIT; It is assumed that the measurement errors of the poloidal magnetic probe signals are characterized by a normal probability distribution on HL-2A. The input signals with errors are calculated using the EFIT code in fitting mode. The analysis results show that the EFIT code is able to complete the calculation in the case with pressure profile, and the proportion with reasonable results is much higher than that without pressure profile, and the windage of minor radius is also smaller. It is very important for the design of magnetic probes on HL-2M.

The edge plasma simulation with B2; We supervised the postgraduate student engaged in edge plasma simulation. Some simulations have been completed only by B2 code. The simulation for the basic configuration of the schemes of $R = 1.90/\alpha = 0.68$ has been finished.

3 Improvements to plasma control system

3.1 Modifications in HL-2A control system

Among the plasma control subsystems, electron density control system has remained an important but difficult one. Electron density control is important, because the electron density of plasma is the most important parameter, which determines the plasma of many properties. Electron density control is difficult, because the electron density of plasma is not only controlled by gas fuelling, but is also strongly influenced by the vacuum wall condition, and the plasma confinement condition; at the same time, the measurement of plasma density would be disturbed by many factors. It is impossible to get rid of fuel to decrease the electron density of the plasma.

In H-mode discharge, the plasma electron density control is particularly important. When electron density is too low, it is impossible to shift from L-mode to H-mode; when density is high enough, there will be other issues. For example, when heating with ECRH X2-mode, if the electron density is larger than that for ECRH cut-off frequency, the ECRH power is no longer absorbed by plasma, the power is reflected to the vacuum wall, causing a big safety trouble to the device.

Because of the above reasons, during the 2010 – 2011 experimental campaign, the plasma electron density feedback control subsystem was improved greatly. Firstly, on the software side, the feedback algorithm has been modified and updated; a validation and verification subroutine has been added to plasma density measurement system to confirm the correctness of density measurement; a plasma state recognition subroutine has been added to make sure there is no violent MHD activity or minor disruption; a reference density waveform is provided which can help us to get flexible density wave curve. Secondly, on the hardware side, supersonic molecular beam injection system has been exploited to fuel by density feedback control; ECRH system has been exploited to actively decrease plasma density; a dedicated industrial personal computer has been added for density feedback control with inputs from diagnostic system carrying plasma density and current information.

After the above efforts, the precision and performance of density control have been significantly improved. The experimental results for shot 16608 are shown in Fig. 1. It is seen from the Fig. 1 that between 200 – 1000 ms in the time interval, the plasma electron density has been effectively controlled by molecular beam system and the ECRH system.

In order to validate the ITER ECRH pre-ionization and assisted startup scenario, and to grasp the ECRH pre-ionization and assisted startup technology, which is very important for HL-2M to get first plasma during its commissioning, when a large stray field exists with small or no field area. We have successfully demonstrated ECRH pre-ionization and assisted startup experiment on the HL-2A, for ECRH O1-mode and X2-mode, for variety of prefilling conditions, and for different

Fig. 1. Density feedback control experimental results for shot 16608.

Fig. 2. ECRH assisted startup experimental results for shots 14444 and 16617.
ECRH injection angles, with the toroidal electric field less than the value of ITER (0.3 V · m⁻¹).

The experimental results for shot 14444 and 16617 are shown in Fig. 2. In the Fig. 2, \( I_p (cc) \) indicates the reference plasma current. Shot 14444 (black) with O1-mode, heating power 250 kW, is preionized without delay, while shot 16617 (red) with X2-mode, heating power 800 kW, is preionized with a delay of 30 ms. The toroidal electrical fields for both shots are less than that of ITER (0.3 V · m⁻¹).

3.2 Progress in the construction of HL-2M plasma control system

In addition to the RTLinux which was introduced in 2009, reflective memory (RFM) network which can transfer data digitally in real time is introduced into the plasma control system in 2010. The architecture of the reflective memory network for central plasma control system and the power supply system is shown in Fig. 3.

NI RT system is adopted as the platform for the real-time data acquisition and the power supply system where NI 6259 is installed as the data acquisition and signal transmitting. RTLinux is chosen as the RT platform for the RT EFIT and plasma control algorithm. Moreover, the RT driver used in RTLinux for the reflective memory card has been programmed and tested.

The plasma current and position code has been accomplished using C + + language and the test is in progress. The central control parameter program base on Matlab has been transplanted from VB and excel platform. The GUI of this program is shown in Fig. 4.

The message transferring mechanism based on RFM has been designed and tested to solve the data synchronization problem occurred in HL-2A experiment. Based on the relevant design of ITER CODAC, the global state monitoring and soft real time control system based on EPICS is being developed.

4 Summary

Much research and development was done for HL-2A experiment, ITER participation, HL-2M design in 2010. Besides, great progress has been made on acquisition and measurement system, plasma numerical simulation, and plasma control system. Based on the current layout, this division will focus on above three main objects to do relative research and development in next year.