tial. We can see from Fig. 2, the poloidal phase velocity presents a clear change in the propagation direction of fluctuations from the electron diamagnetic direction in the inside the limiter radius to the ion diamagnetic direction in the outer edge of the plasma behind the limiter. These facts provide further strong substantiation for the identification of the Reynolds stress gradient as the origin of the development of the increasing v_θ, and indicating that the large change in E_r is associated entirely with the Reynolds strss-driven poloidal flow.

The electrostatic Reynolds stress (proportional to $\langle \tilde{E}_r \tilde{E}_\theta \rangle$) shows a radial gradient in proximity to velocity shear layer, suggesting that the turbulence-induced Reynolds stress might be the dominant mechanism to create the poloidal flow and E_r shear, indicating that this mechanism can play a significant role to explain the physics of poloidal flow in the plasma boundary region.

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1.9 Necessary Considerations for the Machine Control System of the HL-2A Tokamak

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Key words Machine control system PLC communication

The HL-2A tokamak will be put into operation in 2001 according to construction program, therefore the installations of machine control system(MCS) should be finished by October, 2001. MCS is the part for logic and time sequence management of all systems. MCS controls and manages the action time, action logic, monitoring and protections of all subsystems. MCS includes 3 parts, time sequence and logic control, video and audio. All of the control tasks for operation and discharge of HL-2A are carried on by combination of MCS and discharge control system(DCS). The central control hall can be used as an academic exchange place with video and audio devices. We try to build an advanced, economical, extensible and low cost system in the design for MCS and finish the control tasks in time according to the requirement of the HL-2A engineering

construction.

Aided by the technologies of computer, integration circuit and communication, the industrial automation has been developed largely with wide applications of field buses. With strong abilities of computation and communication, it is possible to centrally control a large distributed field only by a controller. So the system becomes a reliable, safe, easily extensible, automatic one with low cost and resource reusable and sharable. Since MCS of the HL-2A tokamak is a totally new one, we choose programmable logic controller (PLC) with Profibus-DP field bus communication to assemble MCS. Compared with other automation instruments, PLC has the advantages of reliability, strong logical calculation ability and low cost. By means of PLC 1 000 basic bool calculations can be finished in 200 μs. Profibus-DP is a fast communication field bus with small amount of data. The information with which 32 slave stations refresh 512 digital I/O points on each can be transmitted in just 2 ms on the bus. The data transmission speed can fit the necessities for real-time protection information communication for HL-2A. The signals on a field bus are digitized and reliable. The optical insulation is available. Furthermore, the system integration investment is largely reduced and simplified with less wire connections. The whole system has strong self-diagnostic ability, the instrument replacement and the function extension become flexible and convenient.

The net communications are widely used at JT-60U and ASDEX-U[1, 2]. PLSs are also used on ASDEX-U. Recently, the calculation ability and speed of a PLC have been largely improved. It can be used as a strong local controller. Industrial Ethernet will be used in MCS of HL-2A. Ethernet is a fast net with lots of available technologies. Ethernet has been widely used in industrial automation. We will develop real time communication programs and the software architecture of Server/Client with open technologies such as DDE, OLE and DCOM, etc, to take advantages of the real time communication ability of Ethernet to meet the control requirements. Meanwhile, the direct I/O and Profibus-DP communications are also used to convey the real time protection information to ensure safeties of machine, instruments and persons. Ethernet and diagnostic LAN are linked mutually. Any terminal can share resources and get messages on the two LANs.

The centralized control must be satisfied with two conditions, hardware and communication. The communication and the coordination among the subsystems are managed with the software. Any user program developed with special software developing kit needs time and specialized persons. We try to use open software, developing kits, nets and hardware to ensure the extension and further development for both hardware and software. The open software technologies such as DDE, OLE and DCOM, etc, will be used. The software will be developed with good GUI, so as to be easily used and studied.

In order to reduce the cost, some automation instruments used on HL-1M such as

PLCs and DAQ cards will be used in MCS of HL-2A. It is clear from the comparison that a large automation system with field bus costs less than that communicates with traditional I/O connections. The audio system in the design plays an important role in system installation, operation and academic exchange. The video system processes and displays the industrial television and VGA graphics, it is important for safety, academic exchange and field monitoring of bad conditions.

After the machine control system is built, all the field signals are connected to the I/O modules of PLCs. The distributed I/O modules manage the I/O modules. As slave stations of Profibus-DP, the distributed I/O modules are connected to CPUs of PLCs through Profibus-DP. These PLC-CPUs manage all of the signals. PLC-CPUs are connected to Ethernet to accept the parameters, instructions, programs and real-time protection information. Ethernet is connected to diagnostic LAN through a server. Any terminal on each net can share the experimental and engineering data on both nets. The audio and video systems are more direct ways to assist PLC system to carry on relevant control tasks.

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