ISSN 0915-633X

NATIONAL INSTITUTE FOR FUSION SCIENCE

Improvement of a High Current DC Power Supply System for Testing the Large Scaled Superconducting Cables and Magnets

S. Yamada, H. Chikaraishi, S. Tanahashi, T. Mito, K. Takahata,
N. Yanagi, M. Sakamoto, A. Nishimura, O. Motojima,
J. Yamamoto, Y. Yonenaga and R. Watanabe

(Received – Oct. 18, 1993)

NIFS-256 Nov. 1993

RESEARCH REPORT
NIFS Series

This report was prepared as a preprint of work performed as a collaboration research of the National Institute for Fusion Science (NIFS) of Japan. This document is intended for information only and for future publication in a journal after some rearrangements of its contents.

Inquiries about copyright and reproduction should be addressed to the Research Information Center, National Institute for Fusion Science, Nagoya 464-01, Japan.

NAGOYA, JAPAN

Improvement of A High Current DC Power Supply System for Testing the Large Scaled Superconducting Cables and Magnets

Shuichi Yamada, Hirotaka Chikaraishi, Shugo Tanahashi, Toshiyuki Mito, Kazuya Takahata, Nagato Yanagi, Mizuki Sakamoto, Arata Nishimura, Osamu Motojima, Junya Yamamoto

National Institute for Fusion Science, 322-6 Oroshi, Toki, Gifu 509-52, Japan

Yuji Yonenaga and Ryouzo Watanabe

Chuo Seisakusyo Ltd., Mizuho,Nagoya 467, Japan

Abstruct

A dc 75 kA power supply system was constructed to test the superconducting (SC) R&D cables and magnets for the Large Helical Device. It consists of three 25 kA unit banks. A unit bank has two double-star-rectifier connections with the inter-phase reactors. A digital feedback control method is applied to the automatic current regulation (ACR) in each unit bank. For shortening the dead time of the feedback process, a new algorithm of a digital phase controller for the ACR is investigated. A Bode diagram of the feedback process is directly measured. It is confirmed that the dead time of the feedback process is reduced to one sixth, and that the feedback gain of PID compensation is improved by a factor of two from the original method.

Key Words : high current, dc power supply, digital feedback control, double-star-rectification, superconducting cable and magnet

I. Introduction

The Large Helical Device (LHD) is a fusion experimental device of heliotron type. It consists of fully superconducting (SC) coils with the total stored magnetic energy of 1.6 GJ [1], [2]. It is not easy to fabricate such large coils so that an R&D program to develop the SC cables and its winding technology for the LHD started in 1989 [3], [4]. The SC magnet testing facilities including a cryogenic system of 200 l/h of liquid helium, a 10 MN mechanical testing machine, a test facility of SC short samples and SC R&D magnets have been constructed since 1990. A dc 75 kA power supply system was also equipped, for testing the SC R&D cables and magnets [5].

As for an SC short sample, the load impedance is nearly equal to that of a short circuits. The power supply system, therefore, must be a low-impedance system. The double-star-rectifier connection with the inter-phase reactors should be suitable for a low voltage and high current system, because a pair of thyristors is fired at the same time and that the thyristors are not connected in series like a Graetz bridge.

This power supply is composed of three 25 kA unit banks, and each bank has two double-star rectifications to decrease the ripple of the output voltage. To improve the signal to noise ratio, digital feedback control method is applied to the automatic current regulation in each unit bank.

Four SC magnets with the inductance of 3.18 ~ 54 mH and eleven SC short samples have been already tested by using this power supply system [6]-[9]. We found that the time response of the output current became blunt in the fast ramp operations of large magnets. This delayed response must be caused by the large dead time of the feedback process and insufficient feedback gain. We developed a new algorithm of the digital feedback control system for shortening the dead time of feedback process. The control characteristic of the new digital phase controller is also investigated.

II. Comparison of a dc 75 kA Power Supply

Figure 1 gives a circuit diagram of a dc 75 kA power supply system which consists of three 25 kA unit banks (A-1, A-2 and A-3). One unit bank has two double-star transformers with the inter-phase reactors, dc ripple filters and 12-phase rectifiers. A-1 and A-2 units are used for exciting the SC R&D magnets with the inductance of 3.18 ~ 54 mH. They have dc circuit breakers (CB), commutating resistors (Rc), with diodes for the coil protection. For decreasing the current ripple to the level which is equivalent to that of 24-phase rectification system, the electrical angles of the transformers in A-1 and A-2 are determined to be +7.5° and -7.5°, respectively. In the short sample tests of the SC cables, all of three units of A-1, A-2 and A-3 are used, which can generate the maximum current of 75 kA simultaneously. The output bus lines are made of aluminum pipes of 180 mm outer diameter with 24 mm thickness. The distance from output terminal of the A-1 unit to the most nearby R&D magnet current leads is about 25 m and the voltage drop of this bus line is about 2.5 V. The voltage drop from A-1 unit to the farthest magnet terminal is about 3.5 V. Specifications of a unit bank are listed in Table 1.

Figure 2 shows a control flow diagram of a unit bank including a central control panel. In order to select the feedback constants continuously and to improve the signal to noise ratio, the digital feedback control method is applied in this power supply. Comparison between the set values and the output values, and the calculating process for the suitable firing angles of the thyristors are carried out on the digital phase controller. To eliminate the electromagnetic noise, the current signals from the shunts and the setting parameters for the output current are converted into digital signals, and transmitted by optical fibers. The available set values for the output current for a unit bank are ; the maximum ramp rate of 999 A/s with a unit of 1 A/s, the maximum current of 25 kA with a unit of 10 A. These set values for the load current, the feedback constants and operational command can be set not only from the central control

panel but also from a externally connected computer.

III. Control Characteristics of the Power Supply

Figure 3(a) shows a typical waveform of the measured current in a short-circuit test, operated the maximum ramp rate of 999 A/s for each unit bank with the total flat top of 75 kA. The short point was made just before the terminals for the test facility of SC short samples (L=6 μH, R=66 μΩ), and the fundamental characteristics of the power supply was investigated. As shown in Fig. 3(a), the output current shows a better agreement with the setting values without a response-delay, when using the suitable feedback parameters of propotional and integral compensation. It was confirmed that the current stability is less than ±0.75% (during 10 minutes) and that the deviation of the measured current from the setting current was less than ±1% at the maximum flat top current.

