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CONTROL-FUNCTION-INTEGRATED TYPE DIGITAL CONTROLLERS FOR HYDRAULIC POWER STATIONS

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1. FOREWORD

Digitalization of controllers for hydraulic power stations has increased the number of applicable power stations and broadened the range of application of the control functions ever since the application of the sequencer controller with only control circuits consisting of magnetic relays in the 1960s. In the 1970s, the progammable controller (PC) controlled with automatic power-factor control, automatic water level control, and other so-called secondary control functions. In recent years, the PC have been made smaller, processing speed faster and given more advanced functions throuth the rapid development of semiconductor technology. Presently, it is developing to a "control-function-integrated type digital controller" with excitation control, turbine speed control, and other primary control functions.

The latest digital controller, concentrating on an outline and the site test results of the controller delivered to the Meguribuchi Power Station of Kyushu Electric Power Co., Inc., which has been in commercial operation since June 1988, and the Uchinoura Power Station of the Kyushu Power Co., Inc., which has been in commercial operation since June 1989.

Table 1 HDC-500 basic specijications

Item		Specification
Instructions	Language	Functional Control Language (FCL)
	Speed	Sequence instruction: 1.2 ~ 1.6μs Fixed-point operation: 9.0 ~ 12.0μs (32 bits) Floating-point operation: 10.0 ~ 14.0μs (32 bits) Analog operation: 15.0 ~ 40.0μs (32 bits)
Memory	Program	System: 64k words (16 bits) Application: 64k words (16 bits)
	Data	System: 32k words (16 bits) Application: 32k words (16 bits)
I/O channels	Digital	T-link: 8192 Bus: 512
	Analog (pulse)	T-link: 2048 Bus: 128
Transmission interface	I/O unit transmission	T-link: 500k bits/sec (optical transmission possible)
	Processor transmission	P-link: 5M bits/sec (optical transmission possible)
	Dataway transmission	DPCS-F:10M bits/sec (optical transmission possible)
Control power supply		DC110V (−20 ~ +30%) AC100/110V (−25 ~ +10%) 50/60Hz
Dielectric strength		AC2000V for 1 minute
Temperature		0 ~ 40° C
Humidity		20 ~ 90%RH

2. HARDWARE

An exterior view of the control-function-integrated type controller is shown in *Fig. 1*. The PC is an HDC-500 (MICREX-F500 series) with a 32-bit processor board. *Table1* shows the basic specifications of the HDC-500. This equipment is used to increase the processing speed. One PC can process control functions that required multiple MPUs in the past. Accompanying this, the number of I/O points is also reduced substantially and the controller can be housed at one panel and installation space can be saved. An operator console unit and sequence monitor unit are also added. The ordinary turbine generator monitoring and operation panel can be omitted.

2.1 PC hardware composition

The hardware composition of the HDC-500 is shown in *Fig. 2*. The card units are listed in *Table 2*. Since the Meguribuchi and Uchinoura power stations are single MPU systems, only a T-link is used as the transmission interface. AIH has a function that simultaneously samples and holds the 3-phase voltage and current values of all the points at a fixed period, and is a generator and bus electric quantity (P, Q, V, I) detection card, PI is a card that executes frequency detection operation. Its detection accuracy is 0.01% or better. The PI card also has a function that compensates the detection error due to SSG shaft runout, etc.

