UDC 681.323:621.316.7.078:621.311.22

DIGITAL CONTROL SYSTEMS FOR THERMAL POWER STATIONS

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1. FOREWORD

With the development of microelectronics technology in recent years, the reliability and serviceability of the PC (Programmable Controller) have been improved and its use has spread to automatic voltage regulators, governors, and other main control equipments.

Concrete application examples of digital control equipments using the 32 bits programmable controller MICREX-F500 in a thermal power station are introduced.

2. APPLICATION TO COMMERCIAL THERMAL POWER PLANT

Since the PC is programmable, it can be applied to control equipments by suitably combining input/output cards. Therfore, multiple equipments can be realized with the same kind of software. Moreover, since the controller PID constant can be set by direct numeric by PC loader, setting and modification are easy and a wider adjusting range than variable resistor, etc. can be taken.

Furthermore, the reliability of the digital control equipments is sufficient even without multilexing, but the equipment can be multiplexed easily and a more reliable system can be built.

A commercial thermal power station automation and control system configuration example is shown in *Fig. 1.* In this example, the PC is applied to the control equipment shown in *Table 1.* Each equipment and management computer are connected by a dataway (DPCS).

2.1 Digital control equipment

2.1.1 Automatic voltage regulator (AVR)

The AVR is control equipment which maintains the output voltage of a generator constant by controlling the generator excitation circuit current.

The hardware configuration of a triplex digital AVR (D-AVR) is shown in *Fig. 2.*

(1) Main Processing Unit (MPU)

Fig. 1 Commercial thermal power plant automation and control system configuration example

