Construction of the Central Control System for the Large Helical Device (LHD) Fusion Experiment

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The world's largest superconducting helical fusion facility, the Large Helical Device (LHD), is in the final stage of the 8-year construction schedule at the National Institute for Fusion Science (NIFS), Toki-City, Japan. For flexible physics experiments and reliable engineering operations of the LHD machine, the Central Operation and Control System (COCOS) has been designed and constructed. A conventional hard-wired logic system has been used between COCOS and several tens of sub-systems in addition to the FDDI computer network communication. The Windows-NT client/server system is adopted as man-machine interface in addition to a Unix data monitoring system using a WWW/Java program. The construction of COCOS will be finished in December, 1997, and the first plasma operation will be started at the end of March, 1998.

1 Introduction

Helical systems have inherent merits of steady-state operations for fusion reactors. The Large Helical Device (LHD)[1-3] (Fig.1), the world's largest superconducting helical fusion machine with a major radius of 3.9 m, a minor radius of 0.6 m and magnetic energy of 1.6 GJ, is now in the final stage of the 8-year construction schedule at Toki-City, Japan.

One of the main objectives of the LHD project is to demonstrate steady-state operations of a helical fusion system extrapolatable to a future fusion reactor and to study toroidal fusion plasma behavior. The construction of all the superconducting coils has already been completed, and the cryostat and the plasma vacuum vessel have been installed on the final location.

In April 1996, we started the construction of the Central Operation & COntrol System (COCOS), the control data monitoring system and the uninterruptable power supply (UPS) system for the LHD Control Building. In addition to this central control system, about 50 sub control systems are being prepared. These systems are composed of a variety of computers such as UNIX engineering workstations, Windows-NT client/server personal computers, VME computer boards with real time OS and programmable logic controllers (PLC).

In this paper, the current status of the LHD central control system COCOS will be presented.

2 Operation scenario

The LHD machine operation is classified into six modes; shut-down mode, facility operation mode, vacuum exhaust

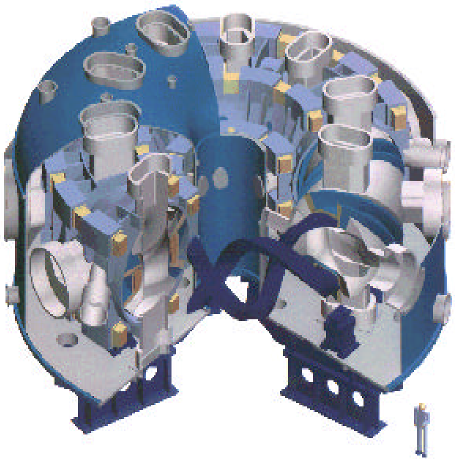

Fig.1 Schematic view of LHD(Large Helical Device)

mode, coil cooling mode, coil operation mode and plasma experiment mode (Fig.2). These modes determine the personnel entrance requirements with respect to electricity and vacuum hazards, magnetic field hazards and possible radiation exposure. Its sequential control is carried out by the COCOS central slow sequence and fast timing system. For simplifying the construction of a reliable control system, we decided firstly to use hardwired connection between the COCOS and the sub systems. In particular, the protective interlock system requires this for its simplicity and reliability. Secondly, we added a flexible LHD Man-machine System (LMS) based on Windows-NT to COCOS.

The superconducting helical and poloidal magnets should be operated safely and reliably, and the plasma experiment require flexibility. These magnets will be operated for about 10 hours per day, and the rate of short-pulsed plasma operations with 10 second duration will be typically 50 - 100 shots per day. The LHD is also going to be operated in steady state mode (more than 1 hour pulse length) and requires interactive control of the machine and the plasma. Advanced control methods such as fuzzy logic, neural network, genetic algorithm (GA) or chaos control schemes will be adopted to perform flexible and reliable LHD operations.

