Upgrade of plasma density feedback control system in HT-7 tokamak

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Abstract The HT-7 is a superconducting tokamak in China used to make researches on the controlled nuclear fusion as a national project for the fusion research. The plasma density feedback control subsystem is the one of the subsystems of the distributed control system in HT-7 tokamak (HT7DCS). The main function of the subsystem is to control the plasma density on real-time. For this reason, the real-time capability and good stability are the most significant factors, which will influence the control results. Since the former plasma density feedback control system (FPDFCS) based on Windows operation system could not fulfill such requirements well, a new subsystem has to be developed. The paper describes the upgrade of the plasma density feedback control system (UPDFCS), based on the dual operation system (Windows and Linux), in detail.

Keywords Tokamak, Density feedback control system, Real-time capability

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1 Introduction

The plasma density feedback control subsystem (PDFCS) is one of the subsystems of the distributed control system in HT-7 tokamak (HT7DCS). It is very complicated because of involving in many sub-tasks, such as data acquisition, handling and sending out gas puffing control pulse to adjust the amount of gas injected into the vacuum vessel of the equipment, in real-time. Thus, both excellent real-time capability for the density feedback control process and good stability for the running of the subsystem are essential, for these two will be the most important factors which decide whether the control behavior is correct or not.

The FPDFCS is based on Windows operation system.[1] It had been used many times in our former experiments. Although we made some improvement each time, there are still some problems we can't solve, because the problems are brought by the platform the FPDFCS is based on. With rapid progress of the HT-7 experiments (such as $t_d = 50.01$ s, $I_p \sim 60$ kA, $n_{eo} > 1.0\times10^{19}$ m^{-3}, $T_e \sim 600$ eV, PLHW ~ 140 kW), we urgently demand that the PDFCS provide more real-time control process and more excellent control results. On such background, we have made an upgrade from FPDFCS to UPDFCS successfully. The paper describes the hardware structure and software implementation of the UPDFCS in detail.

2 Structure design of UPDFCS

In order to make full use of advantages of Windows operation system and Linux operation system, the structure of UPDFCS is designed to be an Up-Down machine style. The Up-machine is based on Windows operation system, which, with excellent man-machine interface, makes parameters setting and data showing in graph and text style very easy, while the Down-machine is based on Linux operation system. Linux is a free Unix-type operating system originally created by Linus Torvalds with the assistance of the developers around the world. Developed under the GNU General Public License, the source code of Linux is freely available for everyone, and its key attractiveness to us is that the kernel and utilities of the Linux operation system can be tailored to the exact requirements of the system. In our case, the main task of the UPDFCS is to provide effective and reliable plasma density control, thus its core components

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should provide the function of data acquisition, data handling and sending out control pulse in real-time. According to the task, we decided finally to utilize such characteristics of Linux to realize the functions in the Down-machine.

The Up-machine provides the parameters and visual signal graphs of experiment and the Down-machine just provides the function of plasma density control. They work respectively except for exchanging necessary information with the assistance of network in TCP/IP protocol. The merit of the structure is that it can divide the general task of the UPDFCS into two sub-tasks. Both of them are simple tasks that are easy to realize with the help of advantages of respective operation system. In recent years, a great progress has been made in HT-7 experiment. For instance, 63.95 s long pulses and lots of advanced experimental parameters have been obtained. This brings up a new conflict between the network speed and the quality of data produced in each shot in such a structure. We must ensure there is no network block occurring during the period of transferring the data to the Up machine under the environment of control sub-LAN. In solving this conflict, we have used two Ethernet cards in the Up-machine. The first card is connected to the Down machine, which makes them to be a ‘Peer to Peer’ LAN and it is only responsible for transferring data between them without disturbance from outside. The second card is connected to the control sub-LAN in order to get a uniform shot number.

Fig.1 shows the basic structure of the UPDFCS.

