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STATUS OF LHD CONTROL SYSTEM DESIGN

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Abstract

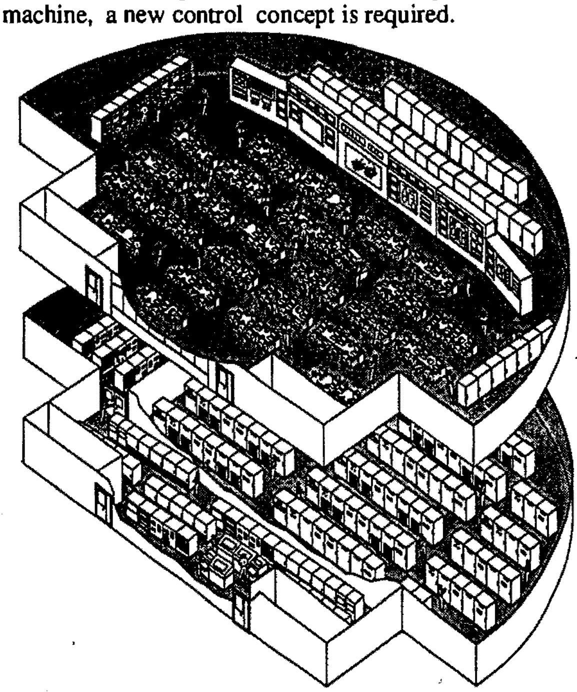
The present status of LHD (Large Helical Device) control system design is described, emphasizing on the plasma operation modes, the architecture of the LHD control system, the real-time plasma feedback system with PID or Fuzzy controllers and the construction schedule of the LHD control system. The conceptual and detailed designs are under way taking flexible and reliable operations for physics experiments into account.

I. INTRODUCTION

The Large Helical Device (LHD) fusion system [1-3] using 1.6 GJ superconducting (SC) magnet is now under construction and its plasma experiments will be started in April, 1997. For this purpose, a new national institute (National Institute for Fusion Science) was established in May,1989, and a new site (Toki city; one-hour drive from the present site in Nagoya) were prepared for these experiments. The main objectives of the LHD project are

(1) the study of the behavior of high temperature / high density plasmas using helical torus device for comprehensive understanding of toroidal plasmas, and
(2) the exploration of the prospect to the steady-state helical system reactor.

The major plasma radius of LHD is 3.9 m , and the magnetic field strength is 3 Tesla (4 Tesla in the second experimental phase), which is the largest SC fusion machine now under construction. To keep flexible and reliable operations of this SC machine, a new control concept is required.



In this paper, the present status of the control system for operations and experiments of the LHD system is presented.

II. LHD MACHINE DESIGN AND CONTROL CONCEPT

The LHD system consists of one pair of SC helical coils, three pairs of SC poloidal coils, plasma vacuum vessel, cryostat, vacuum pumping system, electric power supplies, plasma production system, liquid helium refrigerator, three (NBI, ECH, ICRF) plasma heating systems, many plasma diagnostic systems and so on. All these equipments should be monitored and controlled mainly from the LHD Control Building. Especially, the control system should be flexible as a experimental machine and reliable as a large plant.

In contrast to present helical devices, the LHD is characterized by the steady-state operation using the superconducting helical coils and the built-in divertor, which requires the elaborate control scheme for operational safety and the new plasma feedback system for experimental flexibility.

These LHD machine and central control systems are schematically shown in Fig.1.

III. LHD OPERATION SCENARIOS

The LHD machine operation is divided into three modes; all shut-down mode, facility operation mode and experiment mode. The experiment mode consists of the SC magnet operation mode and the plasma experiment mode (Fig.2). These modes are defined for clarifying the personnel entrance permission, magnetic field hazard and possible radiation exposure. Aside from software interlocks, the hardware interlock logic should be determined independent of these modes.

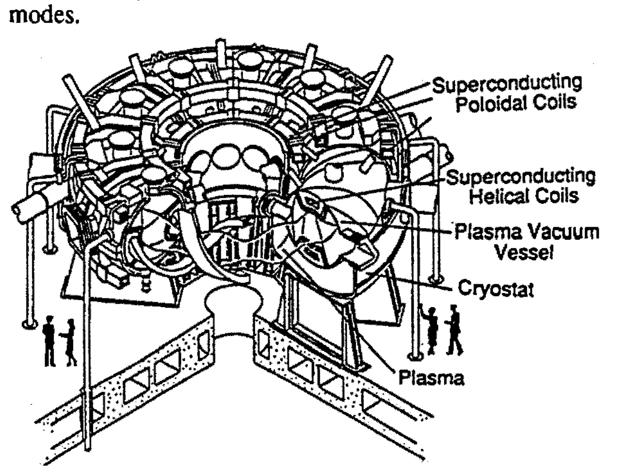


Figure 1 Schematicdrawings of LHD machine (right) and its control system (left).