Fig. 1 Exterior view of control-function-integrated type digital controller

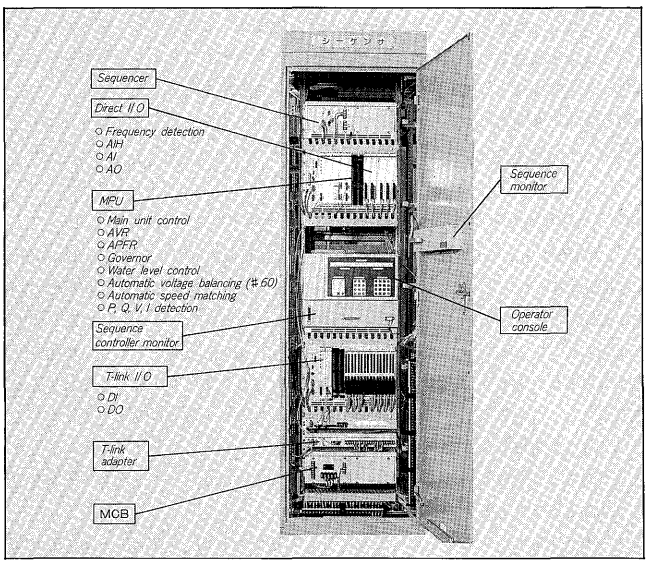


Fig. 2 HDC-500 hardware composition

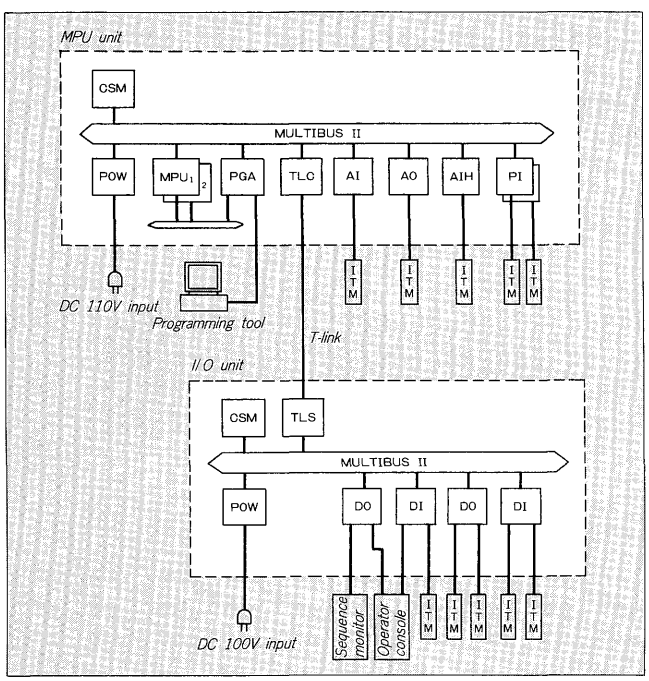
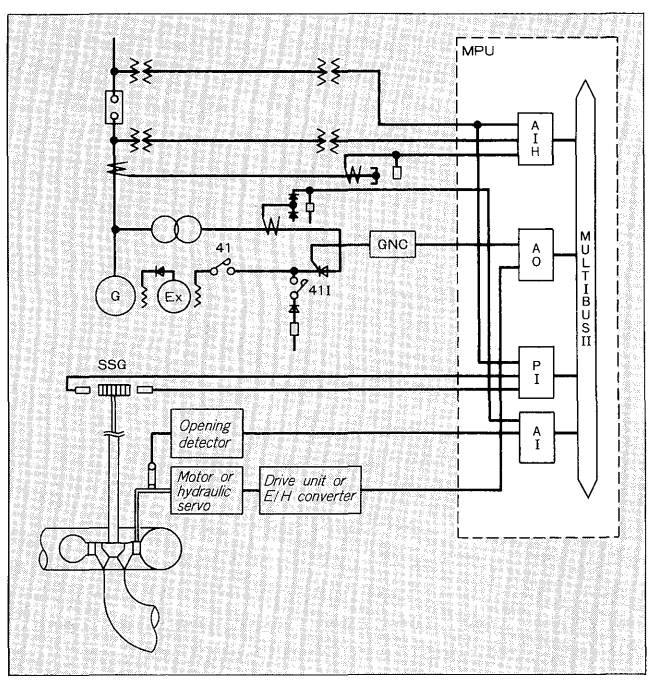


Table 2 Card units table

	Symbol	Explanation
Basic control cards	POW	Power supply card
	CSM	Central service module
	MPU	Main processor unit
	PGA	Program generation adapter
Transmission cards	TLC	T-link central control card
	TLS	T-link slave control card
	PLA	P-link adapter
	DPCS	Distributed process communication system
I/O control cards	DI	Digital input card (64 channels)
	DO	Digital output card (64 channels)
	AI	Analog input card (16 channels)
	AO	Analog output card (16 channels)
	AIH	AI card w/simultaneous sample & hold function (16 channels)
	PI	Pulse input card (frequency detection card) (2 channels)

Fig. 3 I/O signal interface for primary control functions operation



2.2 Turbine generator and PC interface

The I/O signal interface circuit for primary control function operation is shown in *Fig. 3*. Connection to the external cable is performed by terminal board function via an ITM (interface terminal). The ITM also has a digital signal isolation and analog signal level conversion function.

3. CONTROL FUNCTIONS

This system takes advantage of the features of digital control and integration of sequence control functions and primary and secondary control functions in one PC and has control functions and control characteristics difficult to realize with conventional analog amplifiers and magnetic relays. These control functions are described.

3.1 Primary control functions

(1) Generator excitation control

Since the generator voltage, carrent, active power and reactive power are detected by direct digital calculation

using instantenious value of PT and CT secondary, an special external converter is unnecessary, Control performance is improved by using a system that transfers the operated result of each limiting function numerically to a generator voltage setter, etc. The generator excitation control functions are shown below.