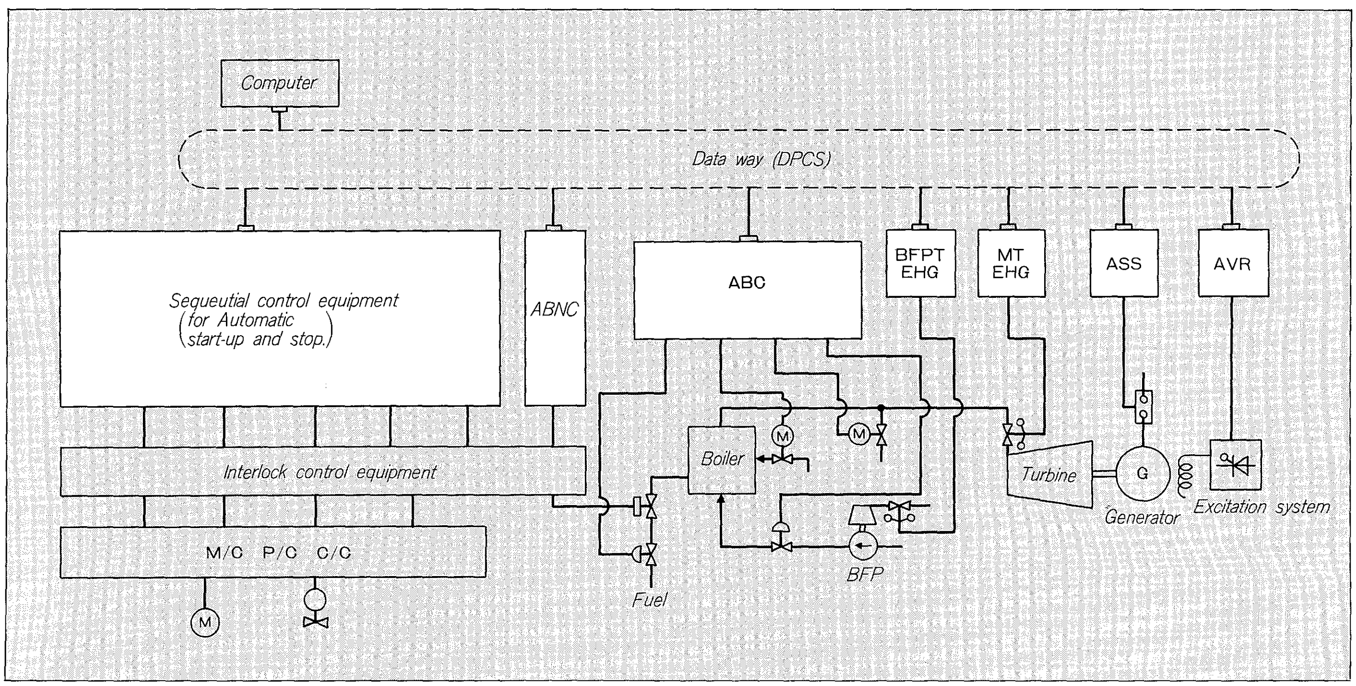


Table 1 PC applied equipment

Digital control equipment	(1) Electro-hydraulic governor for main turbine (MT-EHG) (2) Electro-hydraulic governor for boiler feed water pump turbine (BFPT-EMG) (3) Automatic voltage regulator (AVR) (4) Automatic synchronizing system (ASS)
Sequential control equipment	(1) Automatic burner control system (ABNC) (2) Automatic start-up and stop system for turbine system (3) Automatic start-up and stop system for feedwater system (4) Automatic start-up and stop system for draft system (5) Automatic start-up and stop system for fuel system (6) Automatic start-up and stop system for circulating water system (7) Automatic start-up and stop system for condenser system
Interlock control equipment	(1) Interlock for motor control center (C/C) (2) Interlock for metal clad switchgear (M/C) (3) Interlock for power center (P/C)
Automatic test equipment	(1) Automatic valve test equipment (2) Automatic turbine trip test equipment

Because the MPU executes control and its justifiability cannot be self-judged for the operated result, it can be triplexed (MPU-A, MPU-B, and MPU-C) and decision by majority is possible.

(2) P-link (Duplex system)

The P-link is a network between three MPUs for data tracking and inputs monitoring.

(3) T-link

The T-link is a network between MPU and IOU (inputs and outputs unit). Each MPU has a T-link.

(4) Inputs and outputs unit (IOU)

The operated result of each MPU is passed to an output card via a T-link and are majority decision processed (digital outputs: 2 out of 3, analog outputs: middle value gate) in that card (DO, HRAO). The IOU uses a duplex system and operation can be continued even if one unit fails.