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The SC magnet will be operated for about 10 hours per day, and the number of short-pulsed plasma operations will be typically 50 - 100 shots per day. After 3-year first-stage experiments, the magnetic field strength is upgraded from 3 Tesla to 4 Tesla, and thousands of D-beam / D-plasma operations are planned.

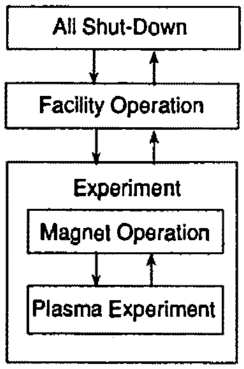

Figure 2 LHD operation mode

IV. LHD CENTRAL CONTROL SYSTEM DESIGN

Based on the above-stated operation scenarios, the designed control system is composed of central experimental control system, and several sub-supervisory control systems such as torus machine control, heating machine control, diagnostic control and electric / cooling utility control systems, as shown in Fig.3. All sub-supervisory systems are connected by the local area network (LAN).

Within the facility operation mode, basically almost all equipments are operated by each subsystem controller. The vacuum pumping and wall conditioning including baking and glow discharge cleanings are controlled from the main torus control system, and each heating system is operated by each controller. On the other hand, in the experiment mode, main input parameters are controlled mainly from the engineering workstation of the central experimental control system. Overall system diagram of LHD control systems is given in Fig. 4.

The details of this system design is described in the separate paper [4].