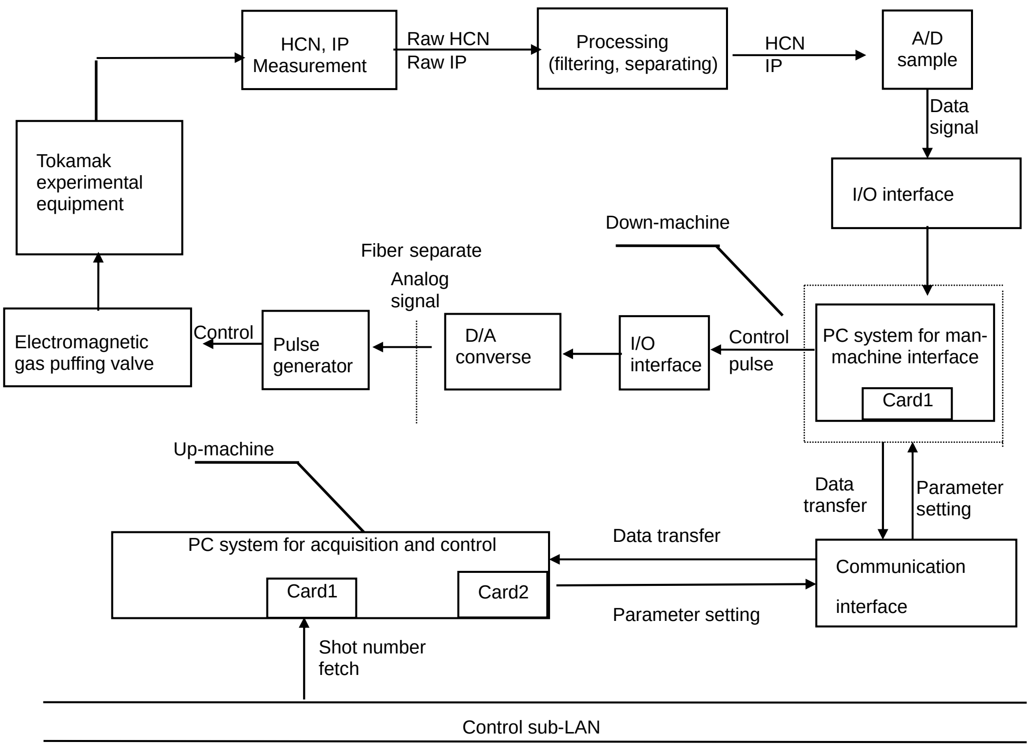

Fig.1 Structure of the UPDFCS.

3 Implementation of UPDFCS

3.1 Software design of UPDFCS

Fig.2 shows the software structure of the UPDFCS. It consists of two parts. One is implemented in the Up-machine, including five sub-modules, i.e. shot number fetch sub-module, data showing sub-module, parameter setting sub-module, data saving sub-module and communication sub-module. The other is implemented in the Down-machine, including three sub-modules, i.e. data acquisition sub-module, control sub-module and also a communication sub-module.

The functions of these sub-modules are as follows:

(1) Parameter setting sub-module is used for reading out the important parameters set by operators. These parameters include PID parameters, pre-set plasma density value and pre-set gas puffing pulse.

(2) Data (signal graphs) showing sub-module is used for drawing wave form of some important signals, such as HCN, IP, Ne, control pulse. All of these are drawn with a graph or text style.

(3) Data saving sub-module is used for saving HCN, IP, Ne, control pulse in the Up-machine received from the Down machine.

(4) Communication sub-module is used for exchanging necessary information between the Up-machine and the Down machine. It is a unique and important one that spans the two machines.

(5) Data acquisition sub-module is an important one among all these sub-modules. Its work can be divided into two steps logically, original signals acquisition and data handling.

(6) Control sub-module is another important one. Its main function is to send out gas puffing control pulse generated in the process of data handling.

(7) Shot number fetch sub-module is used for fetching uniform shot number from the control sub-network.

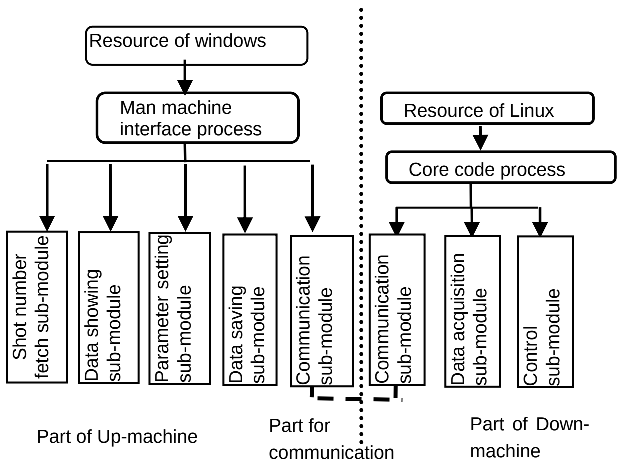

Fig.2 Software components of the UPDFCS.

3.2 Software implementation of UPDFCS

The UPDFCS is the upgraded version of the FPDFCS. It can provide relatively true and good control of plasma density through making full use of the dual operation system. However, with the Up-Down machine structure, it also brings some problems that demand us to solve with an efficient method. The following is the description of the implementation for sub-modules and methods concerned for solving the problems.