Figure 3(b) gives the typical waveform of the measured current with one of the R&D magnets, IV-S & TOKI-PF, which was tested most recently. A little delay of the current rise and a slight overshoot at the beginning of the holding phase were observed in fast ramp operations. These response delays must be caused by the large dead time of the feedback process and by the insufficiency of the feedback gain. To reduce these problems, we have developed a new algorithm of the digital feedback control system. It will be discussed in the next section.

IV. New Digital Feedback Control System

The dead time of the feedback loop must be as short as possible, for quick the current response. In the original digital feedback system of our power

supply system, a maximum dead time of the feedback process was 2.5 cycles of 60 Hz (41.7 ms). The dead time must occur at the averaging process and at the gate control process with a fixed timer-delay for 12-phase thyristors. For shortening the dead time, the defects of the original control method were looked up, and a new control method was developed.

Figure 4 shows a new algorithm of the digital feedback control system. On the new feedback control system, the feedback current signals from the shunts are converted to the frequency signals (V/F) and are directly averaged by the counters circuits (CT). A shunt of the output circuit, SH3, is used for the main feedback-current sensor, to avoid the effect of dc ripple filters, or to eliminate the spike noise from the thyristors. The unbalanced currents from the each 6-phase rectifier detected by the shunts, SH1 and SH2, are converted to the compensational signal of the main feedback loop. The firing pulses of twelve-phase thyristors are partially controlled by the phase-locked loop (PLL) circuit and comparator circuits. The PID (propotional, integral and differential) compensation method is applied in a main feedback process instead of the PI compensation, in order to improve the response in the high frequency region. The differences of before and after the modifications of the feed-back control system are listed in Table 2.

V. Improvement of the Control Characteristics

In order to investigate the control characteristics of the modified feedback control system, a small scaled power supply with the output capacity of 20 A and 20 V was pre-pared. It consists of two double-star rectifier connections to simulate the actual 75 kA power supply system. Experimental set-up used for the frequency response measurement is shown in Fig. 5. A Bode diagram of the closed loop can be directly measured in this set-up. Sine-wave signal with variable frequency is fed to a digital phase controller as a set value. The time

response of the output current was measured as a function of the frequency. Figure 6 shows the typical examples of the Bode diagrams measured in the tests of the digital phase controller. In this test, set values of sine-waves and the gains of the feedback loop (Kp, Ki) were kept in the same conditions. The cut-off frequency of 3 dB decrease in the gain property was about 0.9 Hz in the original method. On the contrary, it became 7 Hz in the new method. It is clearly seen that the phase property of the new method has been improved in the high frequency region.

Figure 7 is a schematic drawings of the time delay process in the digital feedback control system. In the original system as shown in Fig. 7(b), the dominant control delay was caused by the averaging process of the feedback current signals, the watch and wait time to synchronize to the power line of 60 Hz, and fixed firing sequence for 12-phase thyristor. As a result, the total delay was 2.5 cycles of 60 Hz (41.7 ms). On the contrary, the total time of the control delay in the new method is about 6.1 ms, which is reduced to one sixth of that of the original one. As a result, it is confirmed that the maximum available feedback constants, Kp and Ki, can be improved by a factor of two.

The actual inner vertical coil of the LHD, IV-L and IV-U, will be tested in the near future, so that this modification of the control system will be tested for the 75 kA power supply at the same time.

VI. Summary

A dc 75 kA power supply system has been used to test the large scaled SC R&D cables and magnets for the R&D's of LHD. The digital feedback control system was investigated in order to improve the control properties. The results can be summarized as follows : (1) In the original method, maximum dead time of the feedback control process was 41.7 ms. (2) For shotening the control

delay, the averaging operation is directly carried out by the V/F convertor and counter circuit. And the firing pulses of the thyristors are partially controlled by the digital PLL and comparetot circuits. (3) The dead time of the feedback process is reduced to one sixth, and that the feedback gain is improved by a factor of two.

Acknowledgments

We would like to express our appreciation to Director General, Atsuo Iiyosji, Professors Sadao Satoh and Shirou Kitagawa, and the other members of the LHD design group for their kind advice and encouragement.

References

[1] O. Motojima, K. Akaishi, K. Fujii, S. Fujiwaka, S. Imagawa et al, "Physics and engineering design studies on the Large Helical Device", Fusion Engineering and Design, Vol.20, 1993, pp.3-14.

[2] O. Motojima et al, "Engineering design study of super conducting Large Helical Device", Plasma Phys. Controlled Nuclear Fusion Research , Washington, Vol.3, 1990, pp. 513-523.

[3] J. Yamamoto, T. Mito, K. Takahata, N.Yanagi, S. Yamada et al, "A cryogenic system for the superconducting magnet test faci lity", Advances in Cryogenic Engineering, Vol.37, Part A, 1992, pp.755-762.

[4] J. Yamamoto, T. Mito, K. Takahata, S. Yamada et al, "Superconducting test facility of NIFS for the Large Helical Device", Fusion Engineering and Design, Vol.20, 1993, pp.147-151.

[5] S. Yamada, T. Mito, S.Tanahashi, H. Kubo, Y. Yonenaga et al, "Characteristics of a dc 75 kA power supply in the superconducting magnet test facilities", Fusion Engin. and Design, Vol.20, 1993, pp. 201-209.

[6] T. Mito, K. Takahata, N. Yanagi, S. Yamada, A. Nishimura et al, "Short sample test of full-scale superconducting conductor for Large Helical Device", IEEE Trans. on Magn., Vol.28, No.1, 1992, pp.214-217.

[7] K. Takahata, T. Mito, N. Yanagi, M. Sakamoto, A. Nishimura, S. Yamada et al, "Experimental results of the R&D forced-flow poloidal poil (TOKI-PF)", Fusion Engineering and Design, Vol.20, 1993, pp.161-167.

[8] M. Sakamoto, T. Mito, A. Nishimura, S. Imagawa, H.Tamura et al, "Stress analysis of the module coil (TOKI- MC) as an R&D program for the Large Helical Device", Fusion Engineering and Design, Vol.2, 1993, pp.181- 185.