3 LHD control system [4-5]

3.1 Concept of the LHD central control system

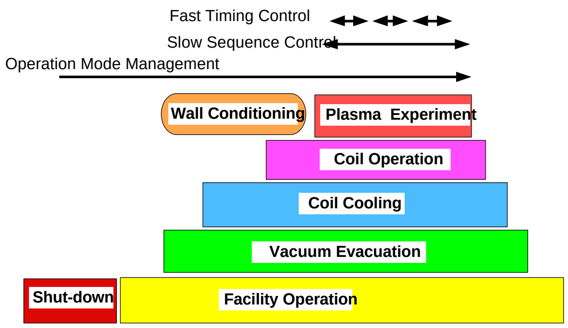

Fig.2 LHD operation modes

The current goal of the LHD project is to produce a first plasma as soon as possible, and as reliably as possible. On the basis of these operation scenarios, the designed control system is composed of the central experimental control system and several subsupervisory facilities which are connected by the FDDI-LAN in addition to hard-wired interlock and sequence control. The construction of the main unit of COCOS was started in April, 1996 based on the following design philosophies;

(1) flexibility for physics experiments,
(2) reliability for the large engineering machine and
(3) expandibility for the central control system.

The design philosophy (1) requires a human-friendly man-machine interface and advanced real-time plasma control systems, item (2) requires reliable, hardwired, protective interlock systems, and requirement (3) leads to distributed and modularized control/ monitoring systems.

A conventional hard-wired logic system has been used between COCOS and several tens of sub-systems in addition to the FDDI computer network communication (Fig.3).

3.2 History of LHD control system studies

At the beginning of the LHD proposal (about 10 years ago), the control system was expected to be based on a centralized control “process computer”. About 5 years later a UNIX engineering work satiation with VME computers was proposed. Now, some client-server systems using Windows-NT have been added for control and data acquisition. These central systems and more than 50 sub-systems are now connected by FDDI and ATM networks.

3.3 Architecture for LHD control system

COCOS is composed of the central control unit (central console, central control board, central control computer, and the timing board), the torus instrumentation unit (torus instrumentation computer board and protective interlock board), the LHD Man-machine System(LMS), the control data acquisition system, the LHD experimental LAN and the uninterruptable power supply(UPS) systems. These systems use a variety of computers such as UNIX engineering work stations, Windows-NT personal computers, VME computer boards with real time OS (VxWorks) and programmable logic controllers (PLC).

Figure3 shows the details of this system architecture. The initial LHD operation should be carried out quickly And reliably. A central board with hardwired progra-

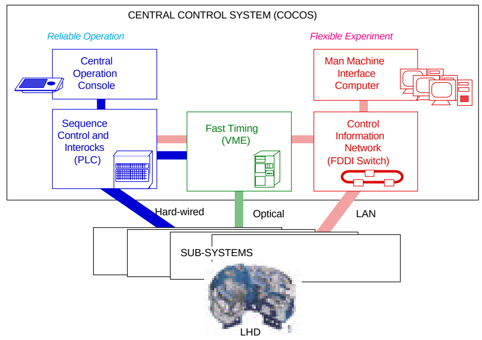

Fig. 3 LHD central control system concept

mmable logic controllers will be used for this initial operation. This is particularly importance for the protective interlock system in COCOS.

The fast timing system with 64 channel optical signals (accuracy: 1 micro-second, set-up interval: 1 ms ~ 10 hr) will be distributed to sub-systems.

The feedback control for plasma current, position and cross-sectional shape will be carried out using intelligent VME control systems, such as applications of fuzzy logic and neural networks in addition to standard PID plasma control algorithms. Related R&D programs have been carried out.

3.4 Data monitoring systems for machine and plasma

For machine supervision one of the data monitoring systems is based on Windows-NT using a 1300 channel VME board [4-5]. The LHD Fast Data Monitoring system[6] with a 512 channel VME and a UNIX workstation was also constructed. Full Java computer software in WWW Browsers was used in the latter system which will be extended to 4000 channels. To manage the data, a relational Data base was used in this system.

On the other hand, the plasma data acquisition system[7] using CAMAC modules is now under construction based on Windows-NT. The large super-computer system for theoretical analyses using experimental data are connected to the experimental control computer by the inter-laboratory FDDI-LAN and ATM system.