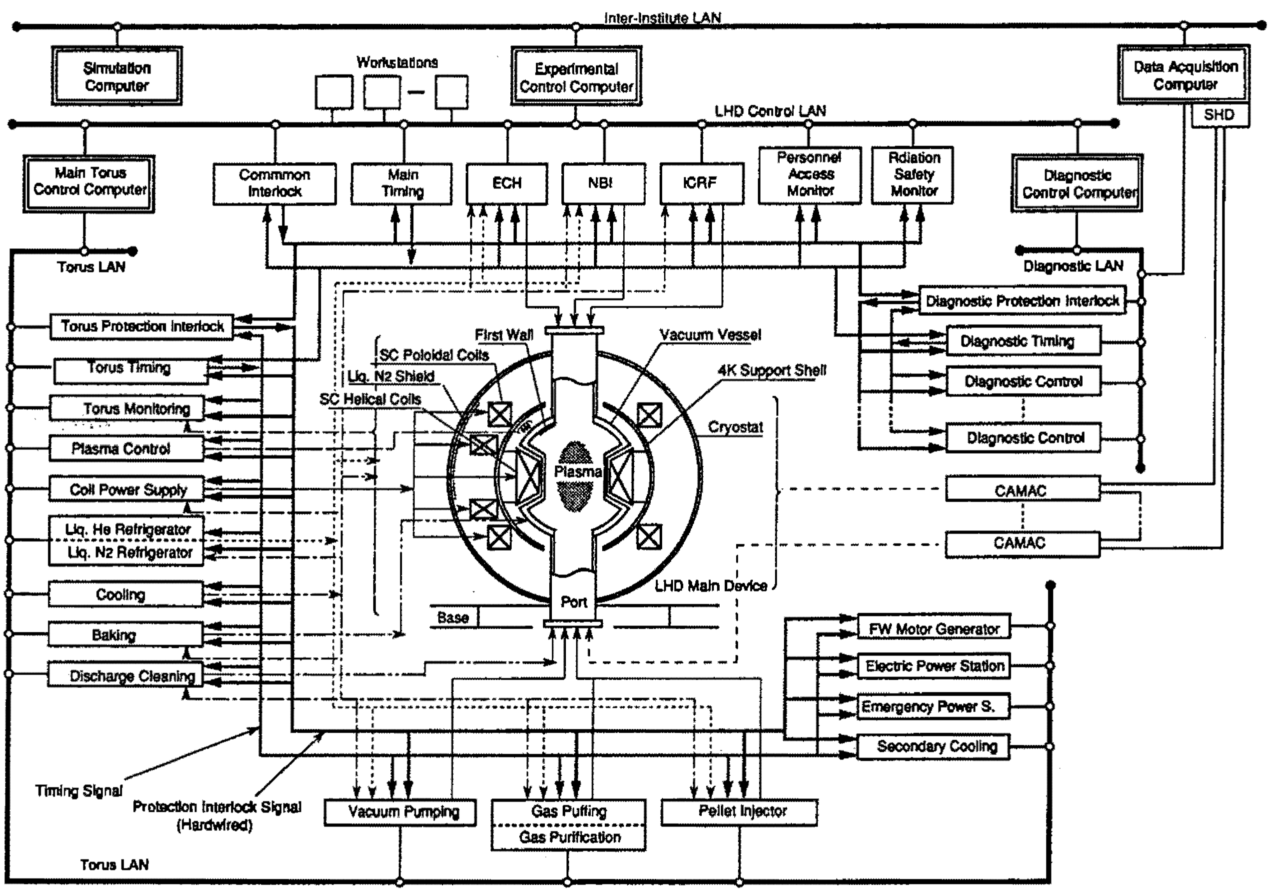

Figure 4 System diagram of LHD control.

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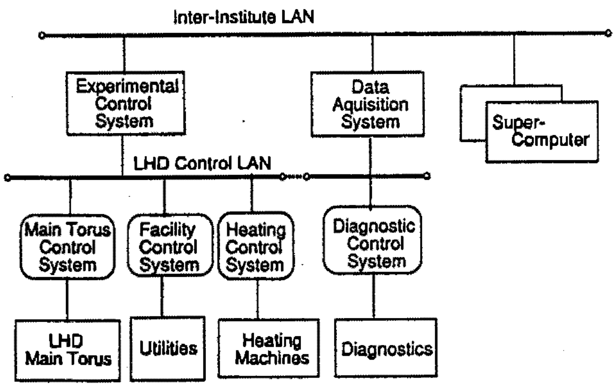

Figure 3 LHD control system architecture

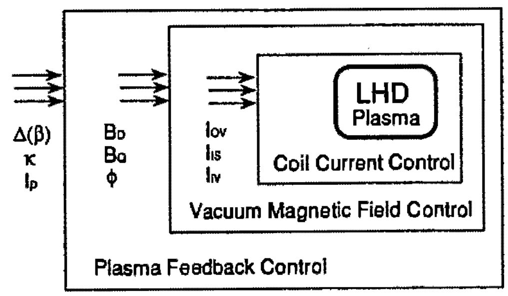

Figure 5 LHD plasma control concept

V. REAL-TIME PLASMA FEEDBACK SYSTEM DESIGN

According to the experimental requirements to make flexible plasma operations, an elaborate feedback control system with PID and Fussy logic control concepts [5,6] are under consideration.

The quantities for feedback are plasma current (Ip), plasma position (Δ), plasma cross-sectional shape(κ), plasma density, heating power and so on. Especially, the former three variables are controlled by the power supplies of one-pair three-block helical coils (HF) and three-pair poloidal coils (OV,IS,IV). The basic concept of the plasma feedback system is shown in Fig.5 as a combination of the coil current feedback (IHF,IOV, IIS, IIV), the vacuum magnetic field feedback (B0,BD, BQ, φ) and the plasma feedback. These components are related to each other trough the magnetic configuration matrix. A typical system diagram of this scheme is shown in Figs.6 and 7(a).

Conventional PID controllers or min-max Fuzzy logic controllers with the center of gravity defuzzification method are analyzed including eddy current loops of the LHD system. The controllability of these two algorithms is compared in Fig.7(b) for the LHD Plasma operations. The details of this analysis will be published somewhere.

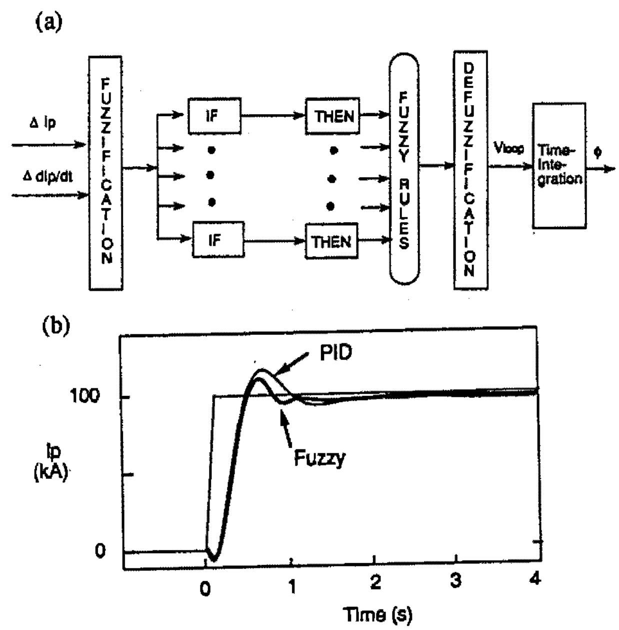

Figure.7 Fuzzy logic control system
(a) Fuzzy algorithm
(b) Comparisons between PID and Fuzzy feedback responses.