[9] N. Yanagi, T. Mito, K. Takahata, M. Sakamoto, A. Nishimura, S. Yamada et al, "Experimental Observation of Anomalous Magnetroresistevity in 10-20 kA Class Aluminum Stabilized Superconductors for Large Helical Device", Presented at CEC/ICMC, Albuquerque, New Mexico, July 12-16, 1993, CX-5.

Figure Captions

Fig. 1. Circuit diagram of a dc 75 kA power supply.

Fig. 2. Control diagram of one unit bank with central panel.

Fig. 3. Typical waveforms of the measured current in a short-circuit test (a) and in the excitation test of one of the R&D magnets (b).

Fig. 4. Algorithm of a new digital feedback control system.

Fig. 5. Experimental arrangement for the digital phase controller.

Fig. 6. Measured Bode diagrams of the modified digital phase controller (a), and of the original one (b).

Fig. 7. Comparison of the time-delays of the modified feedback control system (a), and original one (b).

Table 1. Specifications of the 25 kA unit bank.

AC input voltage	6.6 kV, 3-phase, 60Hz
DC output voltage	8 V or 21 V
DC output current	25 kA
Maximum current ripple	$\leq 10^{-4}$ (for inductive loads)
	$\leq 10^{-2}$ (for short circuits)
Maximum ramp rate	999 A/s
Rectification	two double star (12-phase)
Current Regulation	digital feedback control
	(PID compensation)
DC circuit breaker	≤25 kA (≤1 kV)
Commutating resistor	40 mΩ / 5 mΩ (40 MJ)

Table 2. Differences of before and after the modification.

Items	Before modification	After modification
Control delay	max. 2.5 Cycle	~1/3 Cycle
Signal converter	A/D converter	V/F converter
Averaging process	Software	Hardware
Gate control	Fixed timer delay	Partial control
Compensation	PI compensation	PID compensation

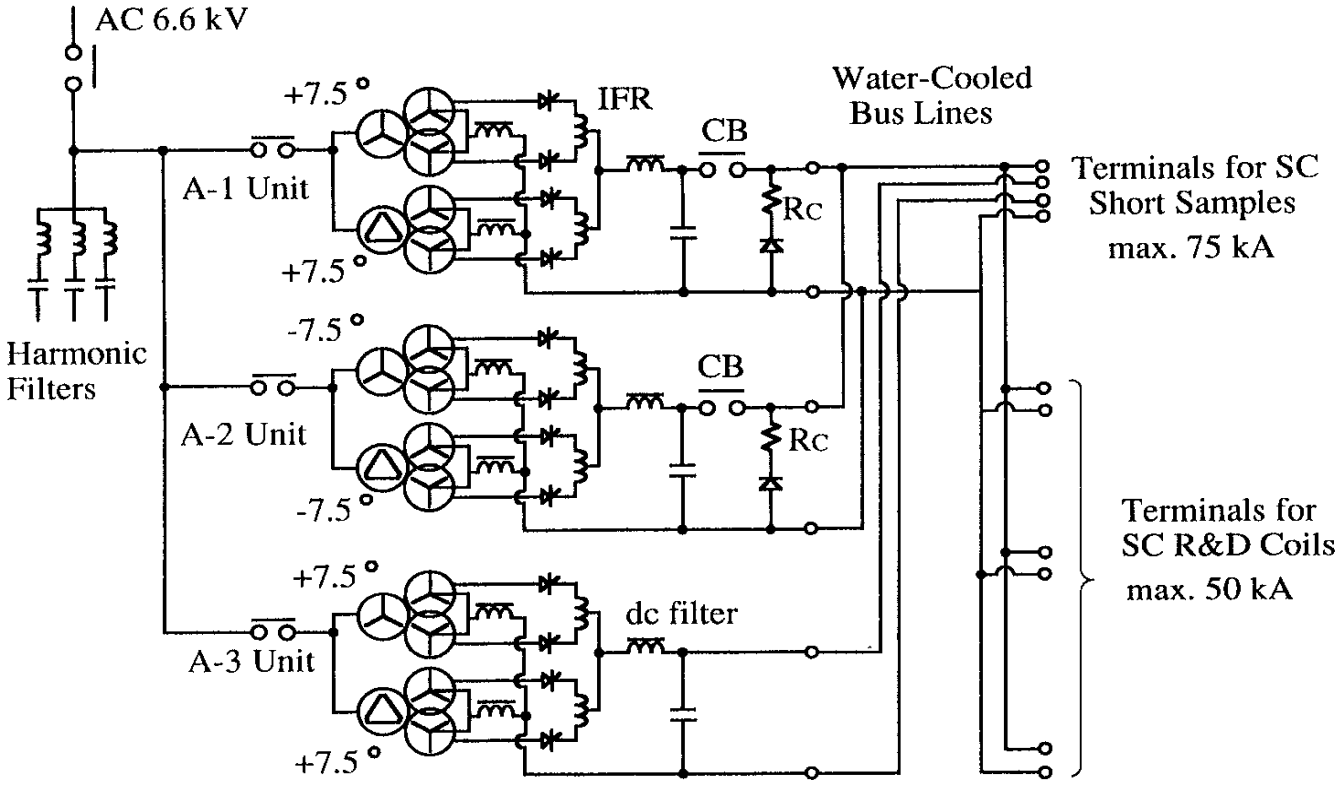

AC 6.6 kV
+7.5°
IFR
CB
Water-Cooled
Bus Lines
A-1 Unit
Rc
+7.5°
Terminals for SC
Short Samples
max. 75 kA
Harmonic
Filters
-7.5°
CB
A-2 Unit
Rc
-7.5°
Terminals for
SC R&D Coils
max. 50 kA
+7.5°
dc filter
A-3 Unit
+7.5°

Fig. 1.