4 Construction of the LHD control building and experimental schedule

In our new site (Toki-city, Gifu-prefecture), the construction of the main experimental hall of the LHD Building was finished in August, 1995, and the superconducting coil winding machine for helical coils had been operated. The construction of the largest superconducting poloidal coil has also been completed in this experimental hall. The lower cryostat, the electric power supply for poloidal coils and the Helium refrigerator were installed there. Both the machine and the building construction are on schedule.

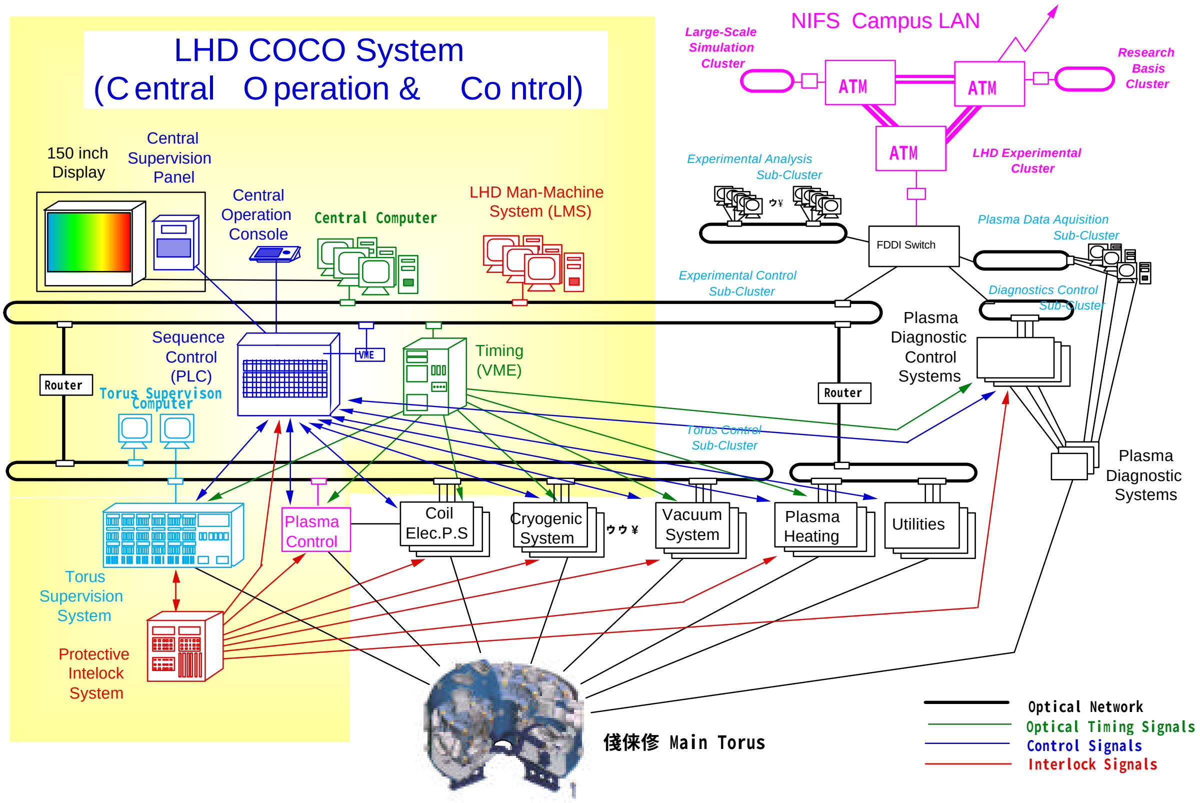

Fig. 3 LHD control system

The LHD Control Building with the main control hall was completed in November, 1996. The plasma experiments will be started at the end of March in 1998, and a variety of experiments using this SC helical device will be performed.

Fig.4 Central control system COCOS installed in the main control hall

5 Summary

The construction of the LHD Central Operation & COntrol system (COCOS) has been started in April, 1996.

The design philosophies of COCOS are (1) flexibility, (2) reliability and (3) expandibility; namely (1) human-friendly man-machine interface and advanced real-time plasma control; (2) reliable hard and soft interlocks; and (3) distributed and modularized control system.

The LHD Control Main Hall was completed, and the construction of the COCO system will be finished on December, 1997. The LHD plasma operation will be started at the end of March, 1998.

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