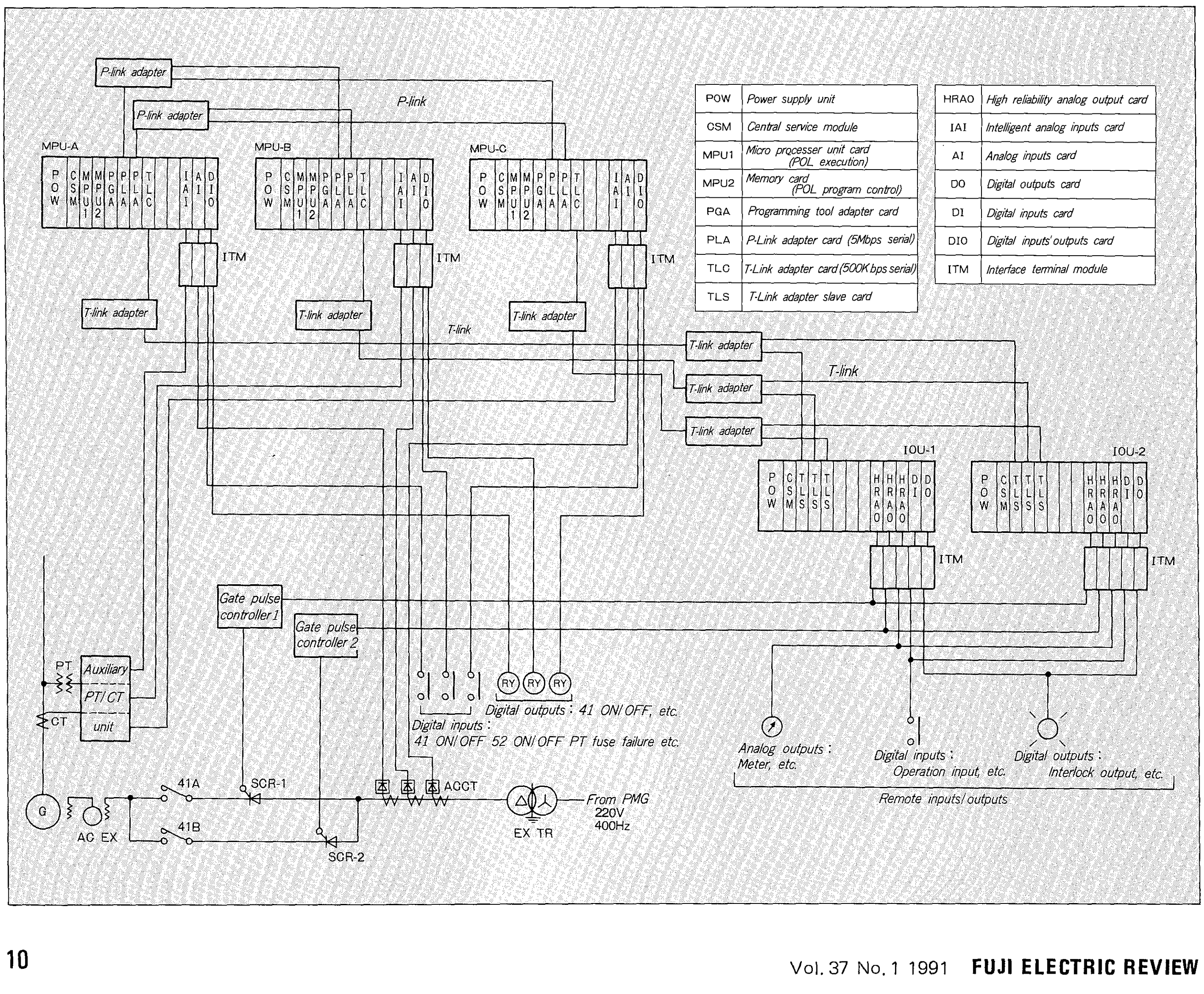
(5) Gate pulse controller

The gate pulse controller is equipment which converts AVR analog control signals to thyristor gate pulses and is installed at each thyristor bridge.

(6) Auxiliary PT/CT unit

The auxiliary PT/CT unit matched the generator main circuit PT/CT secondary outputs and IAI card input

Fig. 2 D-AVR hardware configuration



specification. The 3-phase instantaneous voltage and current of the generator are input to the IAI card via the auxiliary PT/CT unit and the voltage (rms), current (rms), active power, reactive power, and frequency detected values are digitally operated on in that card.

The functions of a triplexed D-AVR are shown in *Fig. 3.*

2.1.2 Electro-hydraulic governor (EHG)

The EHG is control equipment that maintains the turbine speed constant by detecting the turbine speed by counting the pulses sent from an electromagnetic pickup and opening and closing the main steam control valve.

A triplexed digital EHG (D-EHG) is shown in *Fig. 4.* The D-EHG overall system configuration is shown in *Fig. 5* and its functional configuration is shown in *Fig. 6* and the 4/4 load rejection site test results are shown in *Fig. 7.*

When an analog EHG is updated to a digital EHG, if a mechanical governor and electric governor (digital EHG) multiplexed system is considered, the digital EHG does not have to be multiplexed.

2.1.3 Automatic synchronizing system (ASS)

ASS is equipment which automatically synchronizes a generator by matching the generator output voltage and voltage, frequency, and phase of the system voltage and outputs a synchronizing command to the synchronizing circuit breaker. Its functions are divided into automatic speed matching, automatic voltage balancing, and automatic synchronizing.

2.2 Sequential control equipment

Since start-up and stopping of this unit has many steps and takes time, start-up and stopping of turbine system, draft system, fuel system, circulating water system, and condenser system is automated by the sequential control equipments of this unit.

Automation eliminates careless mistakes and raises the unit smoothly and allows unit planned operation.