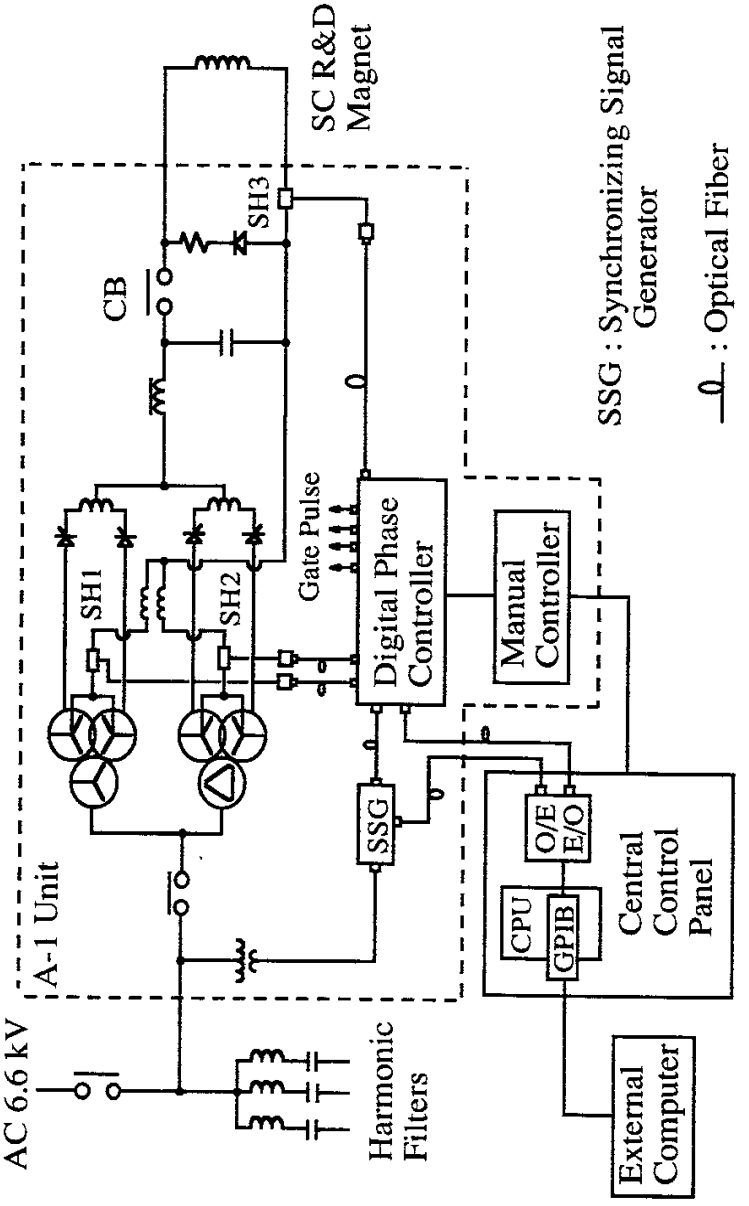
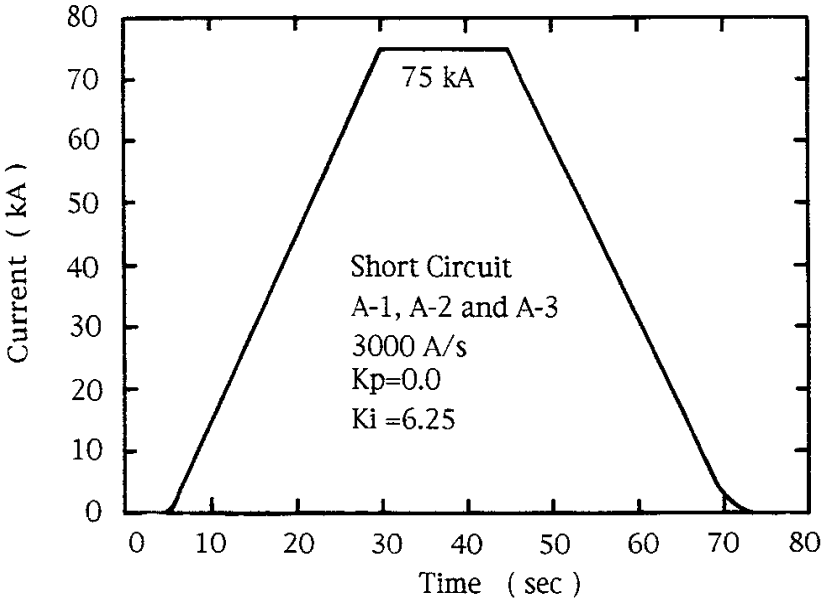

AC 6.6 kV
A-1 Unit
Harmonic Filters
SH1
SH2
SH3
CB
SC R&D Magnet
Gate Pulse
Digital Phase Controller
Manual Controller
SSG
SSG : Synchronizing Signal Generator
: Optical Fiber
CPU
GPIB
O/E
E/O
Central Control Panel
External Computer

Fig. 2.

(a)


80
70
60
50
40
30
20
10
0
Current (kA)
75 kA
Short Circuit
A-1, A-2 and A-3
3000 A/s
Kp=0.0
Ki =6.25
0 10 20 30 40 50 60 70 80
Time (sec)

(b)

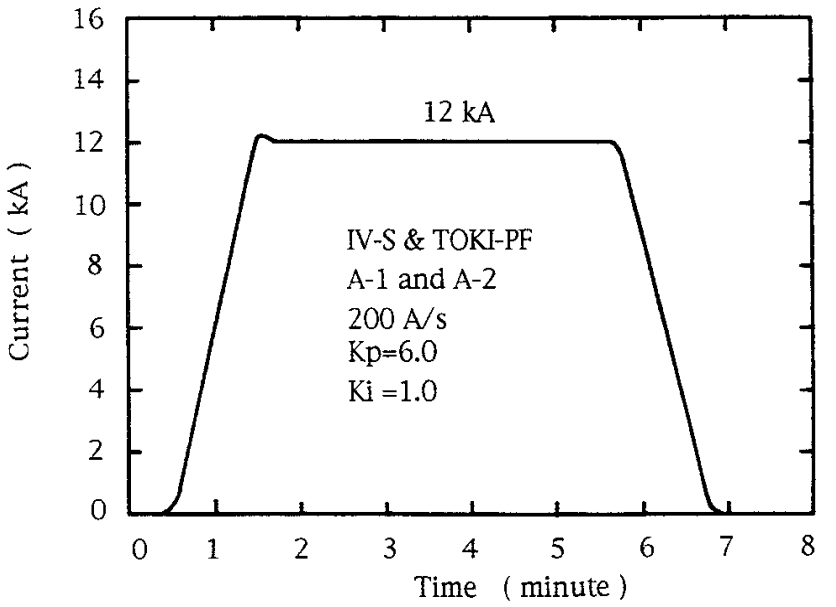

16
14
12
10
8
6
4
2
0
Current (kA)
12 kA
IV-S & TOKI-PF
A-1 and A-2
200 A/s
Kp=6.0
Ki =1.0
0 1 2 3 4 5 6 7 8
Time (minute)

Fig. 3.

