(4) LHD Device Engineering Experiments

1. Introduction

The LHD superconducting system consists of a pair of pool-cooled helical coils (H1 and H2 coil), three pairs of forced-flow-cooled poloidal coils (IV, IS, and OV coils), nine superconducting bus-lines, a helium liquefier and refrigerator in the 10 KW class, and six DC power supplies. Availability higher than 99% has been achieved in a long-term continuous operation both in the cryogenic system and in the power supply system since the first cool-down in February 1998.

The output voltage of the main power supplies for the helical coils and poloidal coils are ±45 V and ±33 V, respectively. They have capacities to charge all the coils to the full currents within 15 minutes. In addition, thyristor rectifiers with the output voltage of ±180 V and current capacity of 6.2 kA are added to the power supply systems for IV coils and IS coils for dynamic control of the plasma axis. They can change the plasma axis by approximately 0.1 m/s at 0.5 T. Remote switches to change the polarity of coil currents have been installed after thirteenth cycle.

The reliable operation of the large superconducting system has been demonstrated, and researches to examine properties of the superconducting coils are continued toward fusion reactors. Results of device engineering experiments and the operations in the thirteenth cycle are summarized.

2. Thirteenth Cycle Operation of LHD

The history of the thirteenth cycle operation of LHD is shown in Table 1. Main compressors of the cryogenic system started on August 21, 2009 and stopped on January 29, 2010. The total operating time was 3,688 hrs. The main compressors were tripped during a quick discharge triggered by malfunction of a quench detector for the helical coils. In addition, the compressors were stopped to restart the control system of the cryogenic system because of a failure of the communication between VME reflective memory boards. Total stop time was seven hours, and the availability in this cycle was 99.8%.

The quick discharge from the high field was triggered twice by malfunction of quench detectors for the helical coils. The cause of the malfunction is not clear, but a possible reason is superannuation of electric devices such as voltage regulators, electrolytic capacitors, relays, etc.

Table 1 The history of the twelfth cycle operation.

Operation mode	Month/Day/Year
<Vacuum pumping system>	
Pumping a cryostat	8/13/2009-1/22/2010
Pumping a plasma vacuum vessel	8/14/2009-1/15/2010
<Cryogenic system>	
Purification	8/21/2009-9/1/2009
Cool-down	9/2/2009-9/27/2009
Steady state operation	9/28/2009-12/24/2009
Warm-up	12/25/2009-1/29/2010

3. Device Engineering Experiments

Excitation tests of the superconducting coils before plasma experiments were conducted from September 28 to 30. Propagation of a normal zone was not observed in the thirteenth campaign. The following values were attained;

(1) *#1-o, B*=2.65 T @ 3.75 m (H-O/M/I = 11.042 kA)

(2) Slow charge and discharge to *#1-d* 2.85 T, γ=1.258 (H-O/M/I = 11.823/11.628/10.749 kA) for strain measurements,

(3) *#1-d, B*=2.783 T @ 3.60 m (H-O/M/I = 11.4/11.0/11.0 kA)

(4) Mode transition at 11.0 kA of the helical coil (radii of the plasma axis were 3.42 to 4.1 m, quadrupole components were 72 to 200%)

(5) *#1-d, B*=2.896 T @ 3.60 m (H-O/M/I = 11.8/11.75 /11.2 kA) and plasma axis shift from 3.5 m to 3.75 m at 11.4 kA of the helical coil in subcooled helium.

(6) *#1-d, B*=3.017 T @ 3.53 m in subcooled helium (H-O/M/I = 12.4/12.0/11.1 kA)

The device engineering experiments were conducted on the following schedule.

<u>October 13, 2009</u>

(1) Measurement of AC losses of the IV coils at the ramp speed of 38, 111, 192, and 231 A/s with using the pulse power supply system.

<u>December 30, 2009</u>

(1) Fast current change under the condition that the voltage is applied on only IV or IS coil with the pulse power supply system at *B*=0.2 and 0.5 T. Fast current change of only IV or IS coils up to 300 and 500 A.

4. Research activities

We have promoted device-engineering researches using the LHD. Their main purpose is optimization of the subcooling system. The titles of the researches are listed in the following;

(1) Analysis of the LHD superconducting coils by correlation of AE signals and balance voltage signals. (Ninomiya, A. (Seikei Univ.))
(2) Long-term Monitoring of Hydraulic Characteristics of LHD Poloidal Coils. (Takahata, K. (NIFS))
(3) Hysteresis Losses in LHD Poloidal Coils. (Takahata, K. (NIFS))
(4) Estimation of Effective Heat Transfer of the LHD Helical Coils in Comparison with Its Model Coil. (Imagawa, S. (NIFS))
(5) Influence of Bypass Valve on Helium Mass Flow Rate of Cold Compressors in Sub-cooling System of the LHD Helical Coils. (Hamaguchi, S. (NIFS))
(6) Estimation of induced current of LHD using pulse power supplies. (Chikaraishi, H. (NIFS))

(Imagawa, S.)