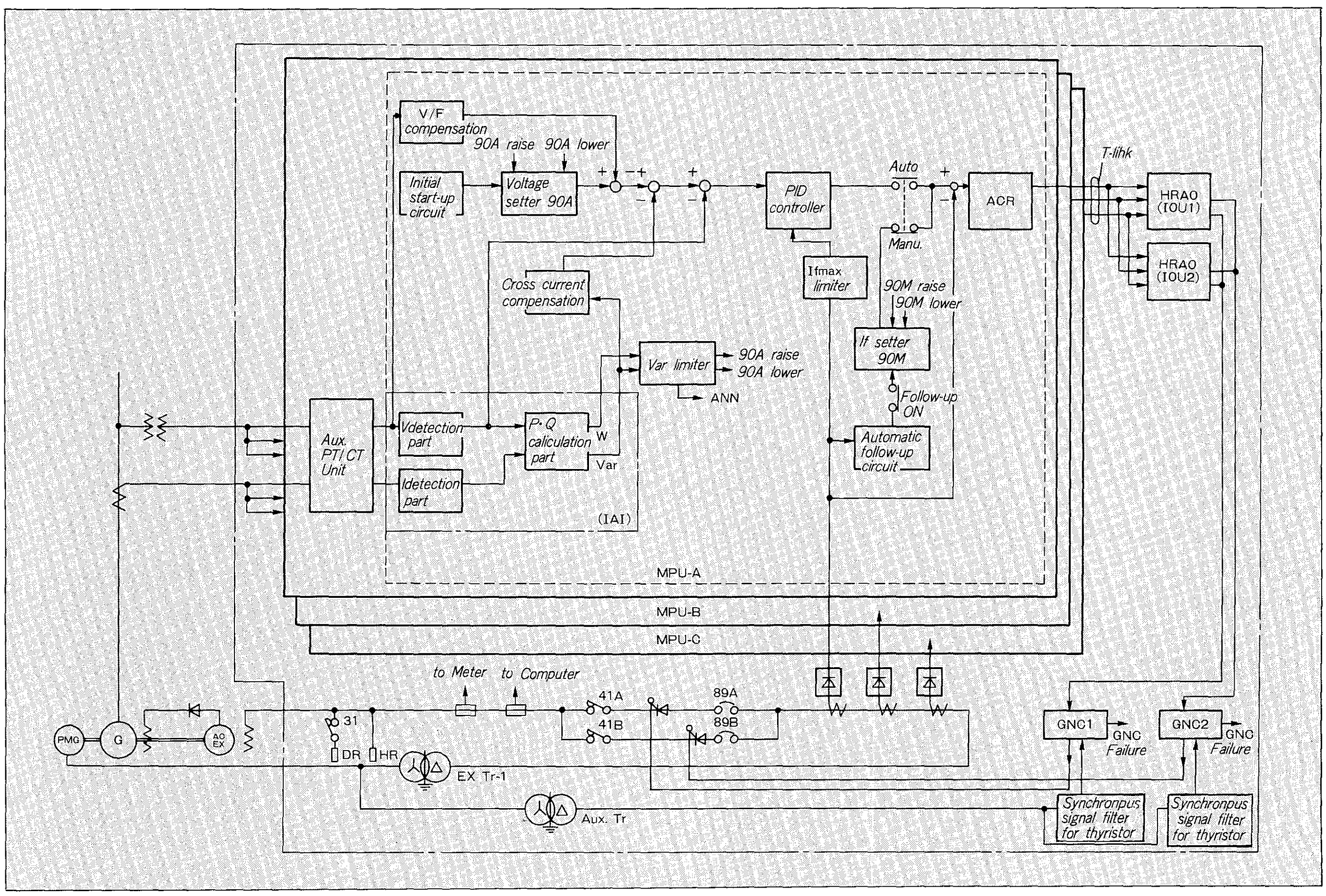
2.3 Interlock control equipment

To operate a thermal turbine, the many auxiliary equipment of the turbine and boil must be controlled. In this case, a complex interlock incorporating local limit switches, operation switches, and other contacts is combined and the number of interlock relay panels is large. Therefore, input/output devices installed at the operating desk and local and control center (C/C) and interlock equipment by PC are installed instead of the interlock relay panels and these are connected by a T-link.

The following advantages are obtained:

(1) Number of panels and installation space are reduced substantially.

Fig. 3 D-AVR functions



(2) The number of cables between interlock relay equipment and control center is reduced considerably and the number of wiring man-hours is reduced.
(3) Interlock modification is easy.