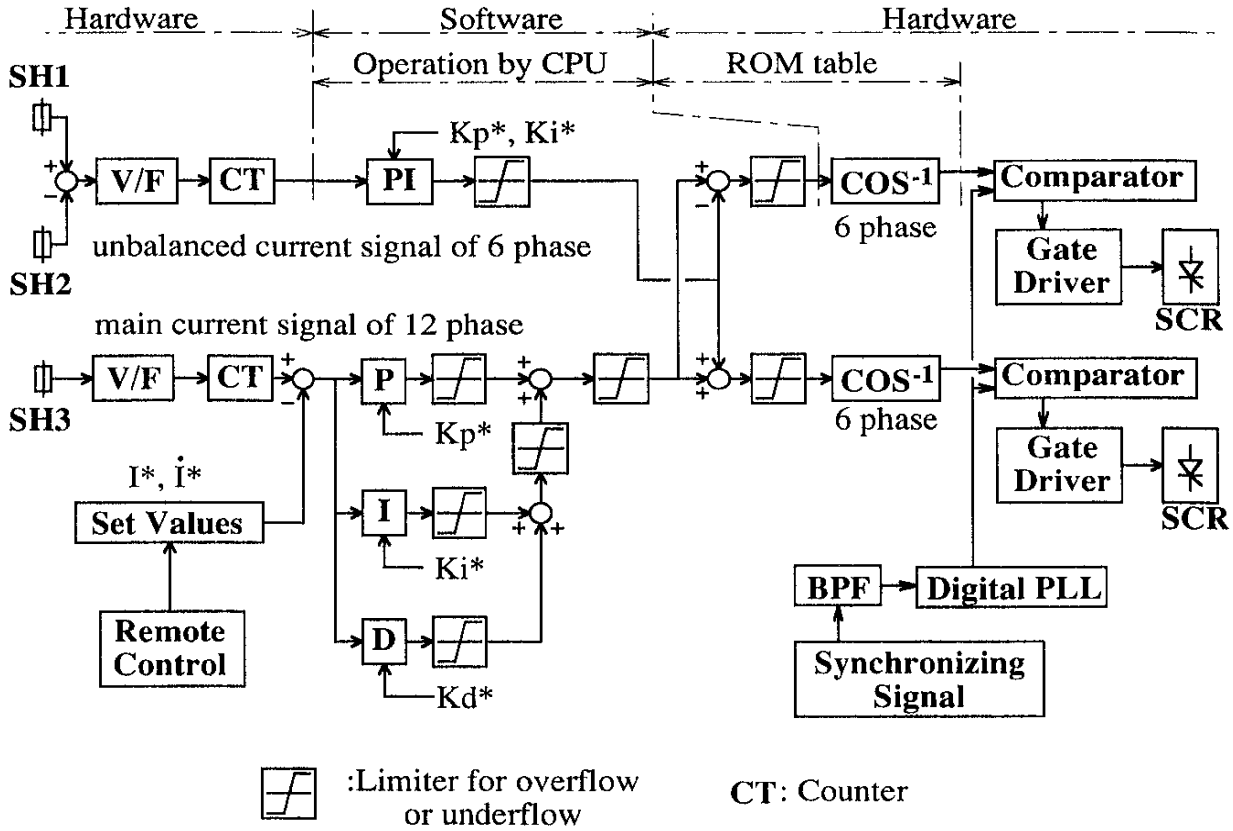

Hardware
Software
Hardware
Operation by CPU
ROM table
SH1
SH2
SH3
V/F
CT
PI
Kp*, Ki*
unbalanced current signal of 6 phase
main current signal of 12 phase
COS-1
6 phase
Comparator
Gate Driver
SCR
P
Kp*
I
Ki*
D
Kd*
I*, İ*
Set Values
Remote Control
BPF
Digital PLL
Synchronizing Signal
:Limiter for overflow or underflow
CT: Counter

Fig. 4.