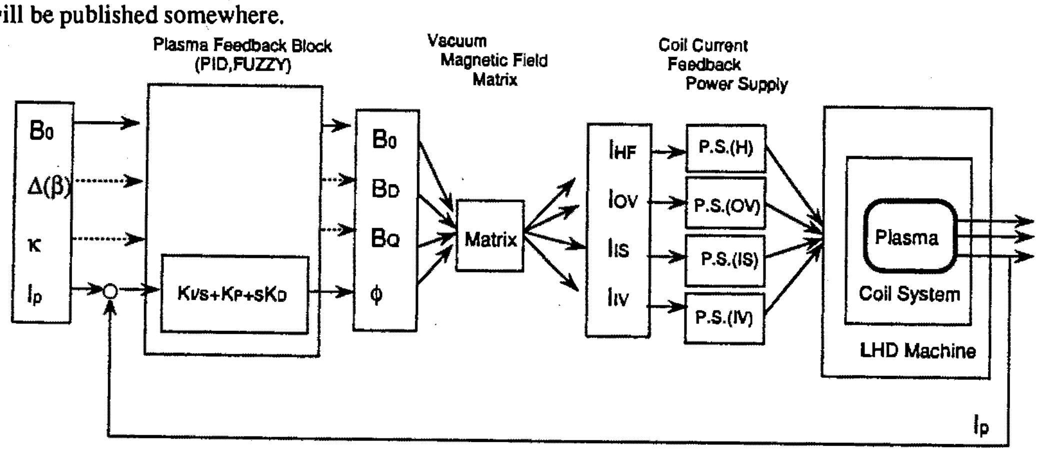

Figure.6 LHD Plasma control system diagram with PID controller.

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VI. CONSTRUCTION SCHEDULE OF CONTROL SYSTEM AND BUILDINGS

The construction of LHD device itself has been started in 1991 as a 7-year project, and a first plasma operation is scheduled in 1997.

The basic design of the LHD central control system has been carried out in 1991-1992, and the detailed design will be done in 1993-1994. The proto-type R&D system for LHD machine operations and plasma controls is under preparation in 1991-1996 for the development of software. The LHD central control system will be constructed in 1995-1996.

In the new site the cryogenic building was firstly constructed in 1990 and the main LHD building is now under construction and will be completed in 1993. The LHD control building will be completed in F.Y.1995, and the central control devices will be installed there.

VII. SUMMARY

The design of the control system for the Large Helical Device (LHD) system has been conducted for the flexible and reliable operations of the large experimental fusion systems. The LHD machine and its control system will be completed in March, 1997.

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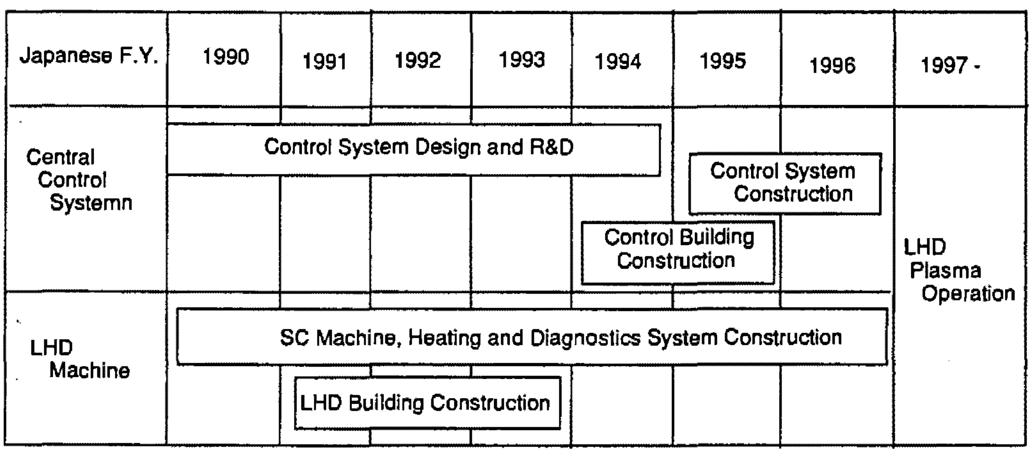

Figure 8 Construction schedule of LHD machine and central control systems