In this case, the reliability of the equipment can be improved by multiplexing the MPU and IOU of the interlock equipment.

Moreover, the effects of electromagnetic waves and noise can be reduced by making the T-link which connects the interlock equipment and input/output devices an optical fiber cable.

Fig. 4 D-EHG

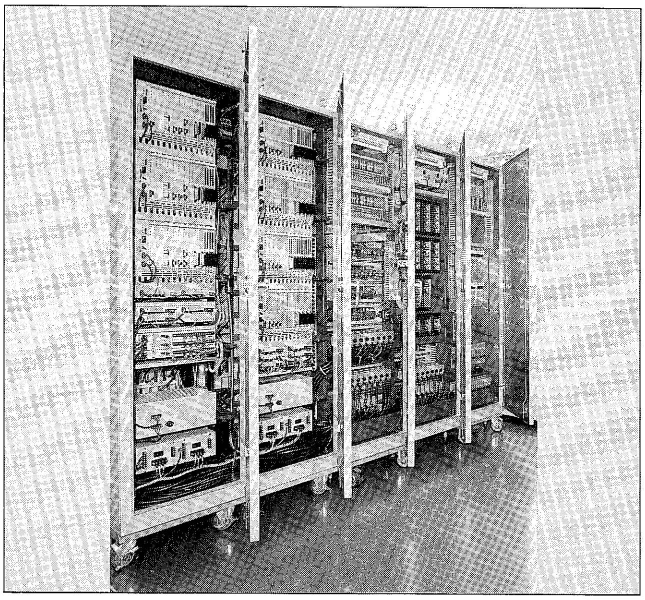


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Fig. 6 D-EHG overall system configuration