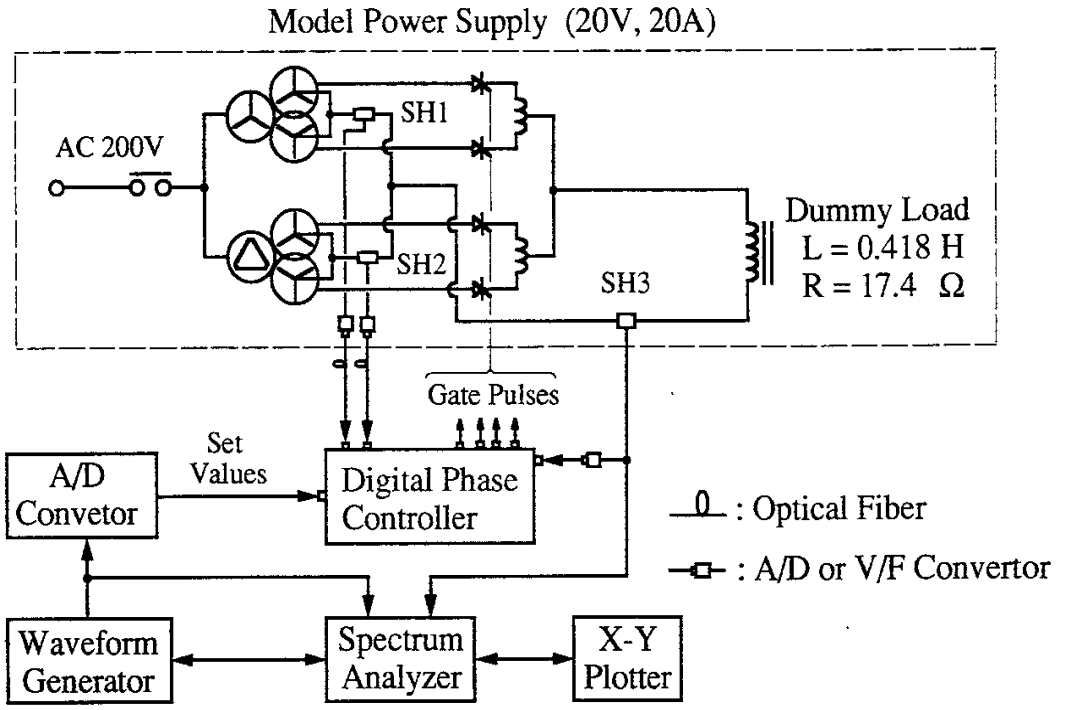
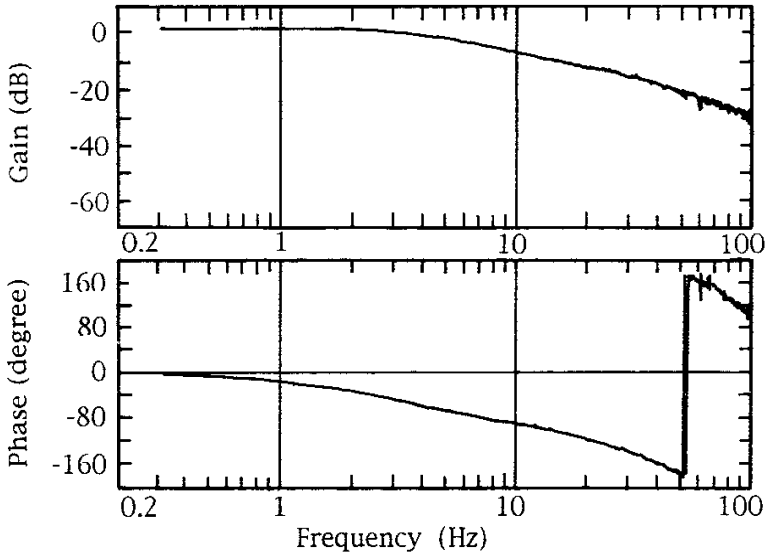

Model Power Supply (20V, 20A)
AC 200V
SH1
SH2
SH3
Dummy Load
L = 0.418 H
R = 17.4 Ω
Gate Pulses
A/D
Convetor
Set
Values
Digital Phase
Controller
: Optical Fiber
: A/D or V/F Convertor
Waveform
Generator
Spectrum
Analyzer
X-Y
Plotter

Fig. 5.

(a)


Gain (dB)
0
-20
-40
-60
0.2
1
10
100
Phase (degree)
160
80
0
-80
-160
0.2
1
10
100
Frequency (Hz)

(b)

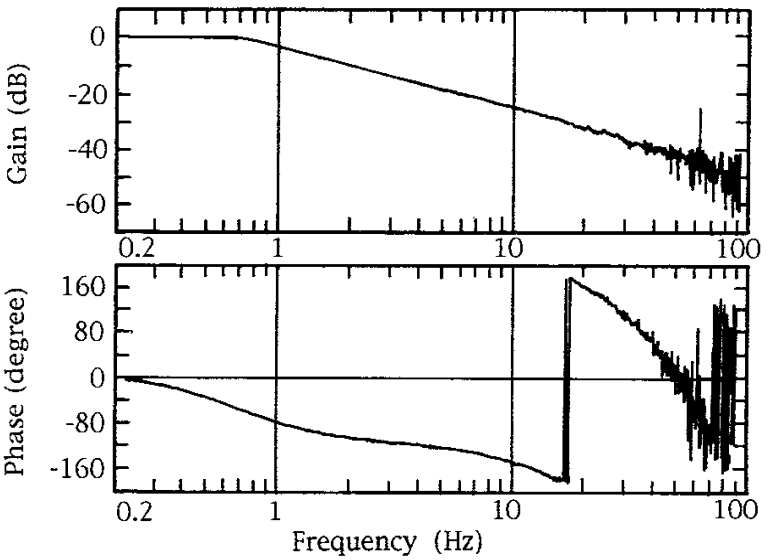
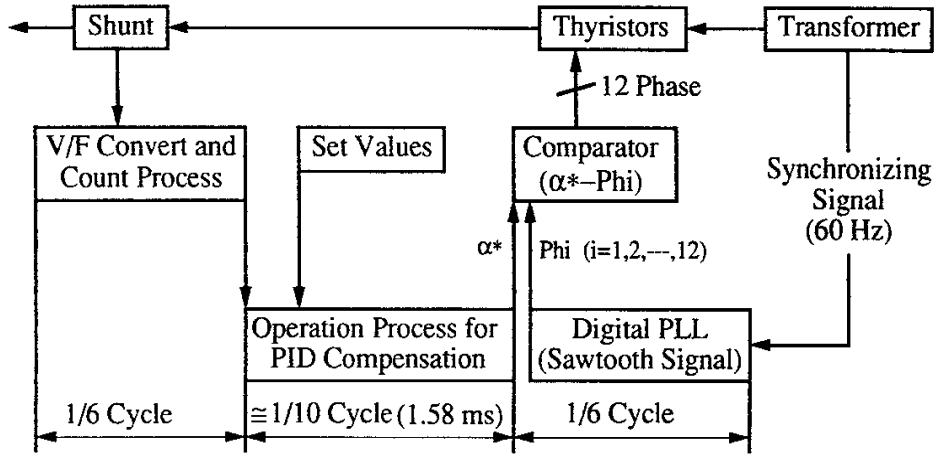

Gain (dB)
0
-20
-40
-60
0.2
1
10
100
Phase (degree)
160
80
0
-80
-160
0.2
1
10
100
Frequency (Hz)