- Automatic voltage regulator (AVR)
- Automatic field current regulator (ACR)
- Over excitation limiter (OEL)
- Reactive power limiter (operation in generator capability)
- Voltage/frequency limiter (*V*/*F* control)
- Voltage matcher (#60)
- Soft start function (voltage built-up control)
- Cross current compensator (voltage droop control)

(2) Turbine speed control

Since the turbine speed detection is used by the pulse signal of a speed signal generator (SSG) and the system frequency is detected by direct digital operation by using the bus PT secondary voltage, and special external converter is unnecessary. By using the stored turbine characteristics data, etc., control performance is improved. The turbine speed control functions are shown below.

- Frequency control function (#65F control loop)
- Active power control function (#65P control loop, speed regulation)
- Wicket-gate opening control function (#65P control loop, speed droop)
- Wicket-gate opening control function (#65L control loop)
- Active power limiter (OPL)
- Speed matcher (#15)
- Soft start function (speed build-up control)

3.2 Secondary control function

(1) Generator power-factor regulator

This function maintains the generator power-factor constant by operating the reactive power set value from the power-factor set value and the detected active power value and giving a control command value (numeric) corresponding to the deviation of this set value and the detected reactive power to the AVR voltage setter.

(2) Water level contrl (WLC)

This function maintains the reservoir water level constant (matches the flow-in amount and generation discharge amount) by operating the appropriate generation discharge amount (wicket-gate opening) from the water level set value and water level and tracking this set value with the set value with the load limit setting position.

3.3 Sequence control functions

Digitalization of these functions has been promoted for some time. However, by using a program, loader, the on/off state of each bit can be judged at once. The main control contents are:

(1) Main unit start and stop sequences
(2) Energency stop sequence
(3) Auxiliary unit start and stop sequences.
(4) Excitation control sequence
(5) Governer control sequence

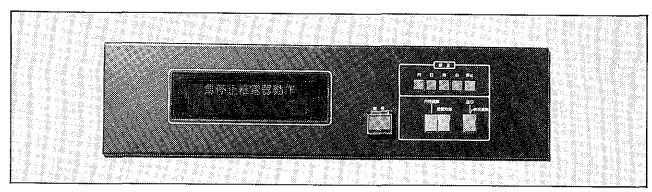
3.4 Abnormalizty monitoring functions

When an abnormality is detected. The contents are displayed in latter (maximum 20 characters, 256 items) on the sequence monitor unit. The time of abnormality occurred is also displayed by switching. The display contents can also be printed by adding an option unit. An exteriror view of the sequence monitor is shown in *Fig. 4*. The abnormality monitoring contents are:

(1) Main unit start and stop sequence time monitoring (main cause notice)
(2) Auxiliary unit continuous operation time, operation interval, and number of times monitoring
(3) Abnormal digital input signal monitoring
(4) Abnormal analog input signal monitoring
(5) Latch type relay coil monitoring
(6) Solenoid valve coil monitoring relay coil monitoring

Bearing temperature monitoring and other turbine generator automatic monitoring functions can also be added by adding sensors, etc.

Fig. 4 Exterior view of sequence monitor unit



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3.5 Operator console functions

The set values, etc. needed in control and monitoring can be changed even during operation by using the program loader. The operator console unit simplifies this set value modification and confirmation work and has turbine generator monitoring and operation functions. An exterior view of the operator console unit is shown in *Fig. 5*. This unit consists of two 4-digit LED displays and flat keys with selection indicator lamp for each application. It also has a built-in key switch to lock the modification operation. The functions of this unit are:

(1) Control constants and timer set value confirmation (by ten keypad)
(2) Control constants and timer set value modification (by ten keypad)
(3) Measured electricity value and machine system current value display (by one-touch keys)
(4) Excitation and speed control setters current value display (by one-touch keys)