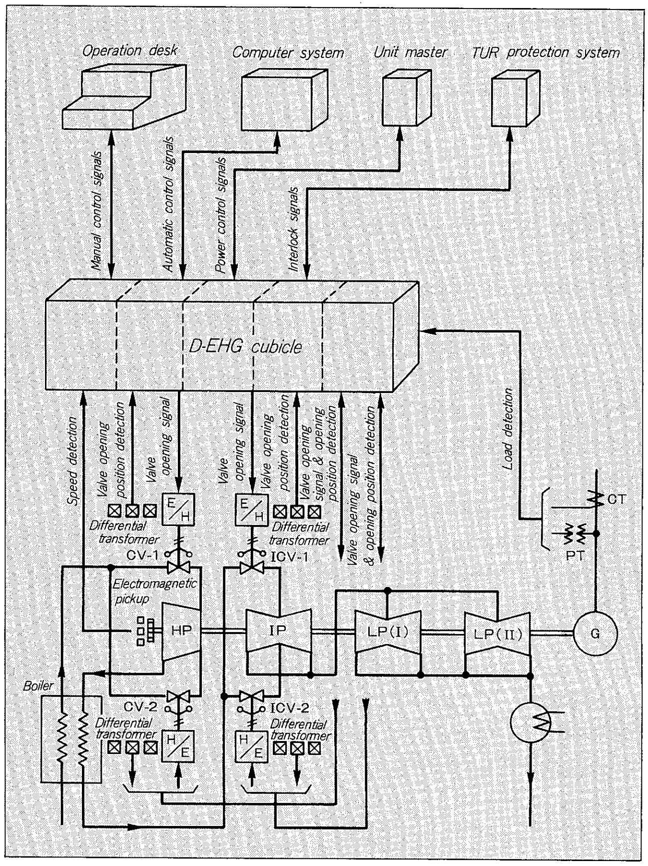


Fig. 5 D-EHG functions block diagram

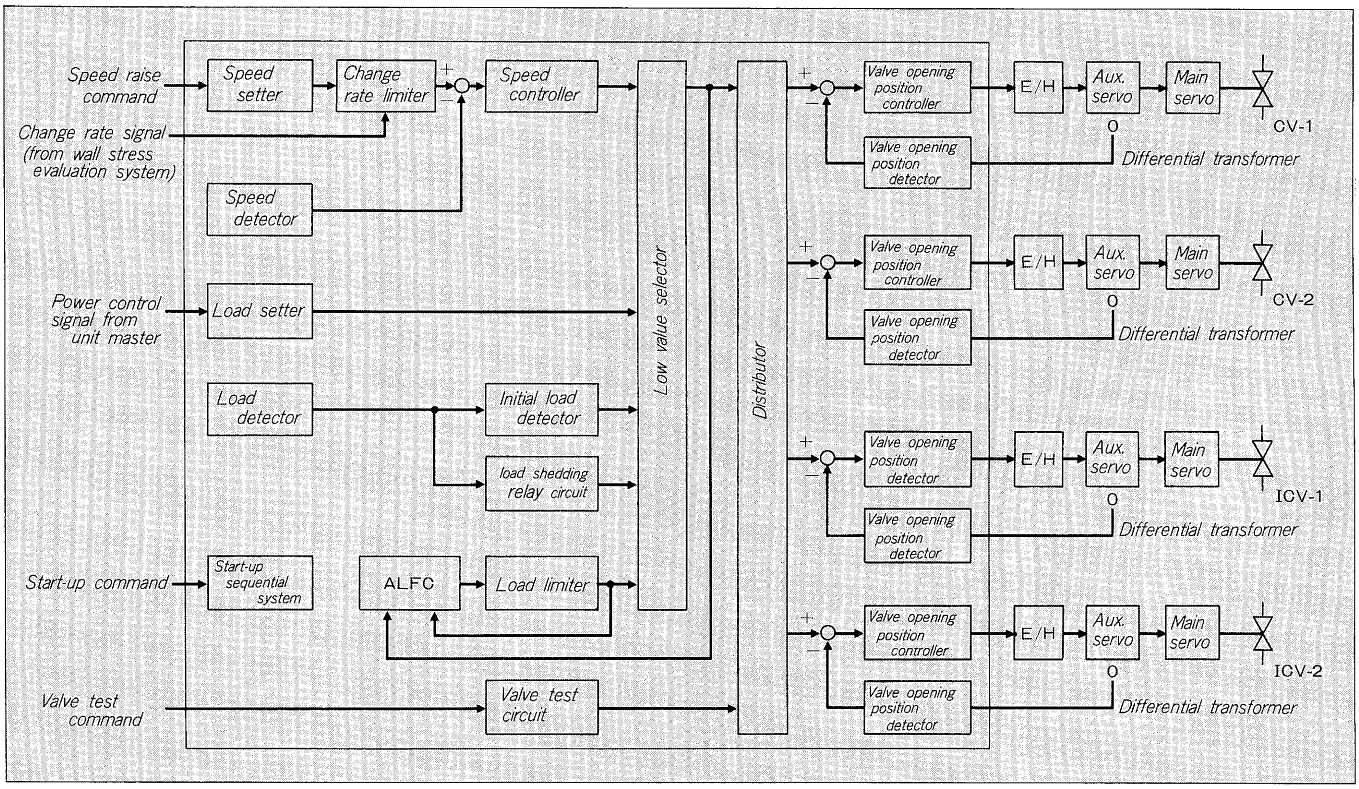
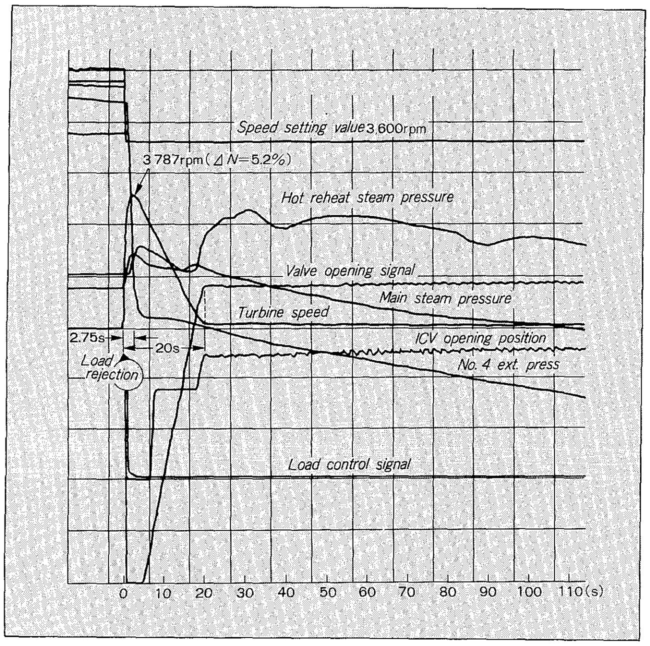