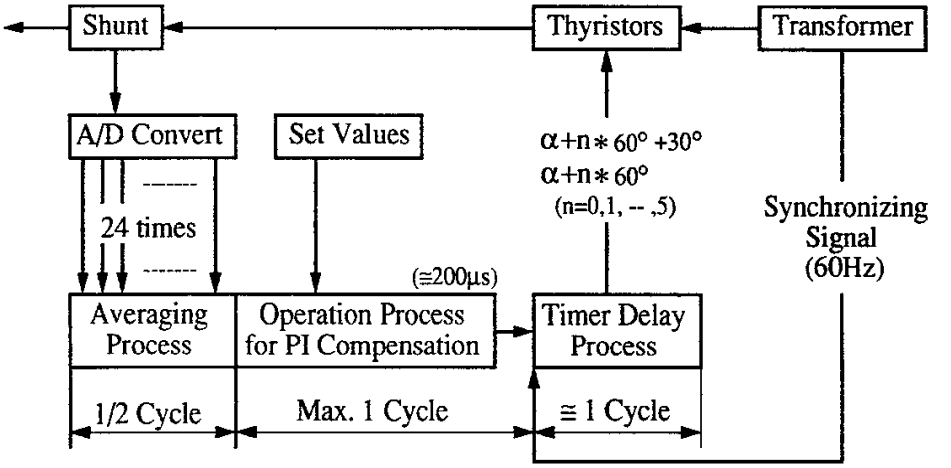
Fig. 6.

(a)



α*:Firing Angle of the Thyristor, Phi:Instantanious Phase

(b)



α : Firing Angle for the Thyristor

Fig. 7.

Recent Issues of NIFS Series

NIFS-203 Y. Hamada, Y. Kawasumi, H. Iguchi, A. Fujisawa, Y. Abe and M. Takahashi, *Mesh Effect in a Parallel Plate Analyzer*; Dec. 1992

NIFS-204 T. Okada and H. Tazawa, *Two-Stream Instability for a Light Ion Beam -Plasma System with External Magnetic Field;* Dec. 1992

NIFS-205 M. Osakabe, S. Itoh, Y. Gotoh, M. Sasao and J. Fujita, *A Compact Neutron Counter Telescope with Thick Radiator (Cotetra) for Fusion Experiment*; Jan. 1993

NIFS-206 T. Yabe and F. Xiao, *Tracking Sharp Interface of Two Fluids by the CIP (Cubic-Interpolated Propagation) Scheme*, Jan. 1993

NIFS-207 A. Kageyama, K. Watanabe and T. Sato, *Simulation Study of MHD Dynamo : Convection in a Rotating Spherical Shell*; Feb. 1993

NIFS-208 M. Okamoto and S. Murakami, *Plasma Heating in Toroidal Systems*; Feb. 1993

NIFS-209 K. Masai, *Density Dependence of Line Intensities and Application to Plasma Diagnostics*; Feb. 1993

NIFS-210 K. Ohkubo, M. Hosokawa, S. Kubo, M. Sato, Y. Takita and T. Kuroda, *R&D of Transmission Lines for ECH System* ; Feb. 1993

NIFS-211 A. A. Shishkin, K. Y. Watanabe, K. Yamazaki, O. Motojima, D. L. Grekov, M. S. Smirnova and A. V. Zolotukhin, *Some Features of Particle Orbit Behavior in LHD Configurations*; Mar. 1993

NIFS-212 Y. Kondoh, Y. Hosaka and J.-L. Liang, *Demonstration for Novel Self-organization Theory by Three-Dimensional Magnetohydrodynamic Simulation*; Mar. 1993

NIFS-213 K. Itoh, H. Sanuki and S.-I. Itoh, *Thermal and Electric Oscillation Driven by Orbit Loss in Helical Systems*; Mar. 1993

NIFS-214 T. Yamagishi, *Effect of Continuous Eigenvalue Spectrum on Plasma Transport in Toroidal Systems*; Mar. 1993

NIFS-215 K. Ida, K. Itoh, S.-I.Itoh, Y. Miura, JFT-2M Group and A. Fukuyama, *Thickness of the Layer of Strong Radial Electric Field in JFT-2M H-mode Plasmas*; Apr. 1993

NIFS-216 M. Yagi, K. Itoh, S.-I. Itoh, A. Fukuyama and M. Azumi, *Analysis of Current Diffusive Ballooning Mode*; Apr. 1993

NIFS-217 J. Guasp, K. Yamazaki and O. Motojima, *Particle Orbit Analysis for LHD Helical Axis Configurations* ; Apr. 1993

NIFS-218 T. Yabe, T. Ito and M. Okazaki, *Holography Machine HORN-1 for Computer-aided Retrieve of Virtual Three-dimensional Image* ; Apr. 1993

NIFS-219 K. Itoh, S.-I. Itoh, A. Fukuyama, M. Yagi and M. Azumi, *Self-sustained Turbulence and L-Mode Confinement in Toroidal Plasmas* ; Apr. 1993

NIFS-220 T. Watari, R. Kumazawa, T. Mutoh, T. Seki, K. Nishimura and F. Shimpo, *Applications of Non-resonant RF Forces to Improvement of Tokamak Reactor Performances Part I: Application of Ponderomotive Force* ; May 1993

NIFS-221 S.-I. Itoh, K. Itoh, and A. Fukuyama, *ELMy-H mode as Limit Cycle and Transient Responses of H-modes in Tokamaks* ; May 1993

NIFS-222 H. Hojo, M. Inutake, M. Ichimura, R. Katsumata and T. Watanabe, *Interchange Stability Criteria for Anisotropic Central-Cell Plasmas in the Tandem Mirror GAMMA 10 ;* May 1993

NIFS-223 K. Itoh, S.-I. Itoh, M. Yagi, A. Fukuyama and M. Azumi, *Theory of Pseudo-Classical Confinement and Transmutation to L-Mode;* May 1993

NIFS-224 M. Tanaka, *HIDENEK: An Implicit Particle Simulation of Kinetic-MHD Phenomena in Three-Dimensional Plasmas;* May 1993

NIFS-225 H. Hojo and T. Hatori, *Bounce Resonance Heating and Transport in a Magnetic Mirror;* May 1993

NIFS-226 S.-I. Iton, K. Itoh, A. Fukuyama, M. Yagi, *Theory of Anomalous Transport in H-Mode Plasmas;* May 1993

NIFS-227 T. Yamagishi, *Anomalous Cross Field Flux in CHS ;* May 1993

NIFS-228 Y. Ohkouchi, S. Sasaki, S. Takamura, T. Kato, *Effective Emission and Ionization Rate Coefficients of Atomic Carbons in Plasmas;* June 1993

NIFS-229 K. Itoh, M. Yagi, A. Fukuyama, S.-I. Itoh and M. Azumi, *Comment on 'A Mean Field Ohm's Law for Collisionless Plasmas;* June 1993

NIFS-230 H. Idei, K. Ida, H. Sanuki, H. Yamada, H. Iguchi, S. Kubo, R. Akiyama, H. Arimoto, M. Fujiwara, M. Hosokawa, K. Matsuoka, S. Morita, K. Nishimura, K. Ohkubo, S. Okamura, S. Sakakibara, C. Takahashi, Y.