3.2.1 Implementation of communication sub-module[2]

The Down-machine must have the ability to acquire parameters needed for data handling before each shot and the ability to transfer original data and handled data to Up-machine for saving and drawing. The communication sub-module is responsible for these tasks. We use Socket method to implement the communication between the Up-machine and the Down machine. Socket is an I/O interface for communication between applications. The detail of how to implement has been described in Ref.[2].

3.2.2 Solving problem of data transfer between two machines

With the improvement of HT7 experiment, shot time will be longer, and data amount will be larger.[3,4] Hence a high data transfer speed between the Up-machine and the Down-machine is demanded. In order to fulfill this requirement, we separate the Up-machine and the Down-machine from control sub-network outside and make them a ‘Peer to Peer’ style network. Thus there will be no disturbance brought by outside factors. Since the UPDFCS has a uniform shot number with other sub-system which produces in control sub-LAN, the Up-machine is also connected to the control subsystem with another net card.

3.2.3 Implementation for data acquisition and control sub-modules

With the software trigger mode and the interrupt data transfer mode, the driver module of the PCI9112 DAS Cards produced by ADLINK TECHNOLOGY INC is programmed in Linux operation system.[5] Fig.3 shows the basic cooperation between the Up machine and the Down machine.

3.2.4 Implementation for sub-modules in Up-machine

Delphi 5.0 program language is implemented into all sub-modules of the Up-machine. The task is relative simple in the Up-machine and the main difficulty is how to cooperate with the Down-machine. The UPDFCS uses multi-thread programming for solving this difficulty.

3.2.5 Performance test for UPDFCS

Table 1 shows the result of data transfer speed between the Up-machine and Down-machine. It shows that the UPDFCS can meet the demand of data transfer speed well.

Table 2 shows the result of real-time capability of the UPDFCS. Real-time capability is the most important factor that affects the control effect, and the comparison obviously shows that the UPDFCS has a more excellent real-time capability.

The stability test has also been made, and the result shows the UPDFCS's stability is very high.

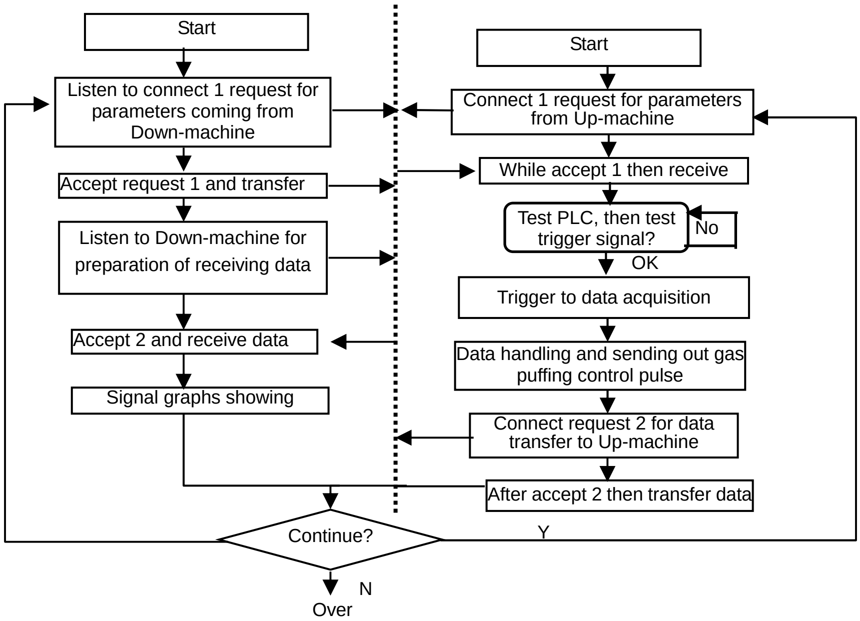

Fig.3 Cooperation chart for the Up-machine and the Down-machine.

Table 1 Test result of transfer speed between the Up-machine and Down-machine

Media type	Processor type	Pre-set shot period (s)	Data amount (byte)	Consumed time (s)	Transfer speed (byte/s)
10 M	PIII 866	100	13946928	$27<t<28$	$\sim 4\times10^6$
100 M	PIII 866	100	13946928	$3<t<4$	$\sim 30\times10^6$

Table 2 Real-time capability test result (sampling rate: 176 μs)

Processor type	Sampling times	Average loss times		Average loss rate	
		UPDFCS	PDFCS	UPDFCS	PDFCS
PIII 866	100000	28	126	0.028%	0.126%
PⅣ 1700	100000	17	----	0.017%	----

4 Conclusion

The UPDFCS is a relative excellent control subsystem compared with the FPDFCS. It can fulfill many requirements for the plasma density control of HT7 experiment, especially in respect of real-time capability and stability.

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