Fig. 7 4/4 load rejection



2.4 Automatic test equipments

Since the complex circuit can also be realized easily, the PC can be applied to the automatic test equipment of each equipment. Therefore, testing of each equipment can be performed easily without stopping the unit and unit faults can be quickly detected by performing automatic testing periodically.

2.4.1 Automatic valve test equipment (AVT)

The automatic valve test equipment tests if the steam stop valves, main steam control valves, reheat stop valves, and intercept valves are closed fully when the turbine is to be tripped while the unit is operating. It is used with a D-EHG. It checks if one control valve is closed slowly and the stop valve is closed by operation of the stop valve tripping solenoid under this state while the unit is operating under a certain load. It also checks if the control valve is opened in the stop valve closed state and that the control valve is closed by operation of the control valve tripping solenoid in that state. Thereafter, after the control valve is closed, the stop valve opens and the control valve is slowly opened and returned to its original state. This series of operations is performed for each stop valve and control valve set.

3. INTEGRATED CONTROL EQUIPMENT FOR PRIVATE THERMAL POWER STATION

These are integrated control equipment stressing economy as turbine generator control equipment. These equipment also have the following functions in one PC:

(1) Automatic voltage regulator (AVR)
  (a) Cross current compensation function
  (b) Voltage regulation function
  (c) Initial start-up function
  (d) Field current limiting function
  (e) Reactive power limiting function
  (f) V/F compensate function
  (g) Manual control with automatic follow-up function
  (h) Automatic reactive power regulation function (AQR)

(2) Electro-hydraulic governor (EHG)
  (a) Speed control function
  (b) Load control function
  (c) Valve opening position control function
  (d) Speed drooping function
  (e) Load limit with automatic follow-up function
  (f) Pressure control function

(3) Sequential control equipment for turbine start-up and stop

(4) Interlock control equipment for some motors

(5) Automatic valve test equipment (AVT)

Table 2 Record of delivery of MICREX-F500 to thermal power stations

Electricity Generating Authority of Thailand Mae Moh thermal power station unit 8 (300MW)	(1) Triplex MT-EHG (2) AVT	Operated started August 1989
Kansai Electric Power Company Miyatsu Energy Laboratory unit 2 (375MW)	(1) Triplex MT-EHG (2) Duplex BFPT-EHG (3) Sequential control equipment for turbine (5 sets) (4) Sequential control equipment for boiler (3 sets) (5) AVT	Operated started December 1989
Electricity Generating Authority of Thailand Mae Moh thermal power station unit 9 (300MW)	(1) Triplex MT-EHG (2) AVT	Operated started July 1990
Electricity Generating Authority of Thailand Mae Moh thermal power station unit 10 (300MW)	(1) Triplex MT-EHG (2) AVT	Under site testing
Electricity Generating Authority of Thailand Mae Moh thermal power station unit 11 (300MW)	(1) Triplex MT-EHG (2) AVT	(Shipped December 1990)
Tokyo Electric Power Company Oi thermal power station unit 3 (350MW)	Triplex MT-EHG	Shipment scheduled for March 1991
Tohoku Electric Power Company Noshiro thermal power station unit 1 (600MW)	(1) Triplex MT-EHG (2) Duplex BFPT-EHG (3) AVT	Shipment scheduled for October 1991

4. DELIVERY RECORD

The record of deliveries of digital control equipment using the MICREX-F500 to thermal power stations is shown in *Table 2.*

5. CONCLUSION

Concrete examples of digital control equipment in thermal power stations were introduced above.

Digital control equipment at thermal power plants do not stop at EHG only, extends up to AVR and digitalization is progressing positively. In the future, each control equipment will be connected to the facility management computer by a dataway and equipment diagnosis system and unit program operation, of course, and thermal power station control, protection, and supervision will be unified.