Fig. 5 Exterior view of operator console unit

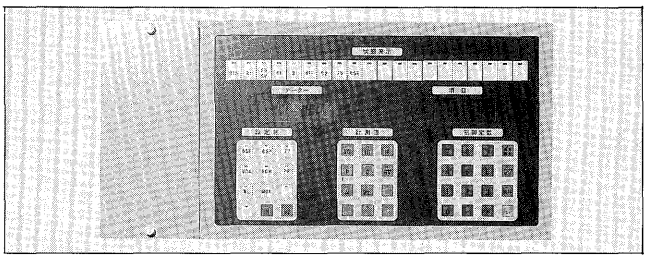

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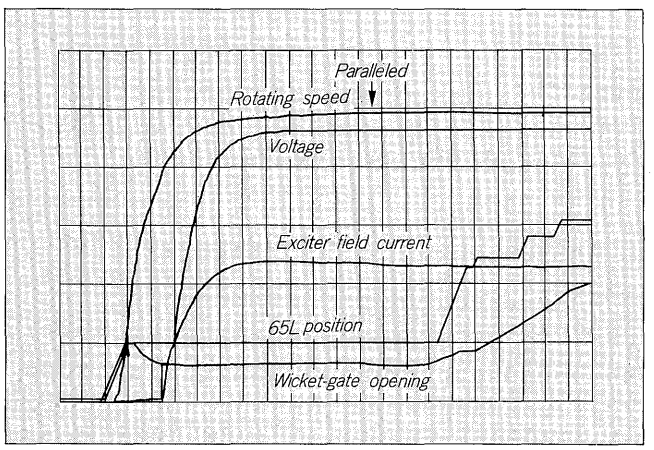
Fig. 6 Starting characteristics test recording



(5) Excitation and speed control setter up/down operation (by one-touch keys)
(6) Sequential status display

4. SITE TEST RESULTS

Good test results were obtained with the control-function integrated type digital controllers delivered to the Meguribuchi Power Station and Uchinoura Power Station of the Kyushu Electric Power Co., Inc. and they are currently in commercial operation. Part of the test results are described below.

4.1 Starting characteristics test

The characteristics test recording from starting to parallel is shown in *Fig. 6*. The voltage and speed are raised quickly and smoothly without any overshoot by the soft start function described in paragraph 3.1. Since the voltage matching function and speed matching functions track the system voltage and frequency exponentially, it is paralleled with the system quickly and smoothly.

4.2 Load regection test

The 1/4 load rejection test recording is shown in *Fig. 7*.

Fig. 7 1/4 load rejection test recording

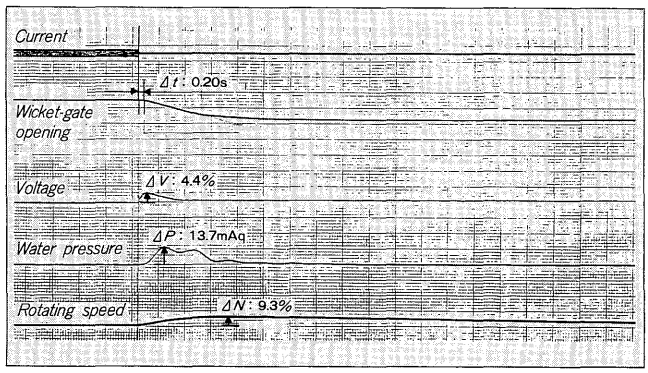
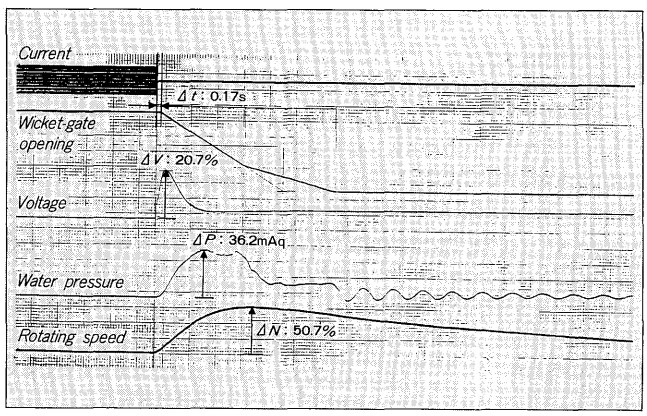


Fig. 8 4/4 load rejection test recording



The 4/4 load rejection test recording is shown in *Fig. 8*. The governor control function satisfies the Class X specifications of the Electric Cooperative Society. Since these power stations have comparatively short generator open circuit time constant and exciter open circuit time constant and a high frequency rise value, satisfying both response and stability with an analog system is difficult, but good tests results were obtained with the excitation control function by the effect of each digital compensater function.

5. CONCLUSION

The control-function-integrated type digital controller was outlined above. PC application technology will be promoted farther in the future and improved operation reliability, maintenance free, and the reduction of panel installation space are expected as a result. The realization of a hydraulic turbine consolidated digital system that connects the operation and monitoring system by CRT, etc. by a dataway is desired. Fuji Electric is designing and manufacturing digital systems matched to these needs. We ask for the guidance and support of all the parties concerned.