Takita, K. Tsumori and I. Yamada, *Transition of Radial Electric Field by Electron Cyclotron Heating in Stellarator Plasmas;* June 1993

NIFS-231 H.J. Gardner and K. Ichiguchi, *Free-Boundary Equilibrium Studies for the Large Helical Device,* June 1993

NIFS-232 K. Itoh, S.-I. Itoh, A. Fukuyama, H. Sanuki and M. Yagi, *Confinement Improvement in H-Mode-Like Plasmas in Helical Systems,* June 1993

NIFS-233 R. Horiuchi and T. Sato, *Collisionless Driven Magnetic Reconnection,* June 1993

NIFS-234 K. Itoh, S.-I. Itoh, A. Fukuyama, M. Yagi and M. *Azumi, Prandtl Number of Toroidal Plasmas;* June 1993

NIFS-235 S. Kawata, S. Kato and S. Kiyokawa , *Screening Constants for Plasma;* June 1993

NIFS-236 A. Fujisawa and Y. Hamada, *Theoretical Study of Cylindrical Energy Analyzers for MeV Range Heavy Ion Beam Probes;* July 1993

NIFS-237 N. Ohyabu, A. Sagara, T. Ono, T. Kawamura and O. Motojima, *Carbon Sheet Pumping;* July 1993

NIFS-238 K. Watanabe, T. Sato and Y. Nakayama, *Q-profile Flattening due to Nonlinear Development of Resistive Kink Mode and Ensuing Fast Crash in Sawtooth Oscillations;* July 1993

NIFS-239 N. Ohyabu, T. Watanabe, Hantao Ji, H. Akao, T. Ono, T. Kawamura, K. Yamazaki, K. Akaishi, N. Inoue, A. Komori, Y. Kubota, N. Noda, A. Sagara, H. Suzuki, O. Motojima, M. Fujiwara, A. Iiyoshi, *LHD Helical Divertor;* July 1993

NIFS-240 Y. Miura, F. Okano, N. Suzuki, M. Mori, K. Hoshino, H. Maeda, T. Takizuka, JFT-2M Group, K. Itoh and S.-I. Itoh, *Ion Heat Pulse after Sawtooth Crash in the JFT-2M Tokamak;* Aug. 1993

NIFS-241 K. Ida, Y.Miura, T. Matsuda, K. Itoh and JFT-2M Group, *Observation of non Diffusive Term of Toroidal Momentum Transport in the JFT-2M Tokamak;* Aug. 1993

NIFS-242 O.J.W.F. Kardaun, S.-I. Itoh, K. Itoh and J.W.P.F. Kardaun, *Discriminant Analysis to Predict the Occurrence of ELMS in H-Mode Discharges;* Aug. 1993

NIFS-243 K. Itoh, S.-I. Itoh, A. Fukuyama, *Modelling of Transport Phenomena;* Sep. 1993

NIFS-244 J. Todoroki,
Averaged Resistive MHD Equations; Sep. 1993

NIFS-245 M. Tanaka,
The Origin of Collisionless Dissipation in Magnetic Reconnection; Sep. 1993

NIFS-246 M. Yagi, K. Itoh, S.-I. Itoh, A. Fukuyama and M. Azumi,
Current Diffusive Ballooning Mode in Seecond Stability Region of Tokamaks; Sep. 1993

NIFS-247 T. Yamagishi,
Trapped Electron Instabilities due to Electron Temperature Gradient and Anomalous Transport; Oct. 1993

NIFS-248 Y. Kondoh,
Attractors of Dissipative Structure in Three Disspative Fluids; Oct. 1993

NIFS-249 S. Murakami, M. Okamoto, N. Nakajima, M. Ohnishi, H. Okada,
Monte Carlo Simulation Study of the ICRF Minority Heating in the Large Helical Device; Oct. 1993

NIFS-250 A. Iiyoshi, H. Momota, O. Motojima, M. Okamoto, S. Sudo, Y. Tomita, S. Yamaguchi, M. Ohnishi, M. Onozuka, C. Uenosono,
Innovative Energy Production in Fusion Reactors; Oct. 1993

NIFS-251 H. Momota, O. Motojima, M. Okamoto, S. Sudo, Y. Tomita, S. Yamaguchi, A. Iiyoshi, M. Onozuka, M. Ohnishi, C. Uenosono,
Characteristics of D-^{3}He Fueled FRC Reactor; ARTEMIS-L; Nov. 1993

NIFS-252 Y. Tomita, L.Y. Shu, H. Momota,
Direct Energy Conversion System for D-^{3}He Fusion; Nov. 1993

NIFS-253 S. Sudo, Y. Tomita, S. Yamaguchi, A. Iiyoshi, H. Momota, O. Motojima, M. Okamoto, M. Ohnishi, M. Onozuka, C. Uenosono,
Hydrogen Production in Fusion Reactors; Nov. 1993

NIFS-254 S. Yamaguchi, A. Iiyoshi, O. Motojima, M. Okamoto, S. Sudo, M. Ohnishi, M. Onozuka, C. Uenosono,
Direct Energy Conversion of Radiation Energy in Fusion Reactor; Nov. 1993

NIFS-255 S. Sudo, M. Kanno, H. Kaneko, S. Saka, T. Shirai, T. Baba,
Proposed High Speed Pellet Injection System "HIPEL" for Large Helical Device;
Nov. 1993